



# Adaptive Signal Timing: Traffic AI Before It Was Cool

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**Presenter:**

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Confidential & Proprietary



# Agenda

Section	Session Topic
1	What is Adaptive Signal Technology?
2	Topology Considerations*
3	An Optimization Algorithm*
4	Setup and Configuration Strategies*
5	Evaluating Its Effectiveness*

*\*Centered around Cubic's SynchroGreen and SPM solutions*

# 1. What is Adaptive Signal Control Technology (ASCT)?



# Prevailing Issues in Traffic Engineering



**Aging  
Infrastructure**



**Rising  
Congestion**



**Manual Timing  
Plans & Studies**

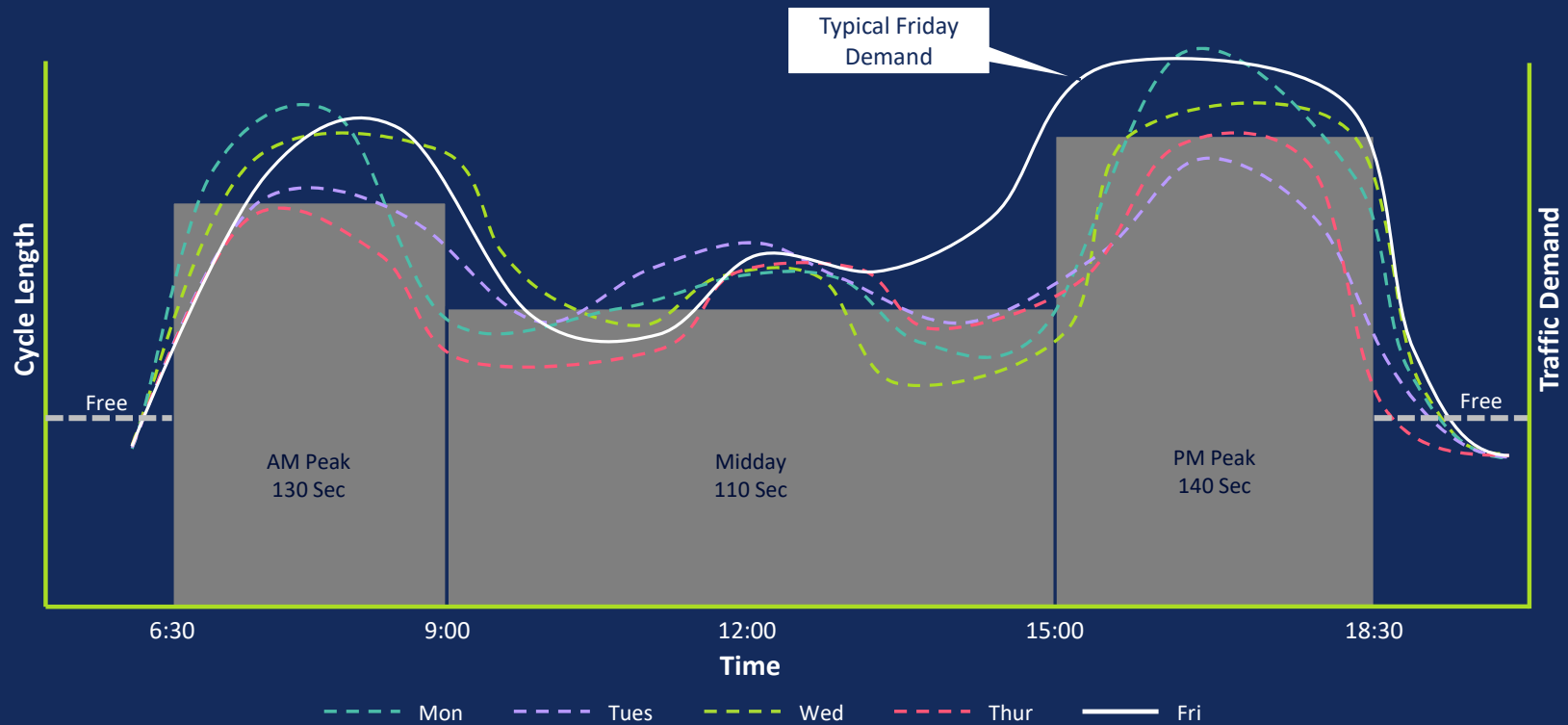


**Long Travel  
Times**



**Increased  
Emissions**

# Typical Weekly (Mon-Fri) Traffic Demand vs Cycle Length



# What is adaptive signal control technology?

- **ASCT systems are:**

- Software and/or hardware platforms that allow a specified group of traffic signals to adjust timing parameters in real-time.
- Typically, the cycle length, splits, offsets and (sometimes) phase sequencing adjust each, or following several, cycle iterations due to:
  - Constantly fluctuating traffic demand and/ or;
  - Temporary unpredictable traffic surges often caused by retail, schools, special events, detouring due to nearby accidents or construction.

**Overall, adaptive signal timing platforms are designed to improve progression and decrease total delay along a corridor system.**

**It can not increase the number of lanes or capacity!**

- It generates a greater probability for more efficient traffic flow at any given time.
- No two corridors or days are ever alike!
- Contributing factors include existing coordination health, typical corridor characteristics, and infrastructure condition.
- SynchroGreen, on average, can improve progression anywhere from 10-30%.

# Adaptive Signal Timing Benefits

- Typically accommodates different vehicular mediums, VRUs and intersection designs (pending adequate traffic and network infrastructure).
- Saves time and money by fostering better narratives to understand historical trends, common traffic pattern tendencies, and future planning.
- Influences more efficient, safer and greener corridors!
  - Maintains coordination without unnecessary transition
  - Reduces emissions and fuel consumption
  - Another resource toward achieving zero-vision goals

# Common Adaptive Solutions

## Most adaptive traffic signal control systems fall into two camps:

- **Proprietary** – adaptive solutions developed and confined to specific controller and infrastructure brands.
- **Agnostic** – adaptive solutions able to conform to many controllers and signal systems regardless of brand. Many newer agnostic adaptive technologies are integrated in detection infrastructure.

# Agnostic Adaptive Solutions

- **Pros:**

- Can interface with a multitude of controller brands and central software
- Not necessarily tied to specific controller or hardware constraints

- **Cons:**

- May require additional hardware (black boxes), specific detection mediums, and/or more cabling inside cabinets
- Can hinder an agency's central software function and usability

- **Examples:**

- NoTraffic, Miovision, InSync (Rhythm), SCATS (Transcore)

# Proprietary Adaptive Solutions

- **Pros:**

- Typically works seamlessly with existing controllers and central software platforms
- Usually requires no additional hardware or cabling

- **Cons:**

- Will not (typically) work across multiple controller brands, so it's difficult to test against other adaptive solutions
- Can be limited by capability of the controllers, cabinets, or the central software themselves.

- **Examples:**

- Fusion (Yunex), Centracs (Econolite), MyCity (McCain), SynchroGreen (Cubic)

# What is SynchroGreen?

- SynchroGreen (SG) is Cubic's real-time adaptive software solution that:
  - Utilizes proprietary Cubic/ Trafficware controller hardware and software;
  - Bases its calculations on pre-existing coordination, controller settings and agency defined constraints; and
  - Does not change intersection phase sequencing from cycle to cycle (including lead/lag).

