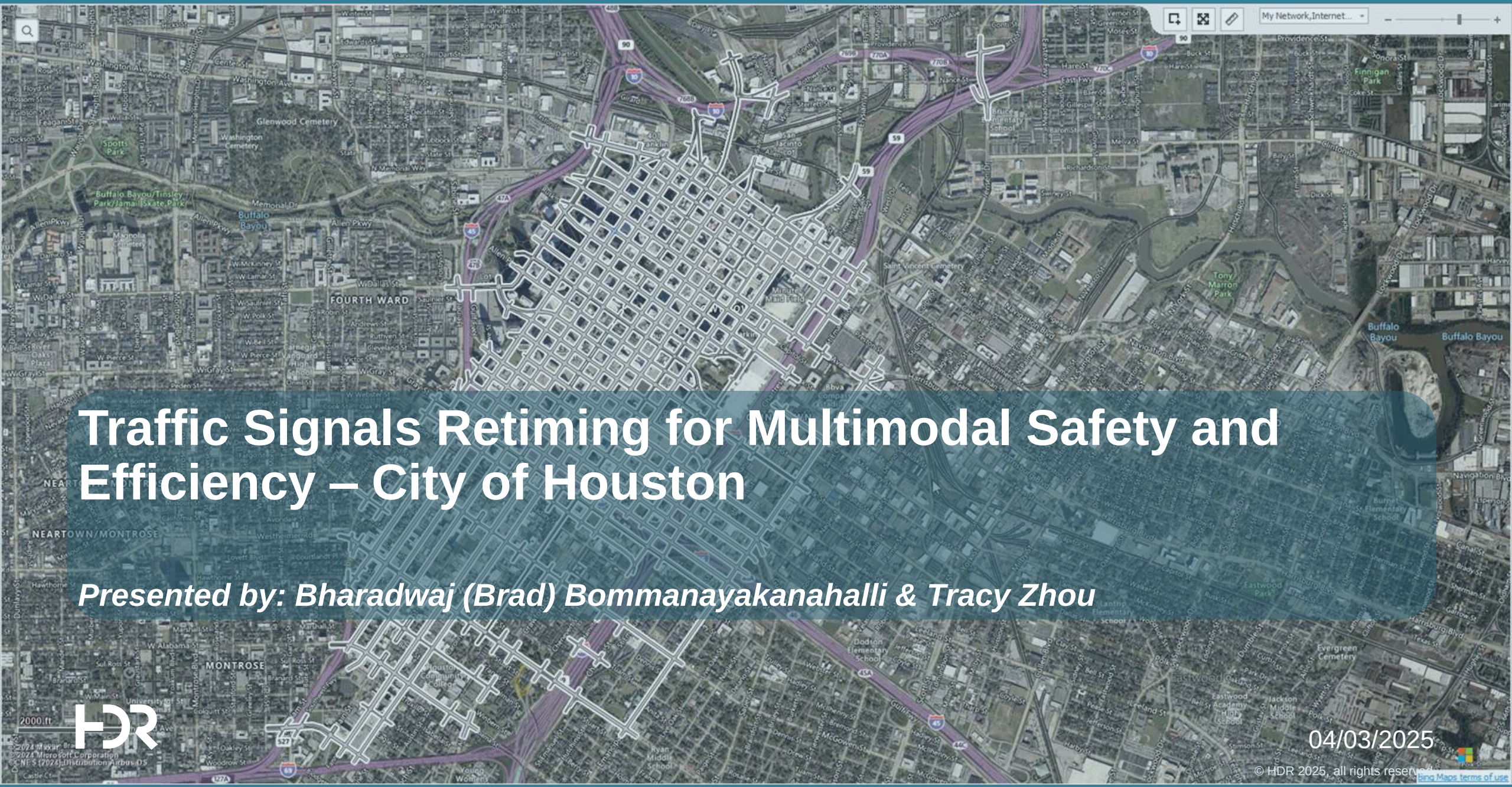


Traffic Signals Retiming for Multimodal Safety and Efficiency – City of Houston

Presented by: Bharadwaj (Brad) Bommanayakanahalli & Tracy Zhou

04/03/2025

Agenda

01 Project Goals

02 Study Area

03 Multimodal Facilities

04 Data Collection

05 Crash Data Analysis

06 Model Development

07 Existing & Proposed Timings

