Using LiDAR To Understand Driver Behavior during Yellow and Red at Signalized Intersections

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Outline

- Background
- LiDAR’s mechanism?
- Driving behavior data collection with LiDAR sensors
- Preliminary results
- Next Steps

Background

Background

- Crashes often occurred during traffic signal change and clearance interval
  - Thus, **yellow** and **all-red** are critical to prevent crashes

- ITE method is advisory, not mandatory.
  - Different practice in different jurisdictions

Yellow Change:

$$Y = t + \frac{1.47V}{2a + 64.4g}$$

$$AR = \left(\frac{L + D}{V_{15}}\right)$$

- ITE has recently updated the calculation of Yellow and all-red by extending the traditional kinematic equation, a.k.a. extended kinematic equation (EKE)

- This study is to provide more decision support for agencies to adopt these methods and produce new insights with new types of data.
  - Including data from AI camera, telematic data, CV2X and LiDAR data.

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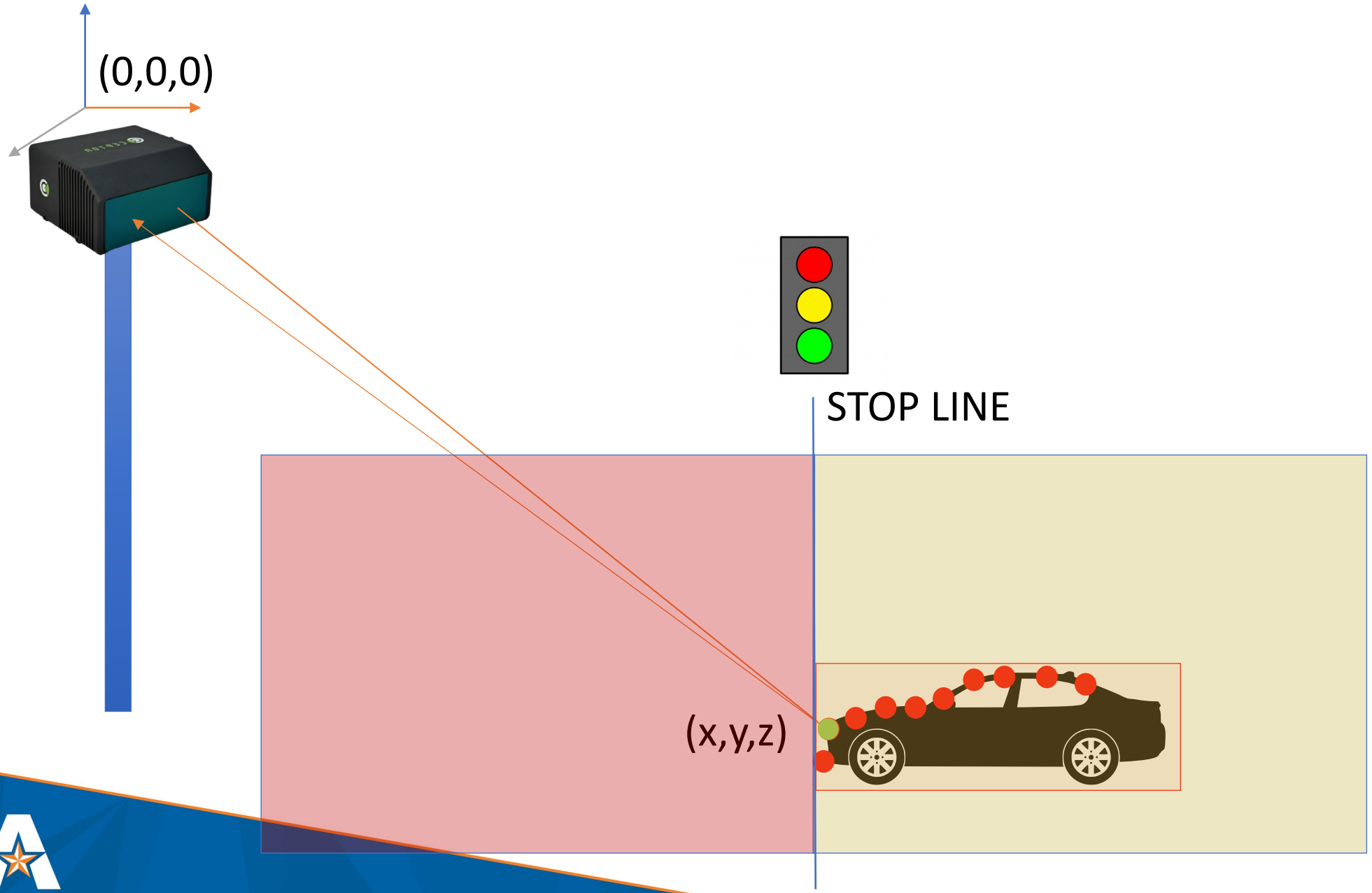
Disclaim

Findings or discussions presented in this talk does not represent options of FHWA or ITE by any means.

LiDAR’s working mechanism

Infrastructure LiDAR


(0,0,0)
STOP LINE
(x,y,z)

System Architecture

Program 1: SPaT info

LiDAR sensor

Program 2 for traffic signal and LIDAR data logging

UTA-in-motion platform (UTAIM)

LiDAR GUI

1% vehicle trajectories for an hour at an intersection of Salt Lake City (Utah)

Three important aspects for LiDAR sensor in the long term

- **Novel traffic data** fabrication
  - Raw trajectory/heatmap plots are less actionable than the first sight

- **New performance measures**
  - What are added to traffic signal operations, in addition to ATSPM?

- **Replacement, or enhancement of current traffic detections?**
  - Long range? Radar outperforms
  - Short range with behaviors: LiDAR is outstanding
  - Object subclassifications?: video is the only option