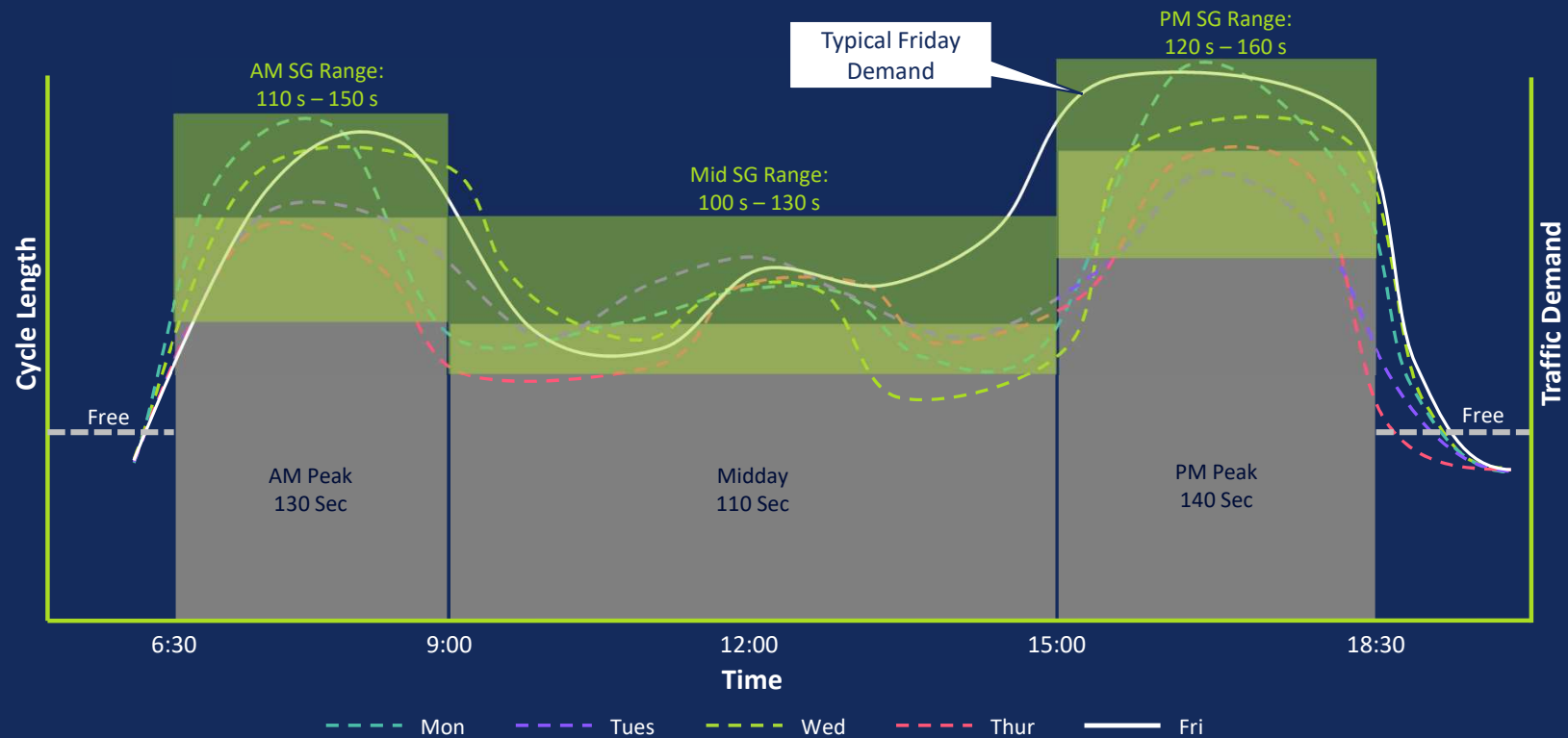
Before we start, we must assume the agency's existing coordination and timing plans are up to date and work generally well.

# What is SynchroGreen?

- **New SynchroGreen plans with flexible timings are developed and implemented.**
  - So instead of distinct static cycle lengths and splits, new specified ranges are programmed and deployed (i.e. 100-150 second cycle lengths).
  - These new discrete patterns are automatically calculated and deployed to the controllers within the timing group(s) which are based on traffic demand detected and programmed user constraints.

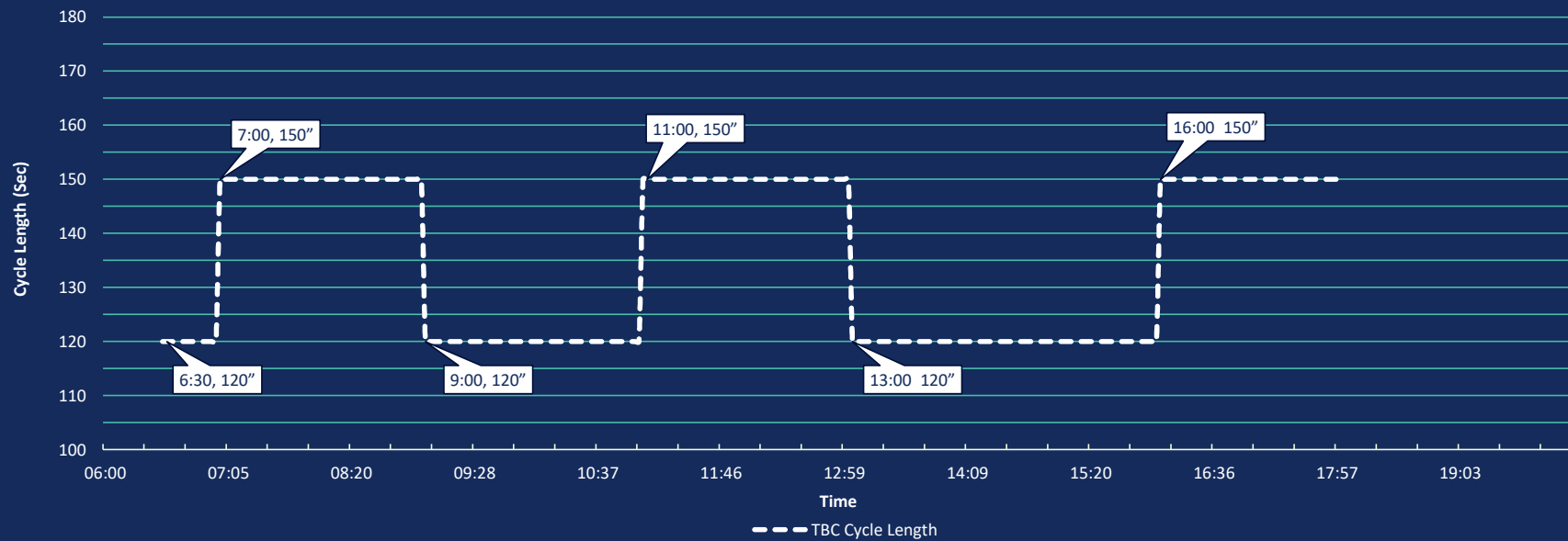
# High-Level Overview, SynchroGreen Timing