08 Other Recommendations

09 Next Steps

01 Project Goals

Goals

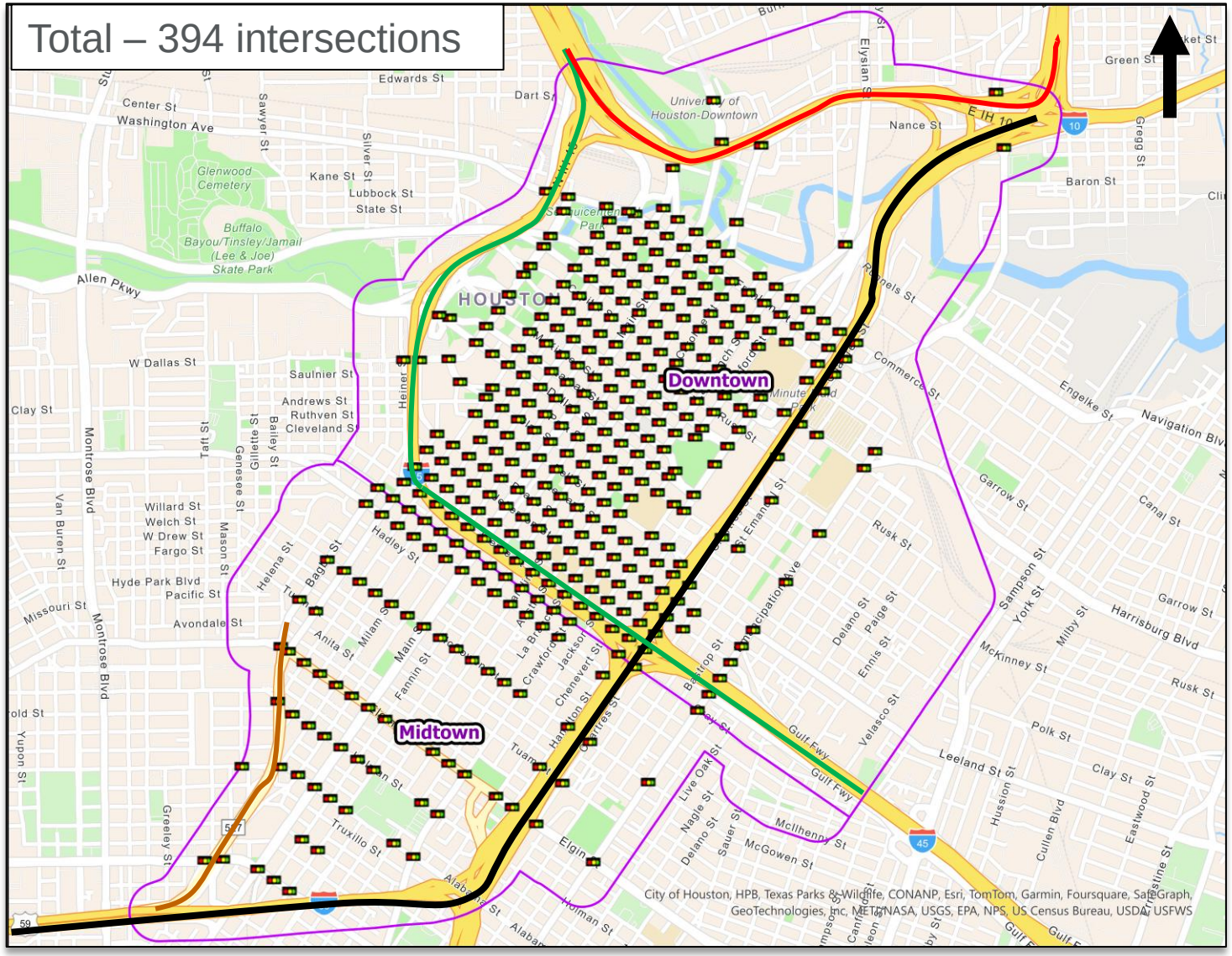
Improve **Safety and Efficiency** of Vehicles & Vulnerable Road Users

Improve **Signal Progression** along Coordinated Arterials

Recommend Other Improvements at Critical Intersections

02 Study Area

Project Limits



I-10 (North)