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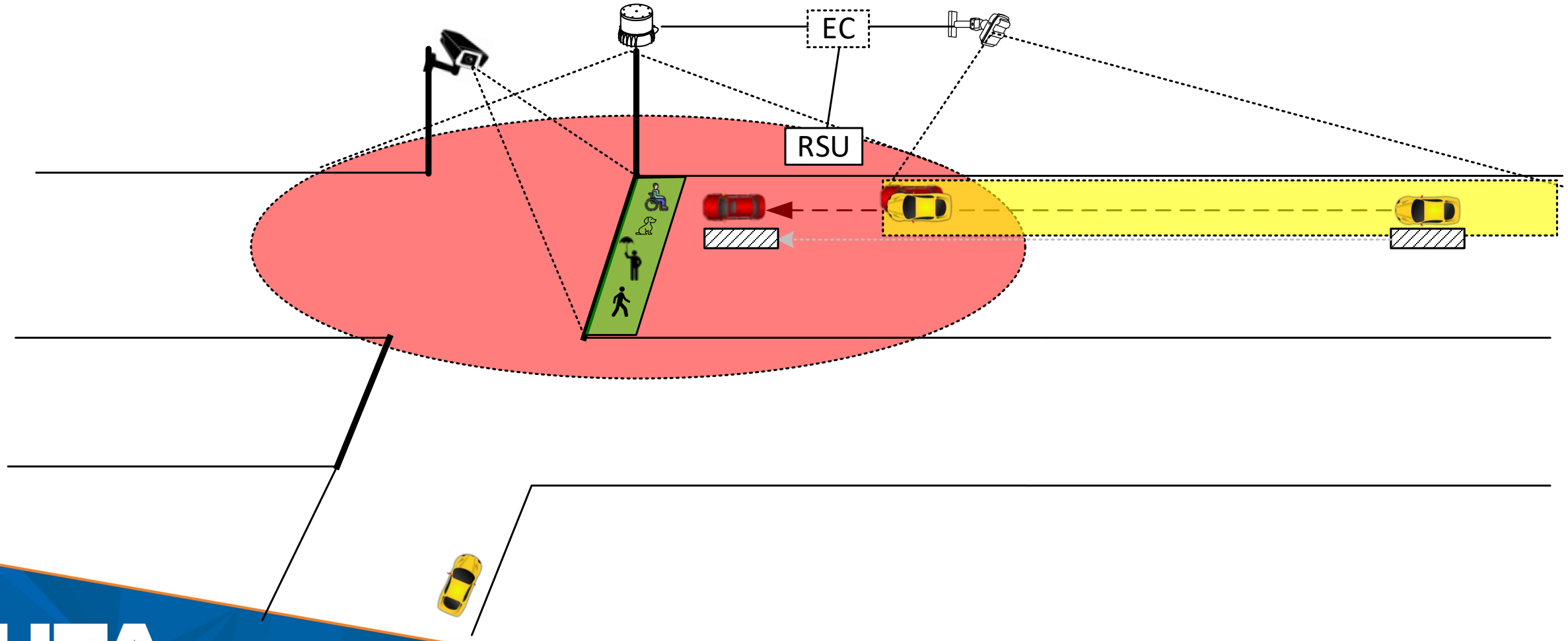
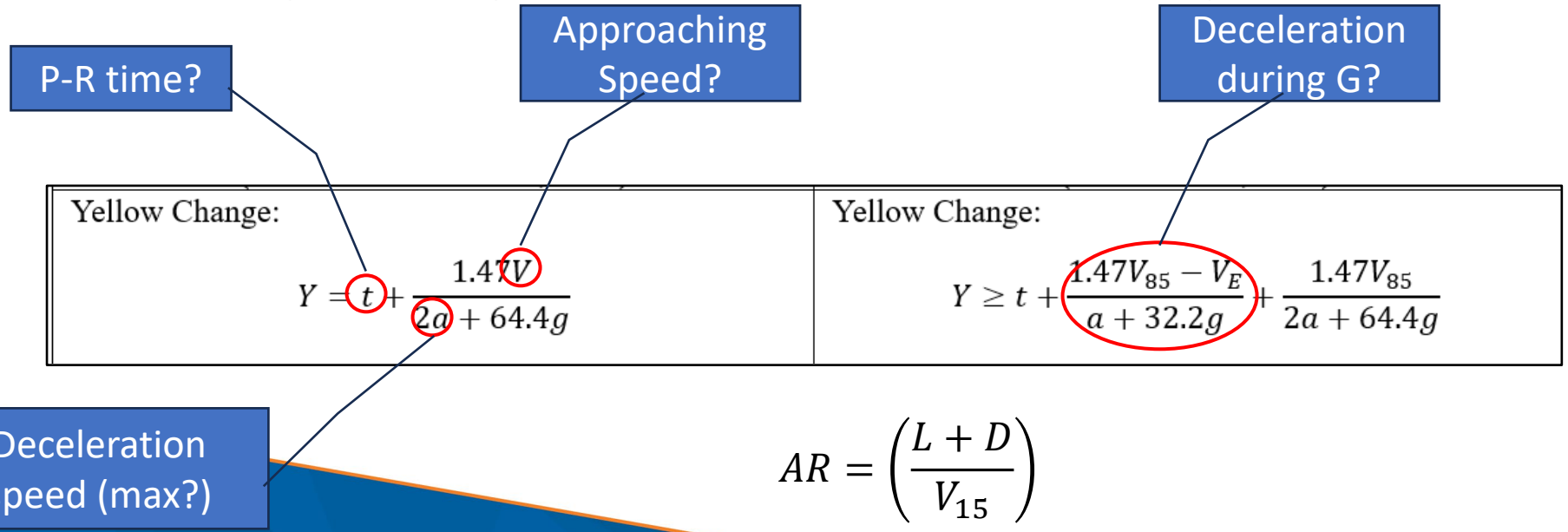
An ideal harmonized traffic detection system



How do we drive when encounter yellow?

ITE approach to yellow and all-red clearance calculation:

- Based on Kinematic equation (KE) and its extension (EKE)
  - Formulated in 1960 and contains many decision assumptions
  - Support or contradiction is impossible unless needed data are available
    - LiDAR-tracked high-res trajectories can be used for this argument