## Typical Weekly (Mon-Fri) Traffic Demand vs Cycle Length



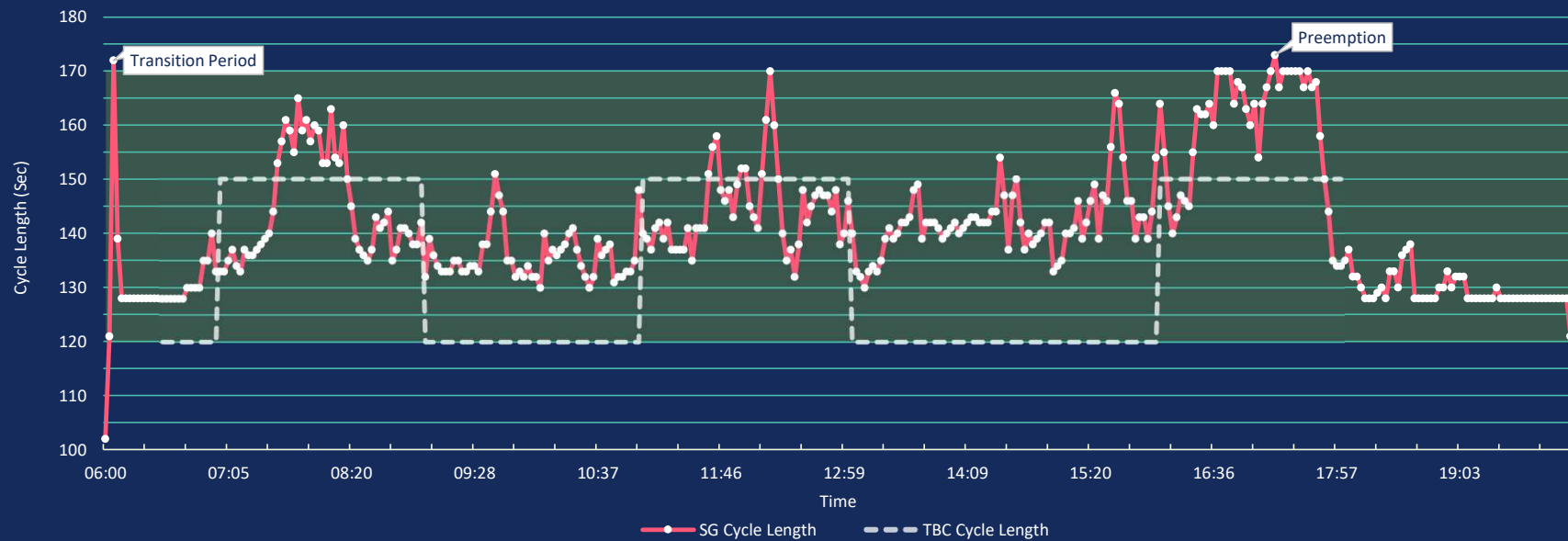
# Intersection Example: Weekday TBC Cycle Lengths

6:00 AM - 8:00 PM



# Intersection Cycle Length History with SynchroGreen

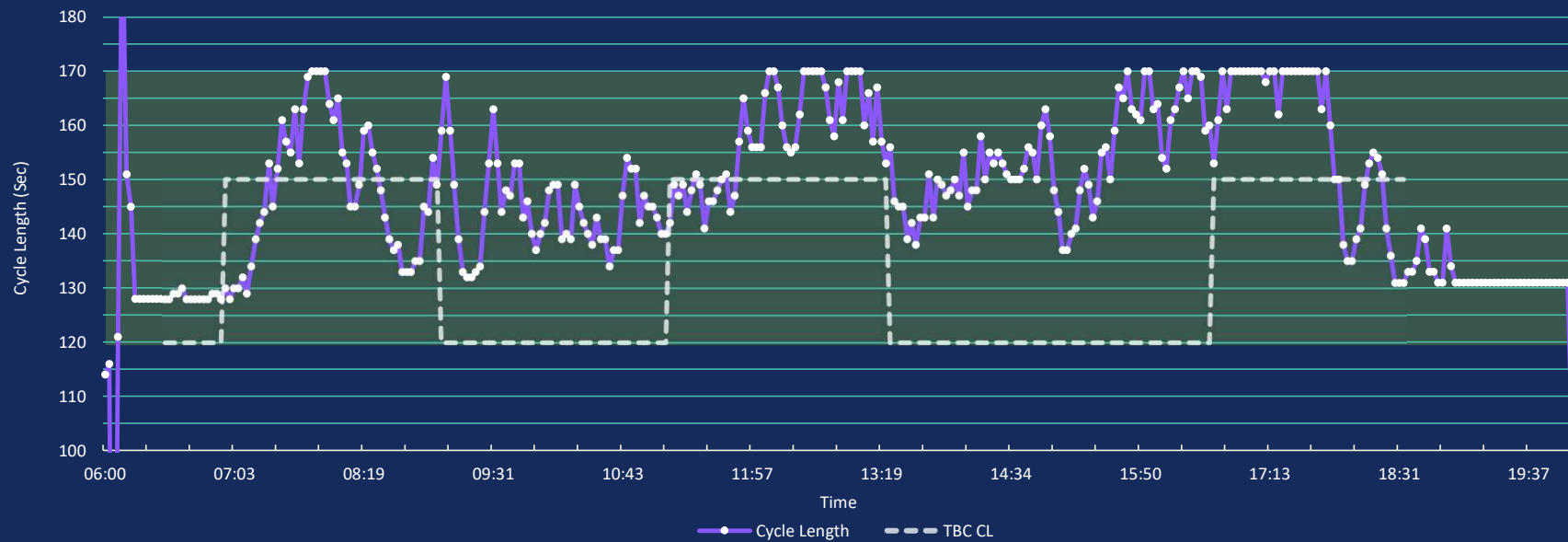
6:00 AM - 8:00 PM, 5/10/2023 (Wednesday)



Note: SG Range: 120 – 170 Seconds

# Intersection Cycle Length History with SynchroGreen

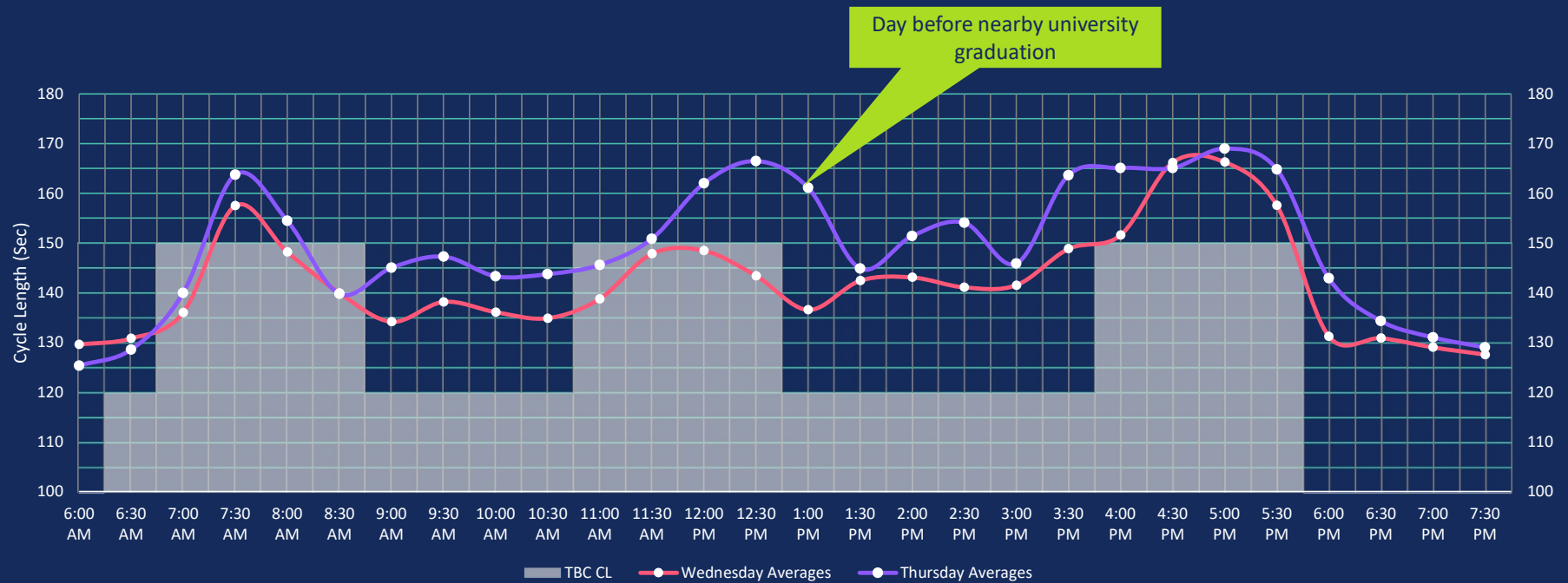
6:00 AM - 8:00 PM, 5/11/2023 (Thursday)