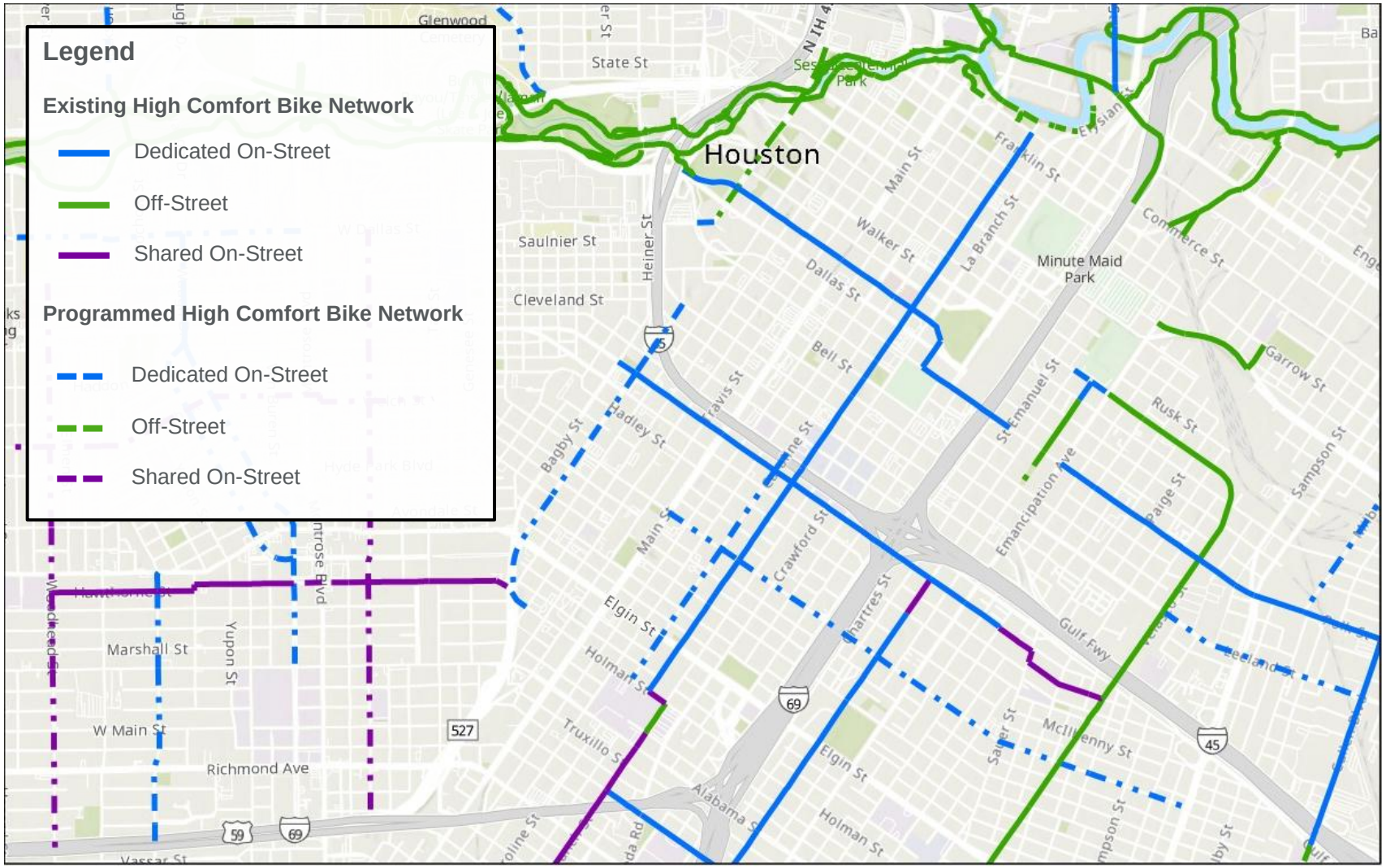
I-69/US 59 (South and East of Downtown)

I-45 (West of Downtown and North of Midtown)

SH Spur 527 (West of Midtown)

03 Multimodal Facilities

Existing & Programmed Bike Network



Exclusive bike lanes / shared-use paths with bike signals along:

- Austin St. (One-Way NB)
- Lamar St. (One-Way WB)
- Gray St. (One-Way WB)
- Bagby St. (Two-Way N-S)