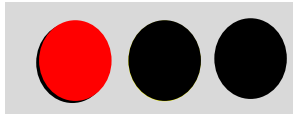


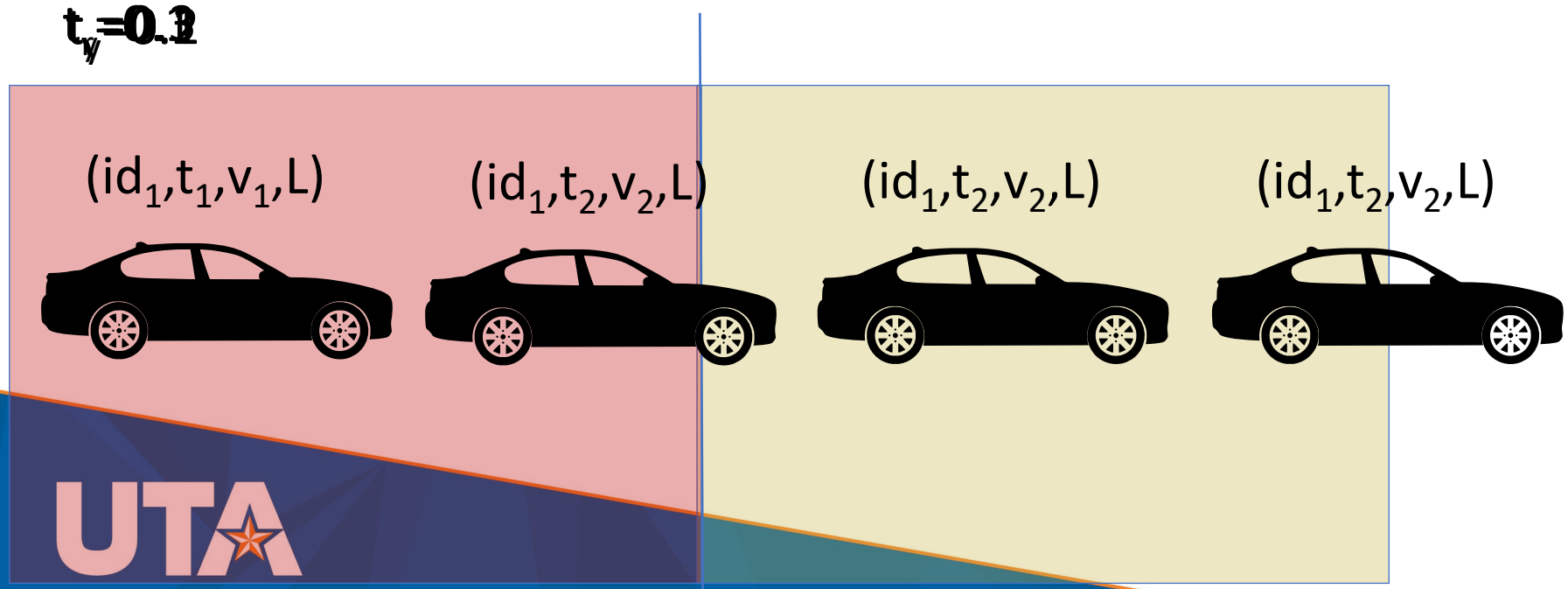
Yellow Change:	Yellow Change:
$Y = t + \frac{1.47V}{2a + 64.4g}$	$Y \geq t + \frac{1.47V_{85} - V_E}{a + 32.2g} + \frac{1.47V_{85}}{2a + 64.4g}$

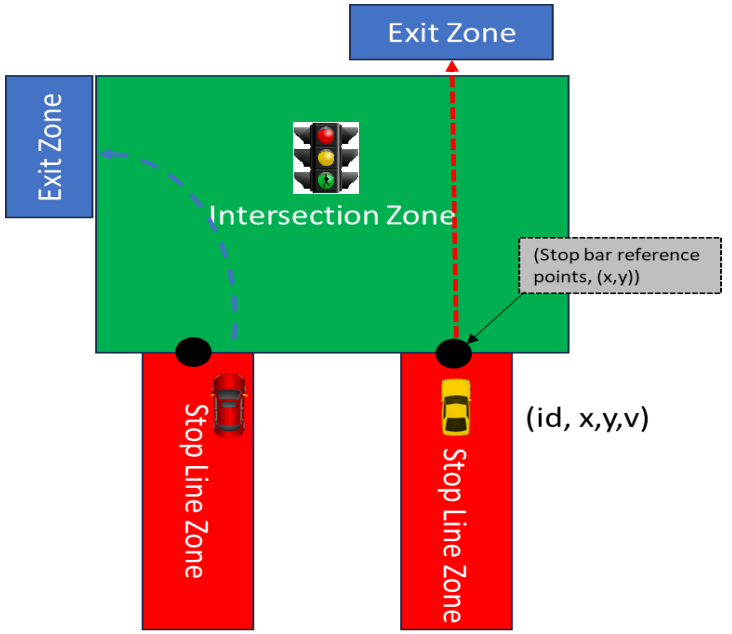
$$AR = \left(\frac{L + D}{V_{15}}\right)$$

Step 1: Relevant Data fabrication

- 100% approaching vehicles' trajectories at 10 Hz grow very fast (at least 3 millions records per day). So, data must be reduced in the field.
  - Only during each yellow + 10 sec red (all-red and early red)