Note: SG Range: 120 – 170 Seconds

# 30-Minute Cycle Length Averages with SynchroGreen

6:00 AM - 8:00 PM, 5/10-11/2023



## 2. Topology Considerations



# Adaptive System Building Blocks



## RELIABLE IT INFRASTRUCTURE

- Current ATMS system
- Adequate server and support capability



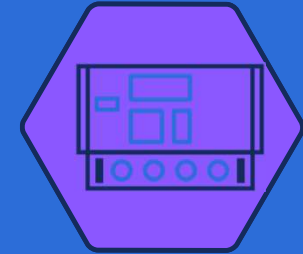
## STRONG COMMUNICATION

- Any reliable brand or medium.
- At least second-by-second polling
  - 10x for hi-resolution



## RELIABLE DETECTION

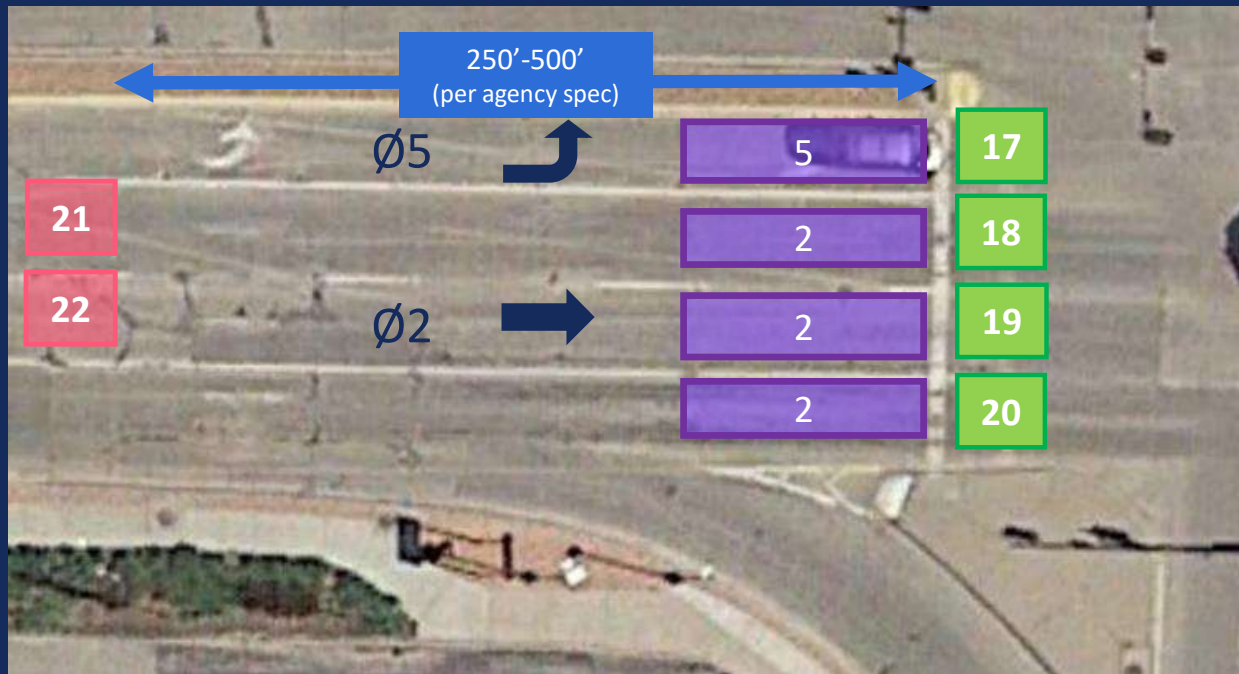
- Any reliable technology or brand:
  - Gridsmart
  - Radar
  - Video
  - Loops
  - Magnetometers



## PROPER CONTROLLER AND CABINET SETUP

- Must conform to adaptive needs and requirements
- Detection settings and coordination rules still must comply.

# Video/Radar Detection Example



## Presence Zones

- Used for call and extend
- Phases (often) on same channel

## SG, Stop Bar Zones

- Measures traffic demand
- Separate channels per lane
- Arranged beyond stop bar
- Typically 6'x6'

## Advance/Arrival Zones

- Required if signal spacing >1000'
- Influences (slight) offset adjustments

# Developing Adaptive Timing Groups

## Each timing group operates independently:

- Between 1 (ideally 3) and up to 20 coordinated signals.
- Signal group sizes can be increased or decreased throughout a day plan based on special circumstances
  - School areas, office parks, etc.
- Each group can run independently.
  - The calculations from one group are not considered for another.
- The impact and overall coordination can be greatly affected by the number of signals, signal spacing, as well as the corridor's overall length.



# Good Adaptive Corridor Candidate Traits

Recently coordinated signal network. Not saturated, but rapidly growing area.

Well designed and MUTCD compliant corridor with new infrastructure

Dense retail and commercial development

Major hospital on rotating shifts

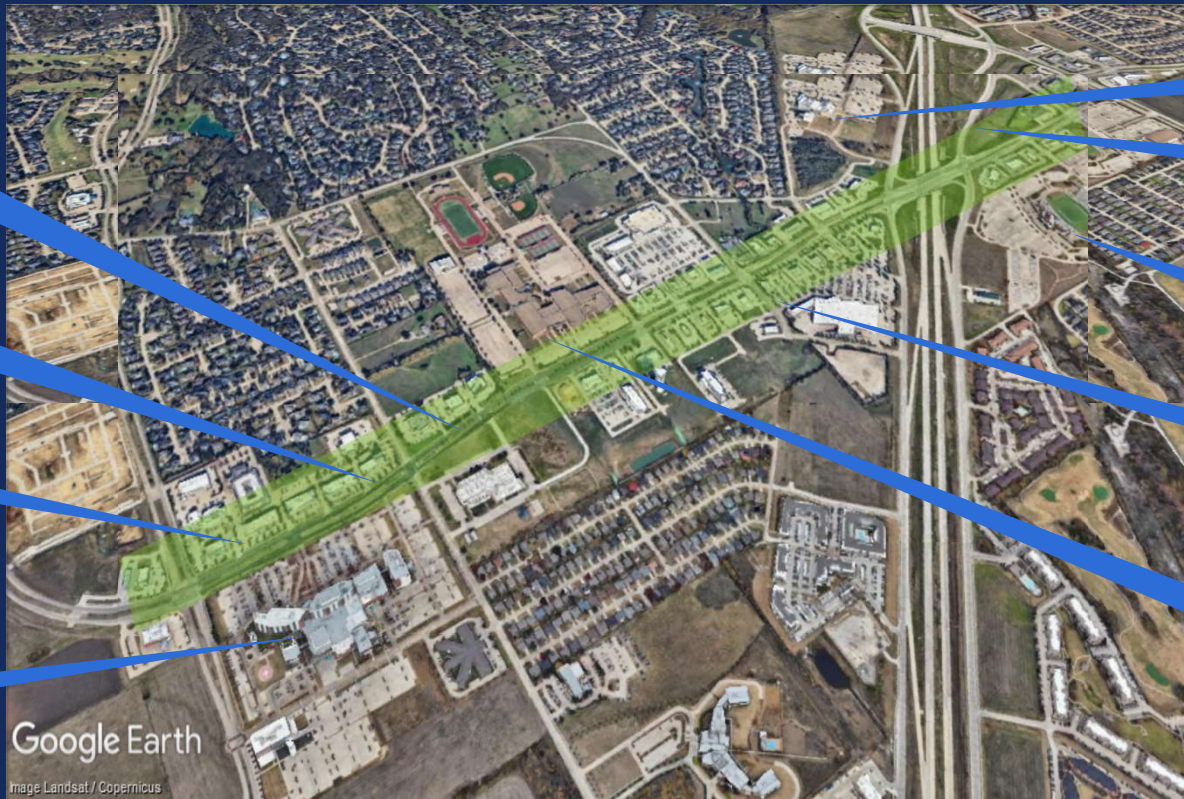
Large church congregation, multiple Sunday services