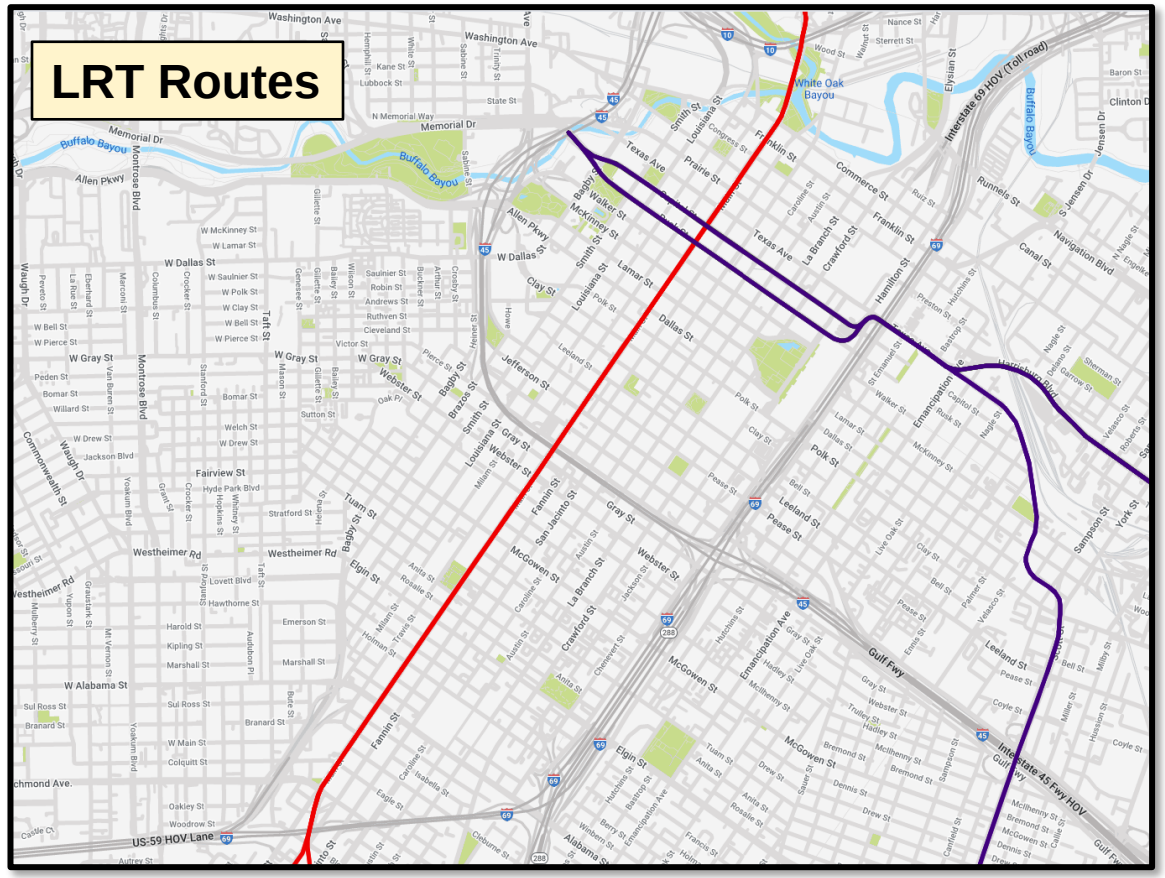
Bike phases operate concurrently with vehicular phases