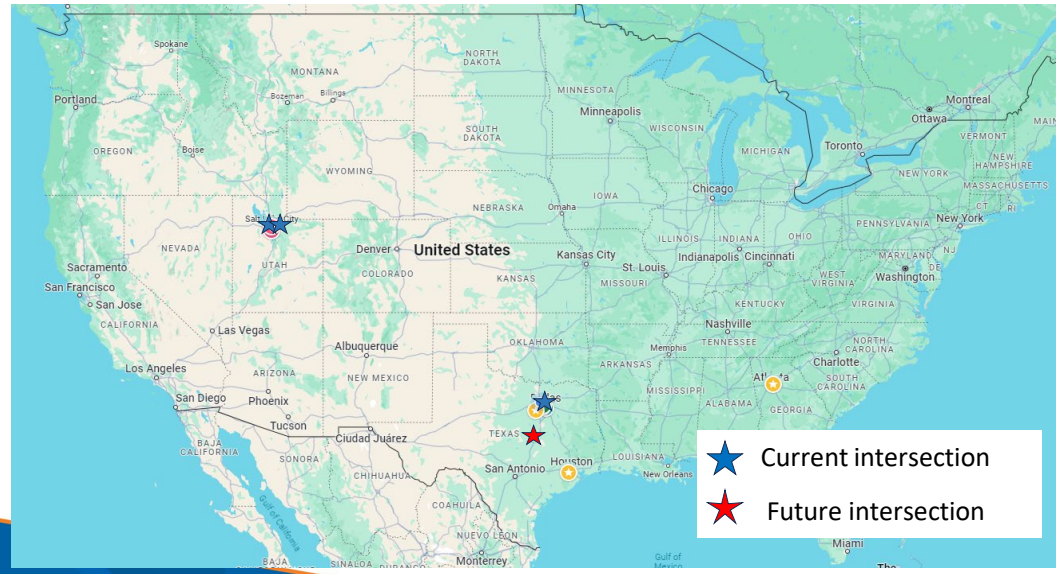


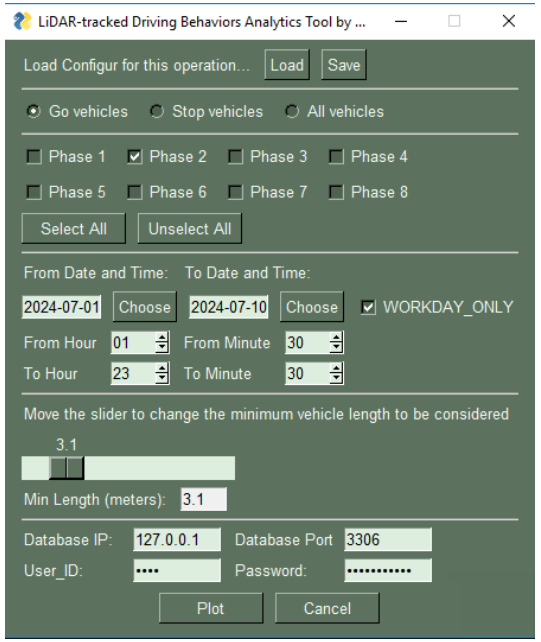


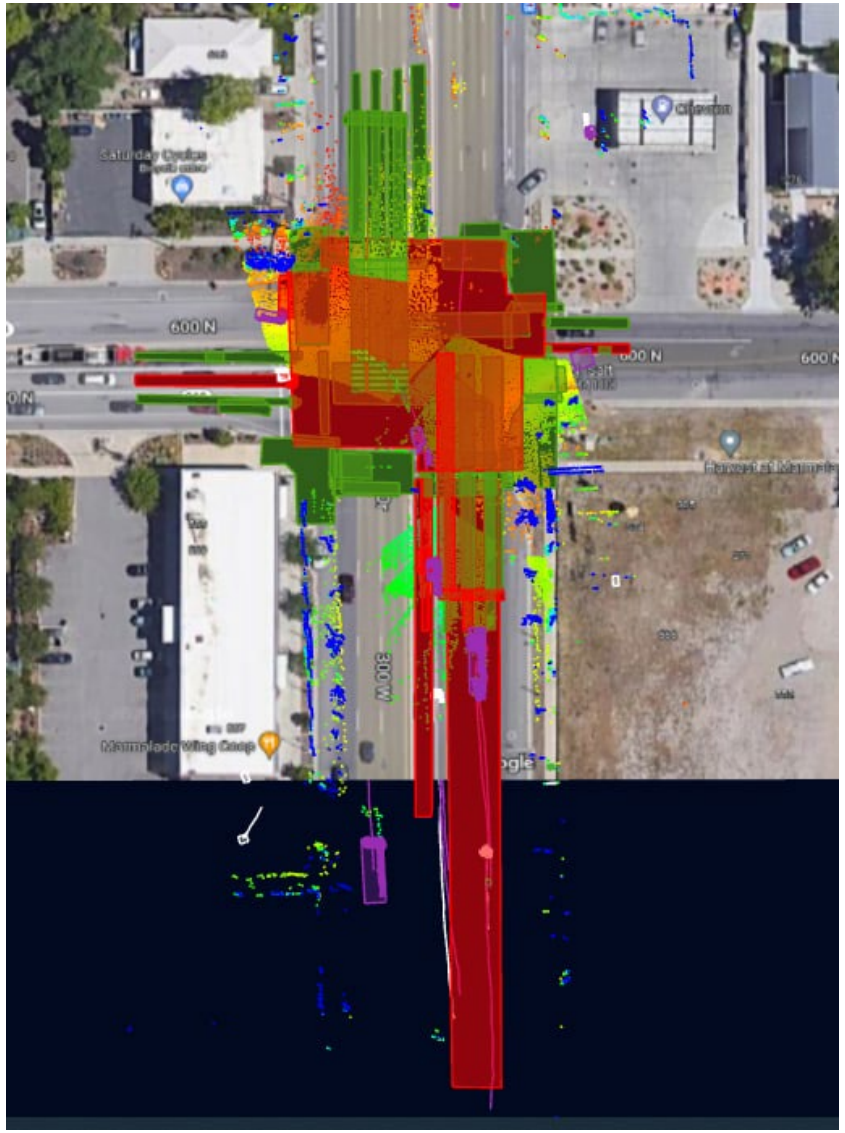


Data collection sites

- Multiple intersections in Utah and Texas
- Two steps data collection
  - Data collection and reduction in the edge computer
  - Data cleaning, visualization in the server