Frontage Roads, common detour routes

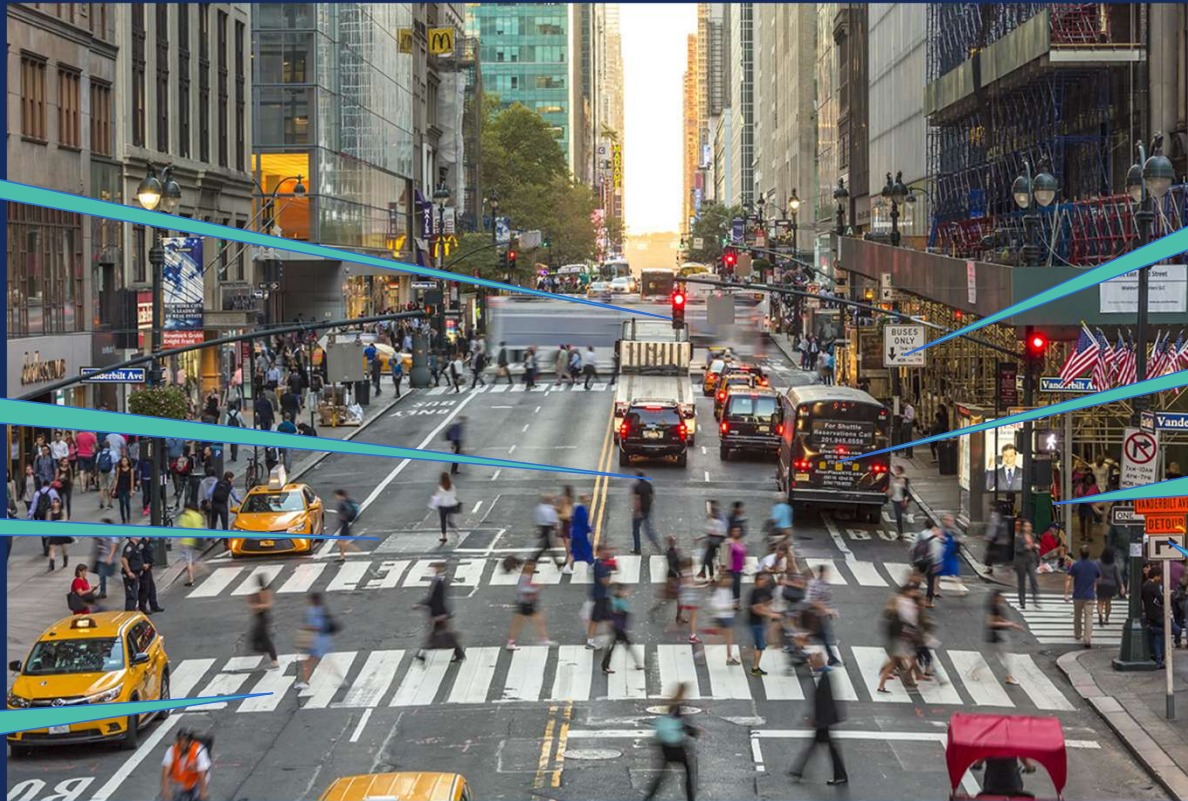
Thursday & Friday night HS football (Capacity >10,000)

Neighboring Chick-Fil-A and Starbucks locations

3,000-student high school, large walking lunch crowd



# Adaptive Corridor Candidate Potential Red Flags



Corridor not coordinated and consistently saturated

No dedicated storage lanes or protected left-turn phases

Little or no detection

Constant pedestrian calls not covered in time-based coordination

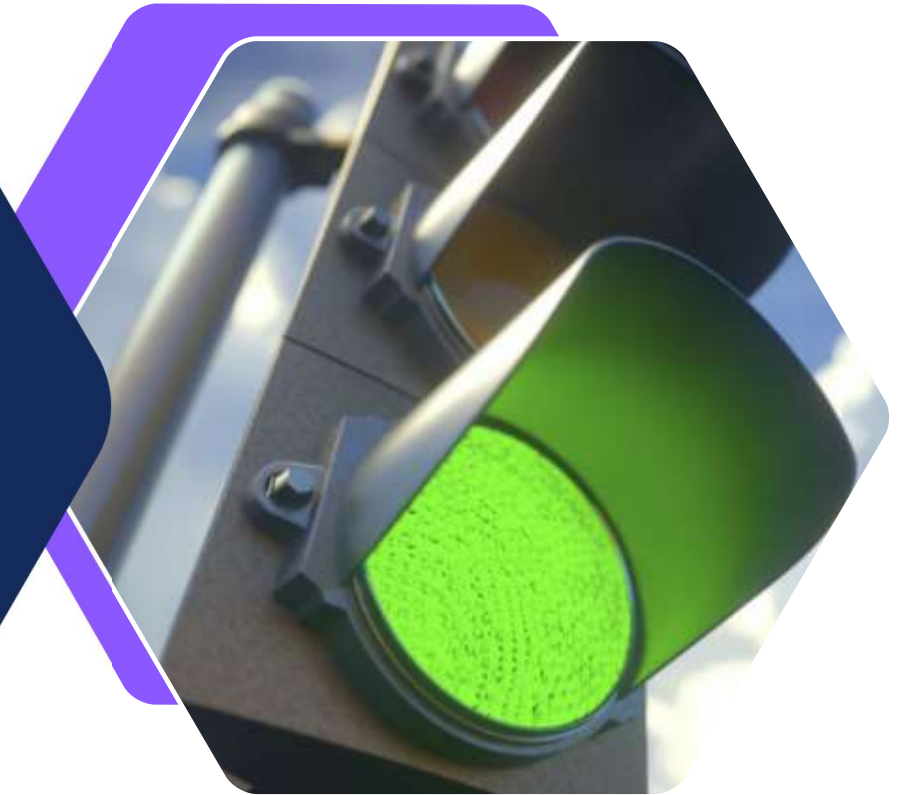
Geometric bottle necks

Frequent lane friction affecting progression

Controller not running on proper software version or cabinet is too small

Atypical long-term direct or indirect construction impact on traffic flow

# 3. An Optimization Algorithm



# Optimization Algorithm

Ultimately, SynchroGreen calculates and optimizes:



## Cycle Lengths

Time to complete all splits, defined by range of times (Period).