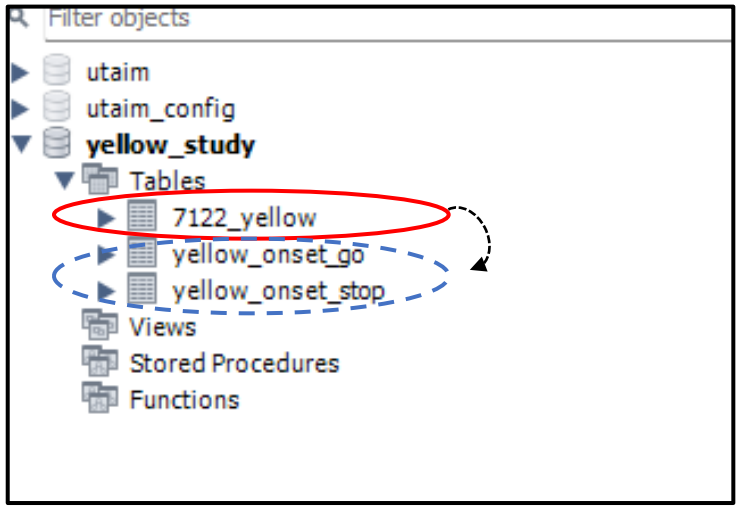


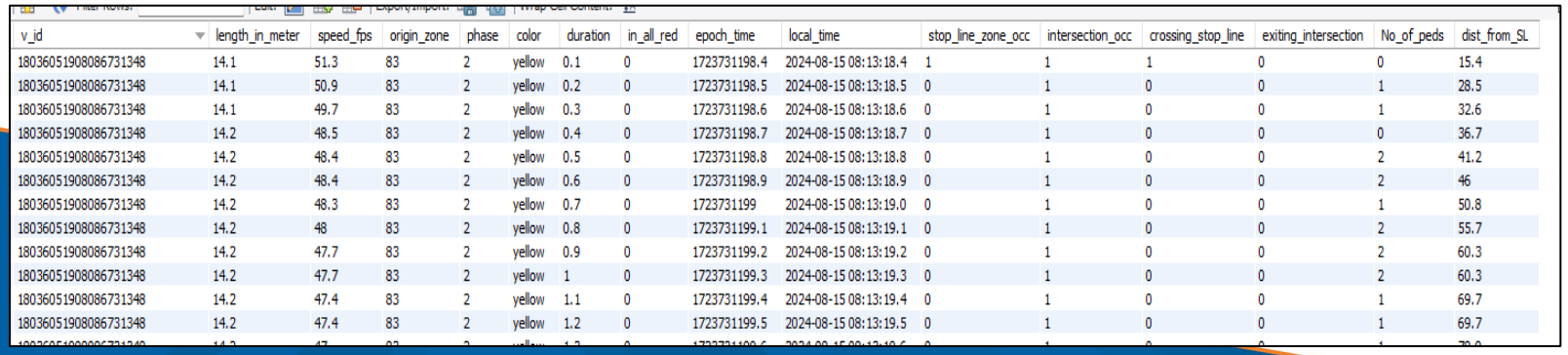




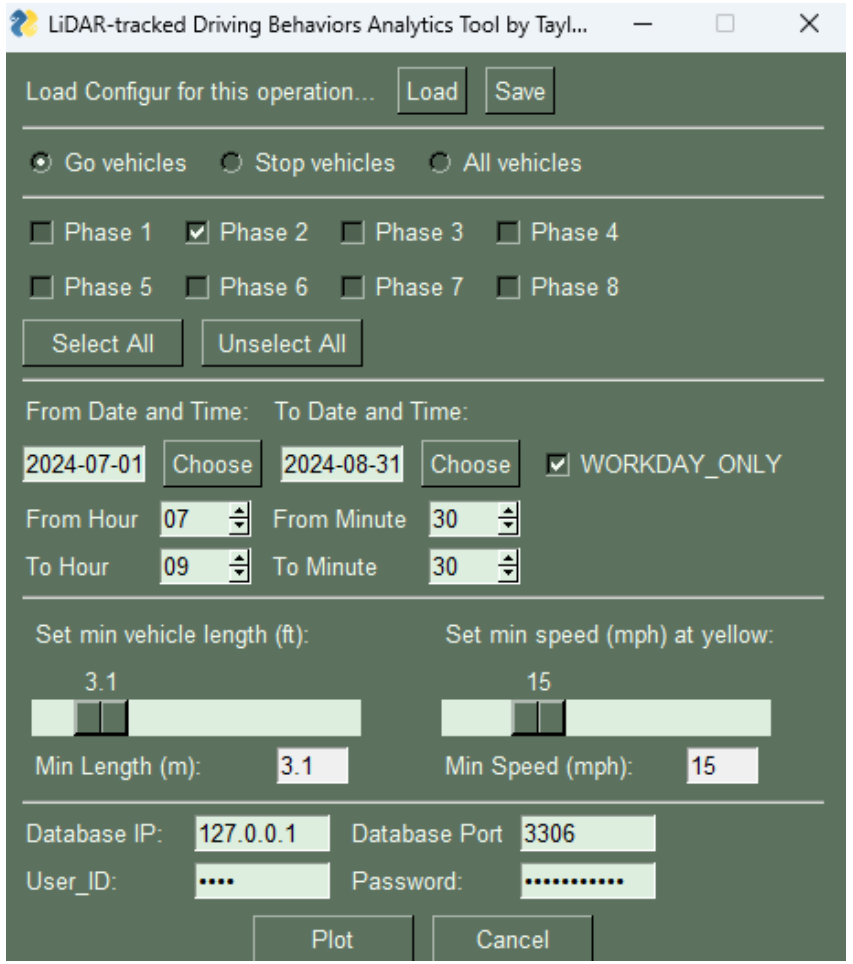
Step 2: Scenario-based performance measures

- Further data processing in the server



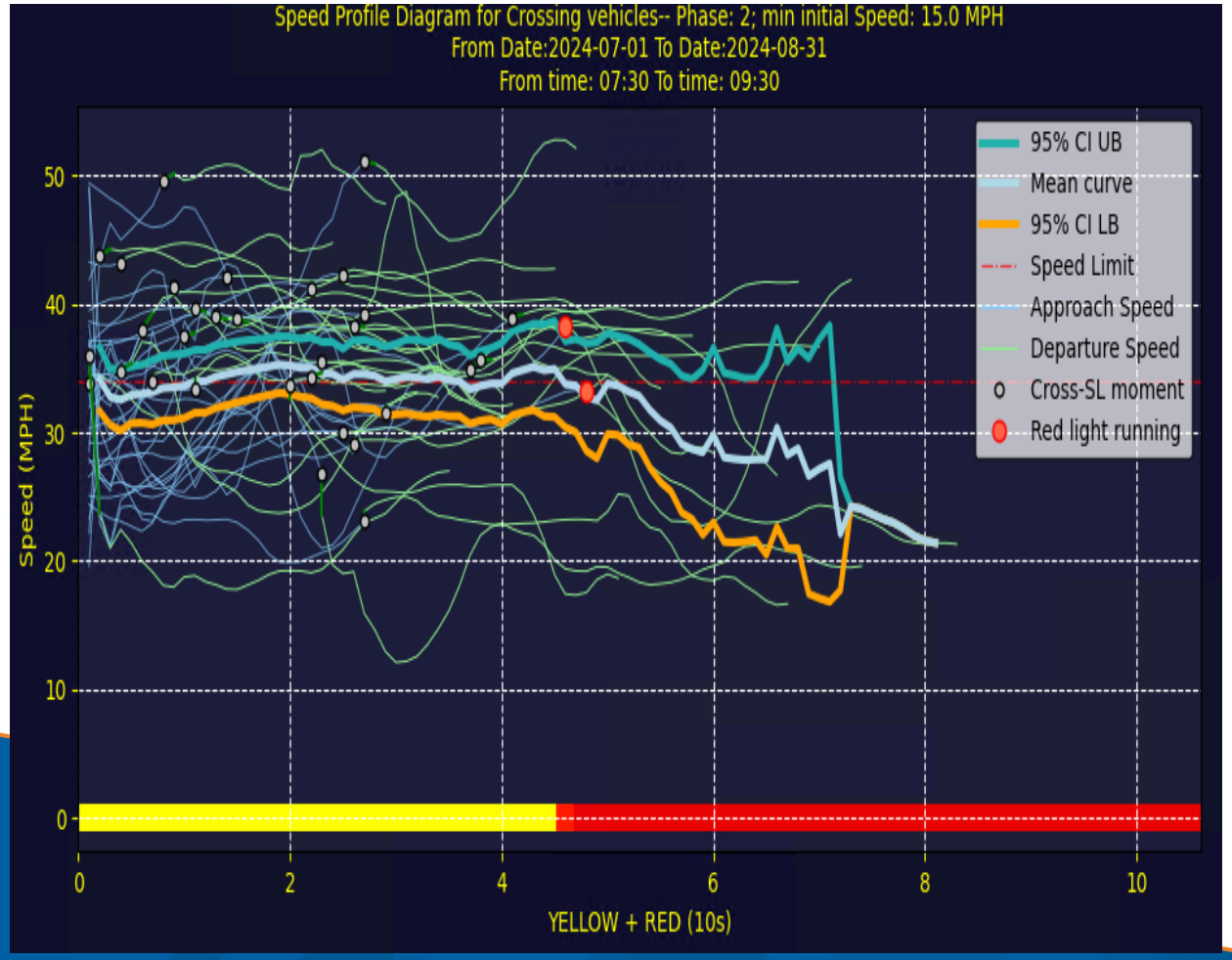


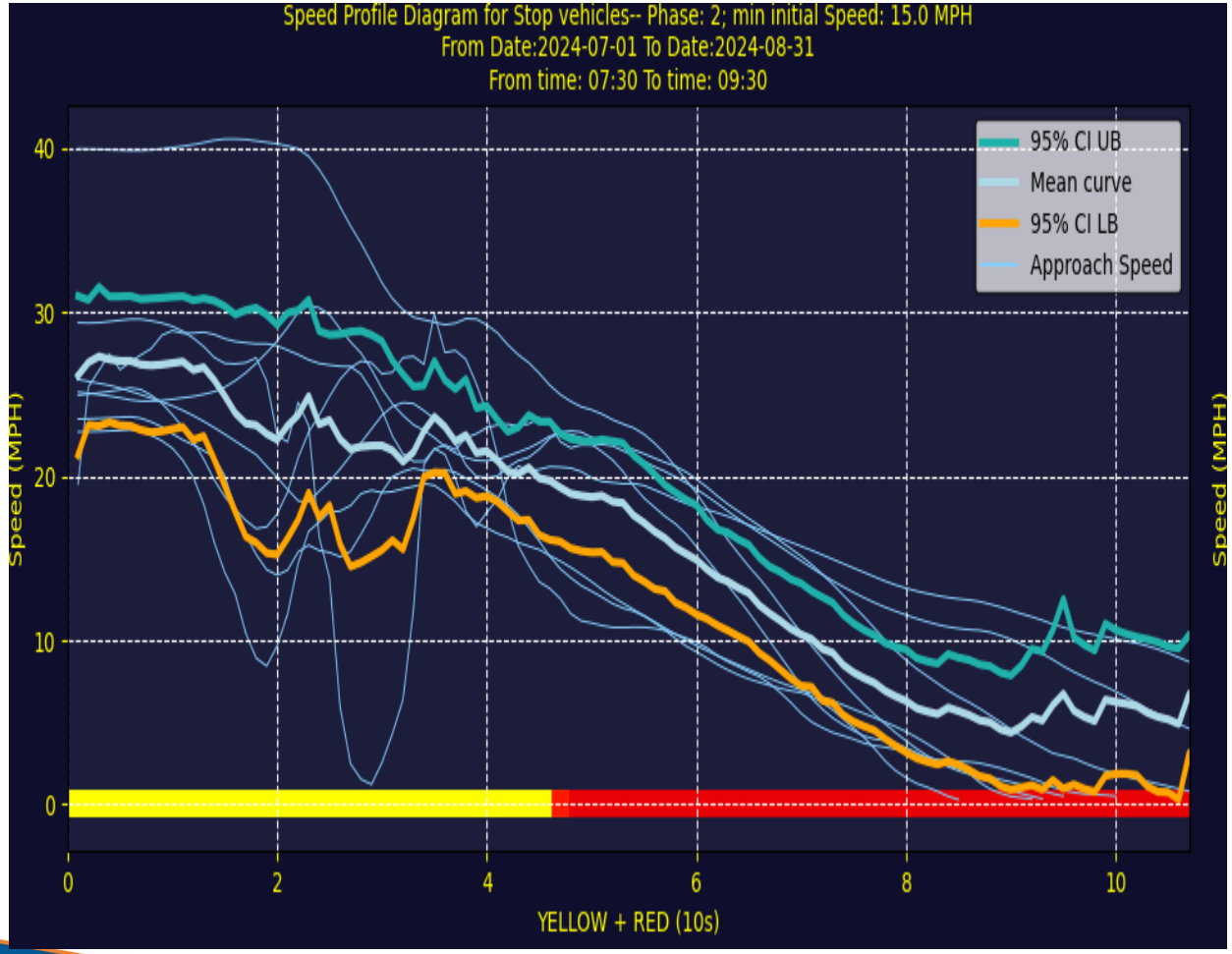
v_id	length_in_meter	speed_fps	origin_zone	phase	color	duration	in_all_red	epoch_time	local_time	stop_line_zone_occ	intersection_occ	crossing_stop_line	exiting_intersection	No_of_peds	dist_from_SL
18036051908086731348	14.1	51.3	83	2	yellow	0.1	0	1723731198.4	2024-08-15 08:13:18.4	1	1	1	0	0	15.4
18036051908086731348	14.1	50.9	83	2	yellow	0.2	0	1723731198.5	2024-08-15 08:13:18.5	0	1	0	0	1	28.5
18036051908086731348	14.1	49.7	83	2	yellow	0.3	0	1723731198.6	2024-08-15 08:13:18.6	0	1	0	0	1	32.6
18036051908086731348	14.2	48.5	83	2	yellow	0.4	0	1723731198.7	2024-08-15 08:13:18.7	0	1	0	0	0	36.7
18036051908086731348	14.2	48.4	83	2	yellow	0.5	0	1723731198.8	2024-08-15 08:13:18.8	0	1	0	0	2	41.2
18036051908086731348	14.2	48.4	83	2	yellow	0.6	0	1723731198.9	2024-08-15 08:13:18.9	0	1	0	0	2	46
18036051908086731348	14.2	48.3	83	2	yellow	0.7	0	1723731199	2024-08-15 08:13:19.0	0	1	0	0	1	50.8
18036051908086731348	14.2	48	83	2	yellow	0.8	0	1723731199.1	2024-08-15 08:13:19.1	0	1	0	0	2	55.7
18036051908086731348	14.2	47.7	83	2	yellow	0.9	0	1723731199.2	2024-08-15 08:13:19.2	0	1	0	0	2	60.3
18036051908086731348	14.2	47.7	83	2	yellow	1	0	1723731199.3	2024-08-15 08:13:19.3	0	1	0	0	2	60.3
18036051908086731348	14.2	47.4	83	2	yellow	1.1	0	1723731199.4	2024-08-15 08:13:19.4	0	1	0	0	1	69.7
18036051908086731348	14.2	47.4	83	2	yellow	1.2	0	1723731199.5	2024-08-15 08:13:19.5	0	1	0	0	1	69.7