## Splits

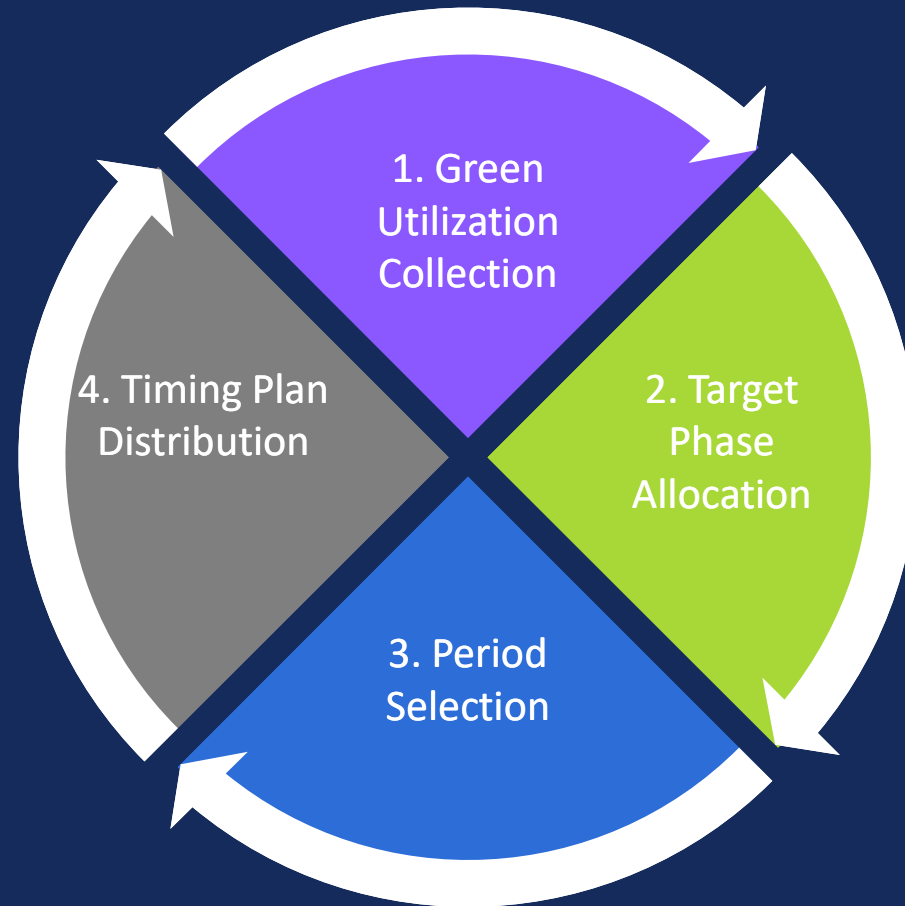
Allocation for each approach phase within predefined ranges.



## Offsets

Defines the start times for coordination, defined in SG via the lag time.

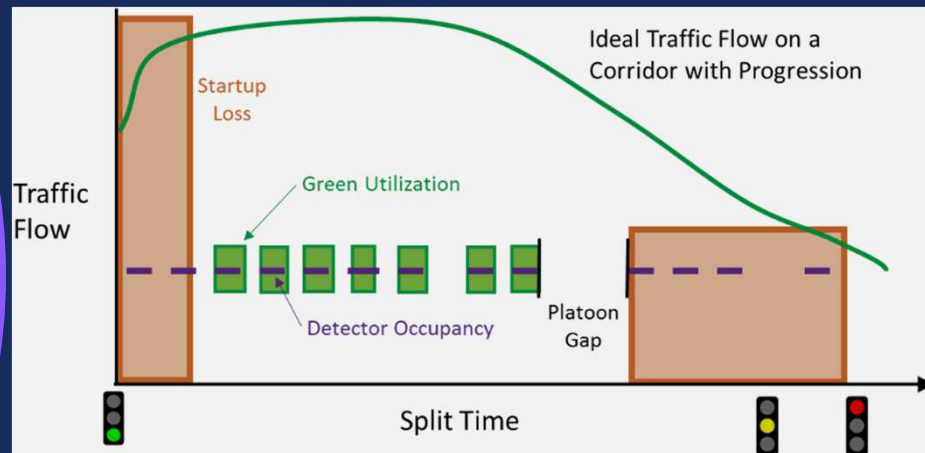
# 4-Step SynchroGreen Algorithm Process



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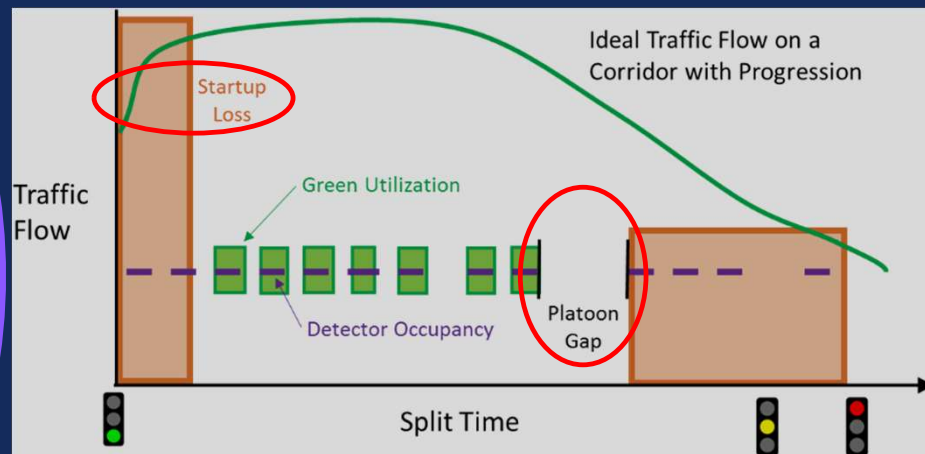
# Green Utilization



Each stop-bar detector collects **green utilization data**.

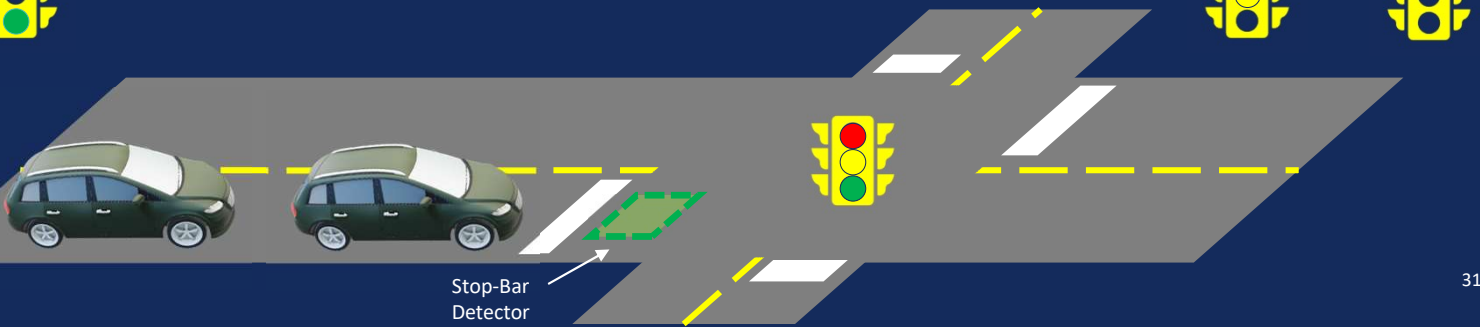
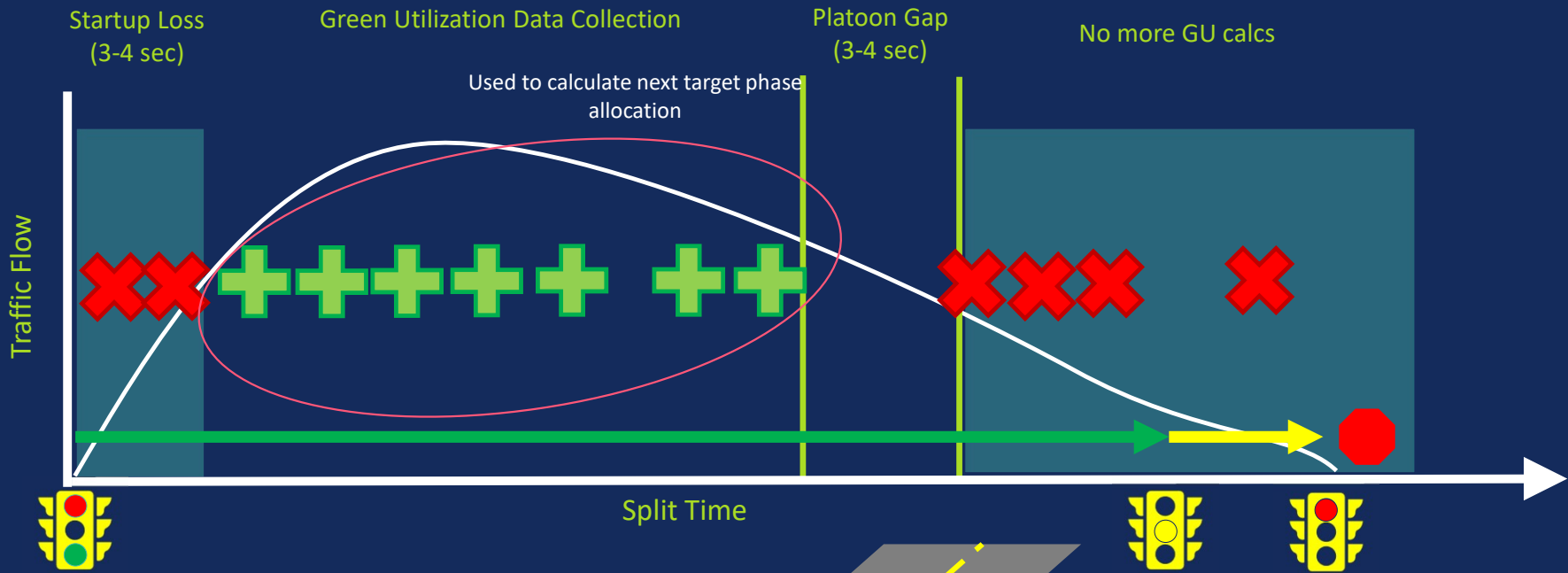
- **Green utilization** - the measurement how long cars are occupying/passing over the stop-bar detector
- Only occurs during a phase's respective green interval