Step 2: Performance measures

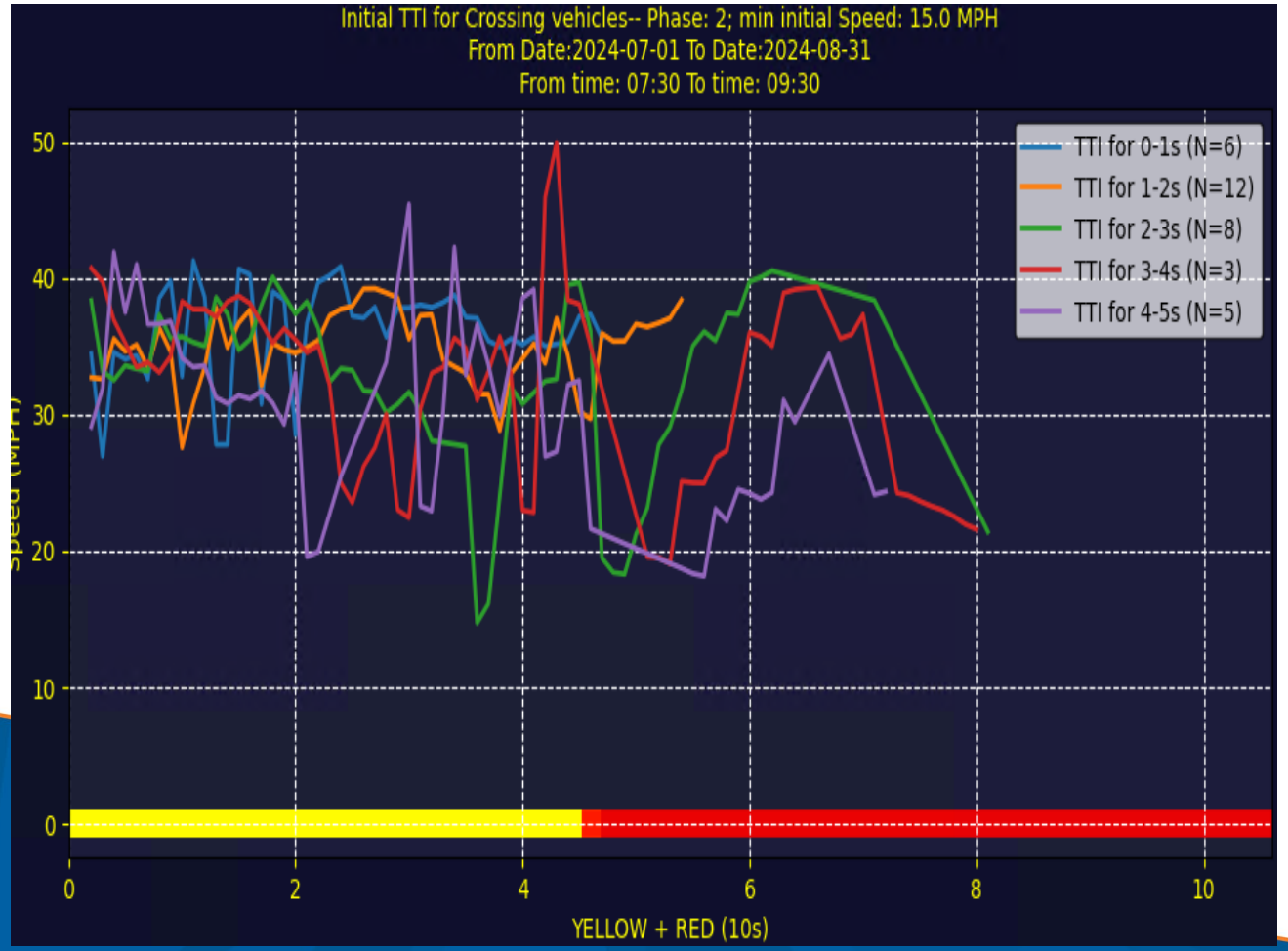
- Speed Profile Diagram (SPD)