# Green Utilization



- Measured after the **Startup Loss** Time. Default 3-4 sec.
- **Platoon Gap** – time which green utilization is not being measured- leading to gapping out if split has not already reached its limit. Default 4-5 seconds.
- Highest green utilization value per lane per approach is reported and used in the phase allocation calculations for that approach.
- Green utilization is not calculated when the approach is not green.

# Green Utilization Visualized (1 Phase)



# Target Phase Allocation

ID	Name	Pat	Dbase	Last Status Message										
1435	Main @ Bob Smith (1435)	30	1	10:59 (19) Controller time outside tolerance										
	Cyc	Off	Idx	1	2	3	4	5	6	7	8	9	10	11
Active (sec)	107	77	240	0	20	0	92	0	20	15	77	0	0	0
Target (sec)	65			0	20	0	30	0	20	15	30		0	0
Grn Util (sec)				0	0	0	4	0	8	1	7	0	0	0

Example above from SynchroGreen Interface

- **Active (sec)** – Current cycle length, offset, index (# of cycle iterations)
- **Target (sec)** – Sum of all target phases under ideal circumstances
- **Green Utilization (sec)** – Duration of time SG detectors occupied (~1 sec/car)

$$* \text{Target Phase Allocation (s)} = \sum \frac{\text{Green Util(s)}}{\text{Det Cal Fact (\%)}}$$

Detector Cal Fact default (%): 0.66

- Sum of all target splits add up to a new target cycle length calculated for each intersection (Indicates its ideal cycle length at any given time).
- The target split timings are calculated based on traffic demand, controller settings (i.e. min green + Y + AR) and user constraints (i.e. split ranges).
- In this example, the low target cycle length (65 seconds) indicates it's probably not a busy intersection while another location in the timing group needs 107 seconds.

2

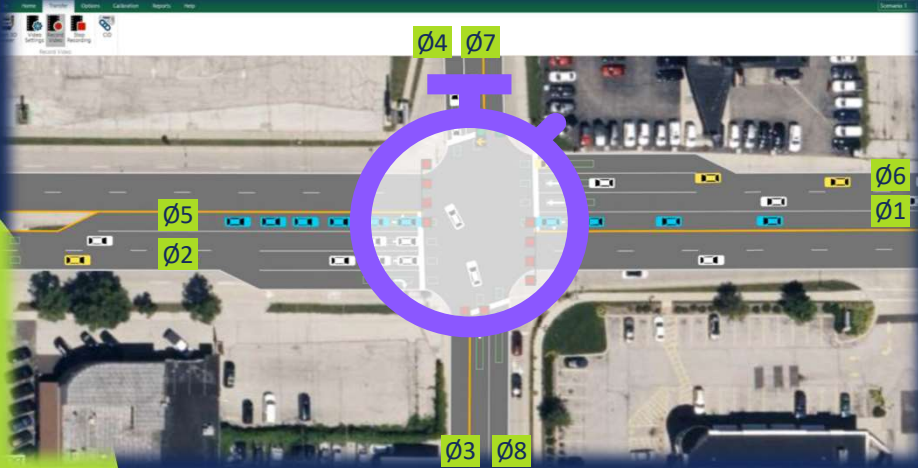
# Target Phase Allocation Example

2



# Main St at 4<sup>th</sup> St Intersection (8 Phases)





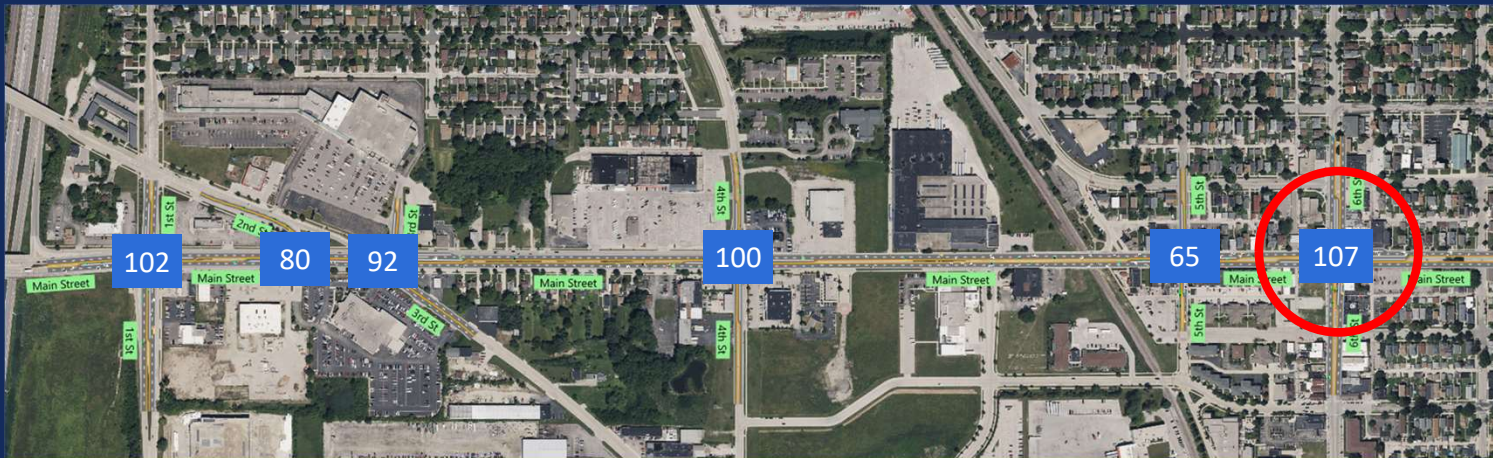
## SG Data Collection Example (Main & 4<sup>th</sup>)

(Green Utilization observation for one cycle iteration starting on Phase 2/5's green interval)

» Little to no side-street traffic will yield minimum split times.



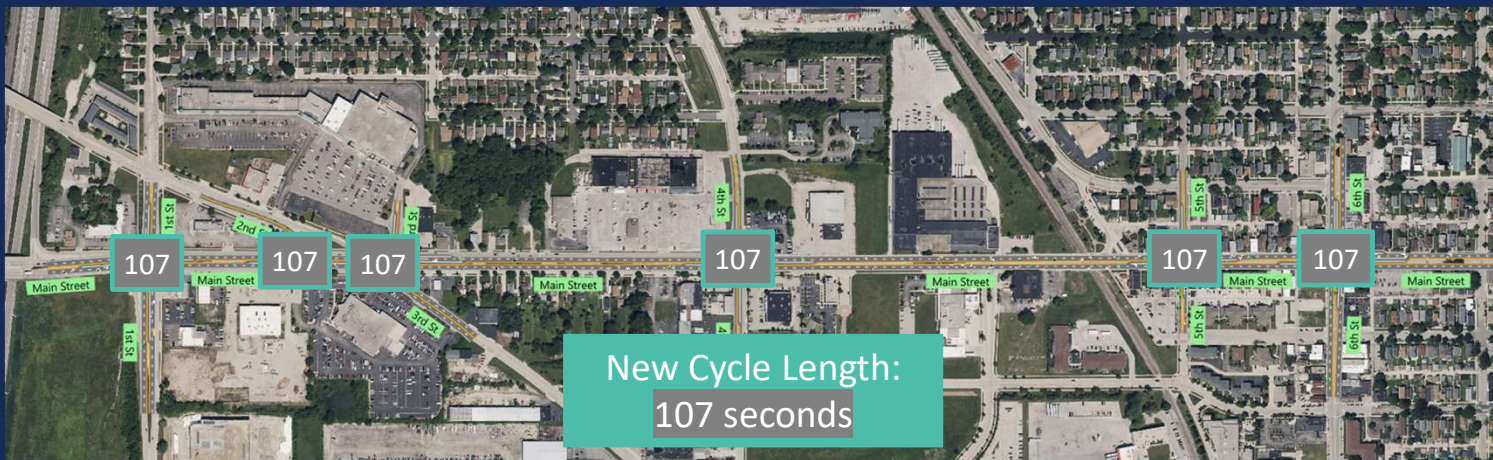
# Period Selection



- After analyzing the target cycle lengths, the driving or critical intersection with the highest demand is chosen. In this case - 107 seconds.
- The critical intersection can vary per cycle.

3

# Timing Plan Distribution



- After the algorithm selects target cycle length, it then recalculates splits and distributes the new timing plans accordingly to the other intersections to match the cycle lengths.
  - Note: The extra time other intersections receive is determined by the 'storage' setting- typically back to the main phases.
- This completes the iteration and the process is then repeated.

4

# 4. Setup and Configuration Strategies



# Database Conversion

New SynchroGreen day plans are NOT developed from brand new controller settings, but rather on the existing plans and settings. This is done for a few reasons:

- SG timings will not exceedingly stray far from existing timing plans, nor will they alter major controller database settings (including sequences).
- If SG frequently falls out of coordination, experiences communication failure, or has any other problematic symptoms requiring its termination, the controller(s) will seamlessly fall back to the regular TOD plan.
- Matching existing driver expectations is our priority.

# Maintaining Coordination

- **Coordination preserved in SynchroGreen with Lag Times.**
  - Inputted based on the programmed TOD offsets.
  - Time difference is still maintained between offsets and lag times.
- **Head node typically assigned with 0 second lag time**
  - Acts as a coordination starting point for SynchroGreen.
  - Time is added/subtracted from TOD offset value to achieve a 0 second lag time and then applied concurrently to the other intersections
  - Head nodes are arbitrarily chosen.
    - Often at the end of a corridor or bisecting SG intersection.
  - Unique coordination pathways or daisy chaining signals both possible.

**Emphasizes importance of good coordination before implementing adaptive!**

# Triggers

Triggers are special customized condition commands that activate when an intersection or timing group's detection respond accordingly to specific circumstances. These can be situations due to:

- Equipment failures
- Unique traffic conditions
  - Blocked railroad crossings
  - Highway spillback prevention
  - Nearby accident mitigation
  - Post Brewers game
  - Free Chick-Fil-A sandwich giveaways

Triggers plans are automatically implemented for specified amounts of time and continue until the threshold requirements are no longer met.

# 5. Going a Step Further



# Adaptive is running, so what now?

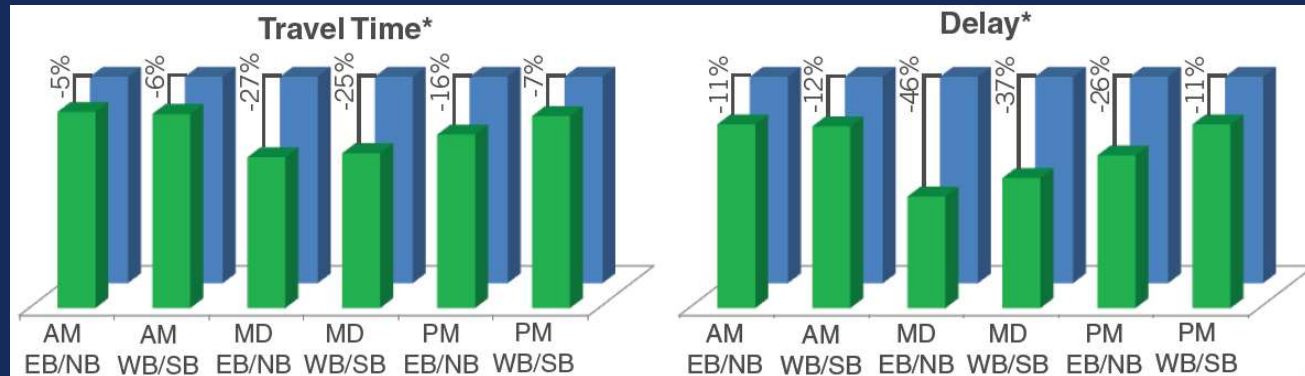
- What kind of goals are agencies looking to accomplish?
  - Alleviate off-peak congestion? Improve travel times? More arrivals on green?
- Should you continue evaluating and tweaking after deploying?
  - Yes! Adaptive is self sufficient, but not a complete set-it-and-forget-it solution.
- Conduct before and after studies that include travel time runs.
- Consider high-resolution data analytics and signal performance measures (SPM) to determine if conditions are better or worse.
  - Arrivals on green/red, platoon ratios, phase delays, split failures, etc.

# Case Study: Seminole County, FL

SR 436 in Seminole County, FL (near Orlando) upgraded 12 signals to include SynchroGreen

Project background included:

- 1.7-mile, minimum 6-lane corridor
- Average daily traffic (ADT) of nearly 60,000 vehicles
- Near emergency services, mall, retail, restaurant and entertainment
- Over 1,000 pedestrians daily along corridor



# Case Study: Chula Vista, California

## Conditions:

- 28 intersections across 3 corridor arterials

## Congestion Reduction:

- 32.9% decrease in cumulative stop delay
- 33.2% decrease in cumulative no. of stops
- 15.1% decrease in cumulative travel time

## Environmental Impact:

- 10% decrease in  $TNO_x$
- 11.1% decrease in  $TCO_2$
- 6.7% decrease in fuel consumption

**cubic**



# Final Takeaways

- Adaptive signal timing solutions will not magically make traffic disappear!
- Well-maintained traffic infrastructure and timing plans are critical to an adaptive solution's success.
  - Well-calibrated and finely-tuned peak hour plans may yield less benefit than the unplanned and unpredictable surges during the off-peaks.
- Sometimes the trade off for better corridor progression with adaptive is sacrificing side streets performance results.
- Analytic data may only reveal small improvements at first, and that's OK. Keep working at it!

# Small Improvements Matter!

$$(1)^{365} = 1$$

$$(1.01)^{365} = 37.7$$

$$(1.015)^{365} = 229.1$$

# Thank you!

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