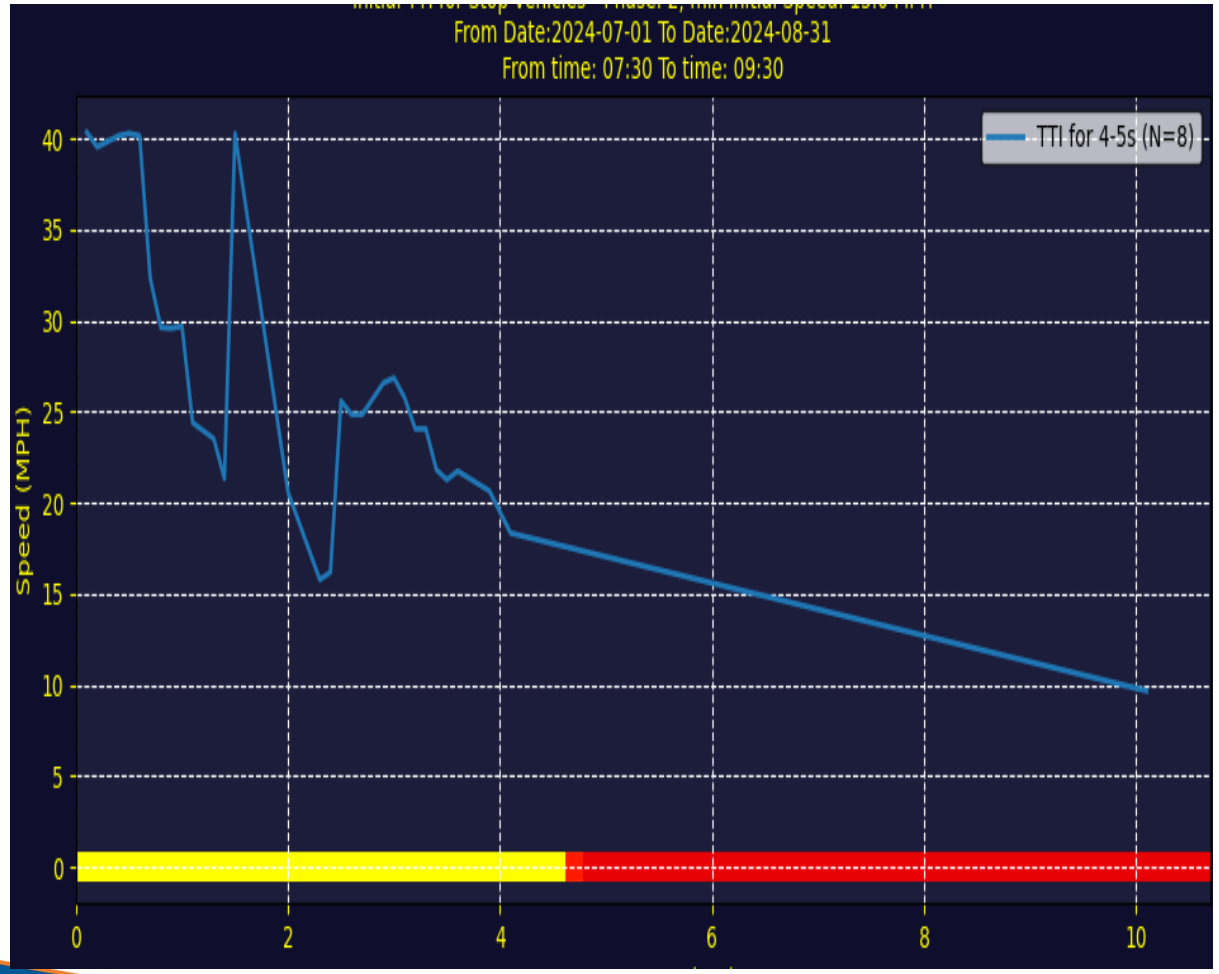




Step 2: Performance measures

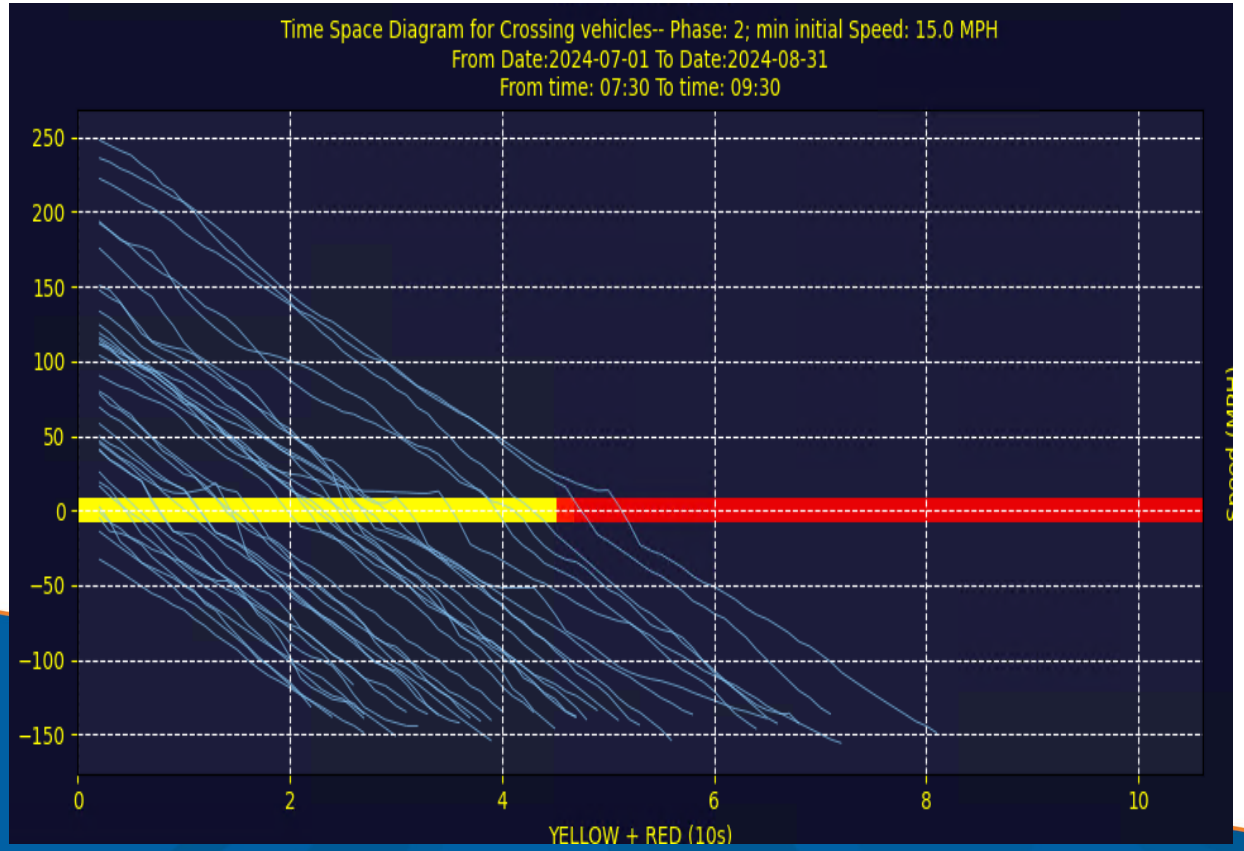
- Aggregated speed Profile Diagram grouped by initial positions

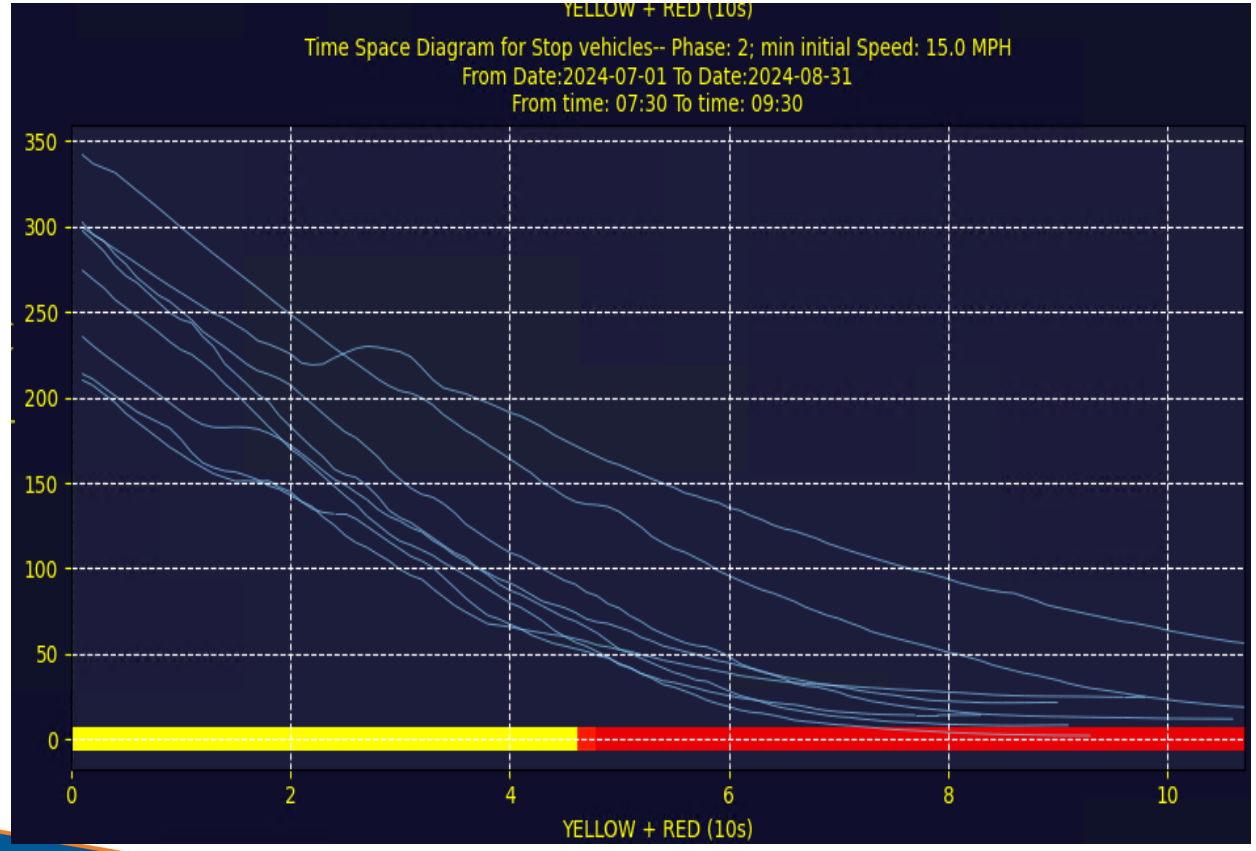




Step 2: Performance measures

- Time-space diagrams at intersections





Next Steps: In-depth driving behavior analysis at more locations

- P-R time?
- Approaching speed reduction?
- Acceleration rate?
- Deceleration rate?
- The entire decision process?

Yellow Change:

$$AR = \left(\frac{L+D}{V_{15}}\right) \qquad Y = t + \frac{1.47V}{2a + 64.4g}$$

Volunteer agencies are needed!

- We need to collection the data at more locations
- The developed edge solutions support multiple perception software

Thanks and Questions?

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