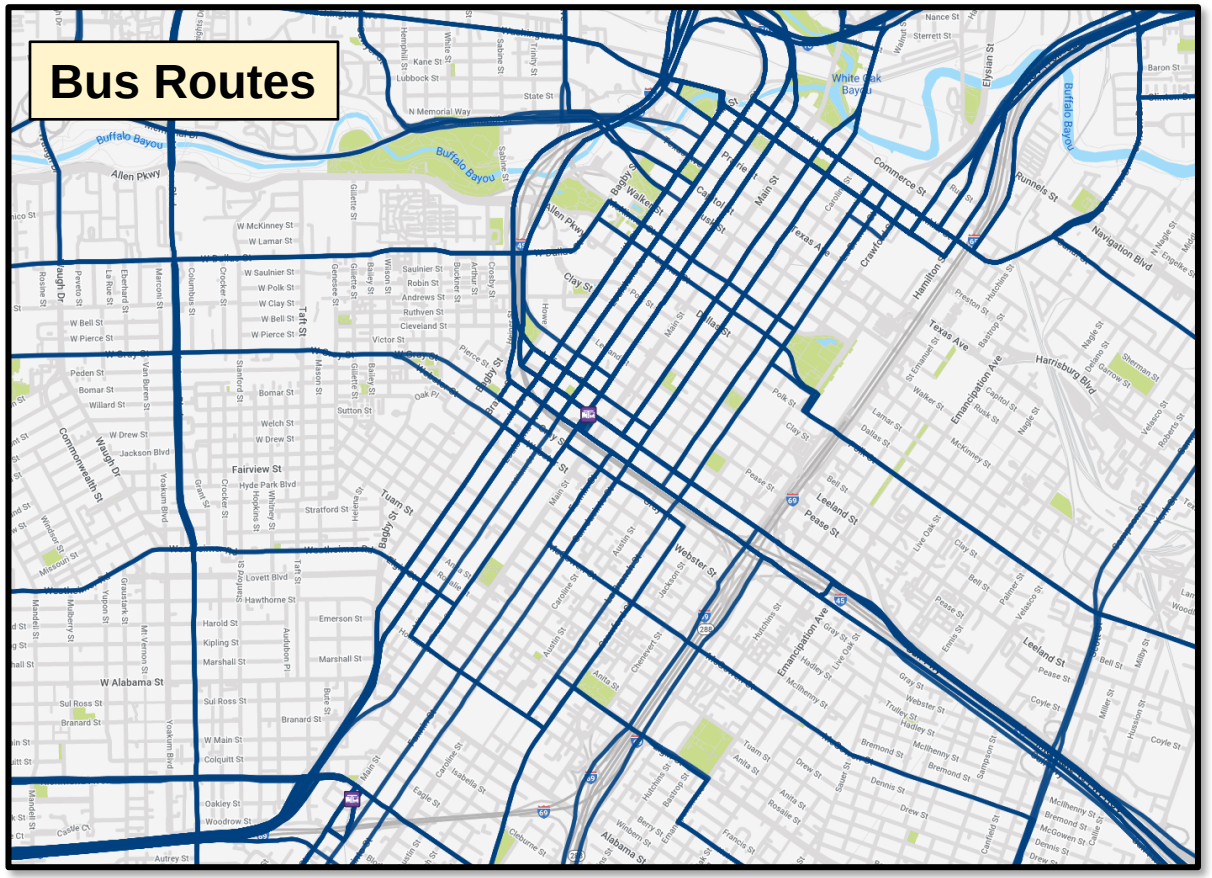
To reduce potential conflicts:

- Vehicle Turns are protected/restricted
  - Austin St. - No RTOR via Protected RT on major streets or restrict RTOR on side streets
  - Gray St. - No Turn on Red via protected left-turn phases
- Leading Bike-Interval (LBI) of 5-sec

Source: Houston Bike Plan Network, https://mycity.maps.arcgis.com/apps/webappviewer/index.html?id=4b5467e117d0459b84e2f2e94ba4fdc2. *Updated: April 2022*

Existing Bus & Light Rail Transit (LRT) Routes





- Red Line – Main St. 6-min headway
- Green Line & Purple Line – Capitol St. & Rusk St. 12-min headway
- LRT Preemption:
  - All signals along Red Line
  - Some signals along Green/Purple Lines
- Signals w/o preemption: concurrent LRT phases / exclusive LRT phase
- Separate signal heads for LRT phase
- City & METRO's effort in providing preemption

- ~ 50 Bus Routes through parts of Downtown & Midtown
- Bus-Only Lanes along Milam St. (SB) and Travis St. (NB)
- No priority or separate signal heads for buses
- Operations impacted on corridors with a lot of bus activities

04 Data Collection

Traffic Data

- **Field Observations** – lane configuration, lane utilization, coordination, queue lengths, split failures, and spillbacks
- **Traffic Volumes**
  - Turning Movement Counts (TMCs) – 2 hours in each peak (AM, Mid, PM & Sat) at 91 intersections in Apr & May 2024
  - TMCs at 29 additional intersections from 2022 & 2023
  - Weekday ADT data from City GIS site for 2022 & 2023
  - Tube Count Data on Saturdays at 81 locations 2024
  - **Streetlight Data** – interpolate TMCs at locations w/o data
- **Travel Time Runs (TTR)**
  - Nine major N-S corridors & One major E-W corridor
  - Three TTRs in each peak
  - Tru-Traffic to interpret the travel time data

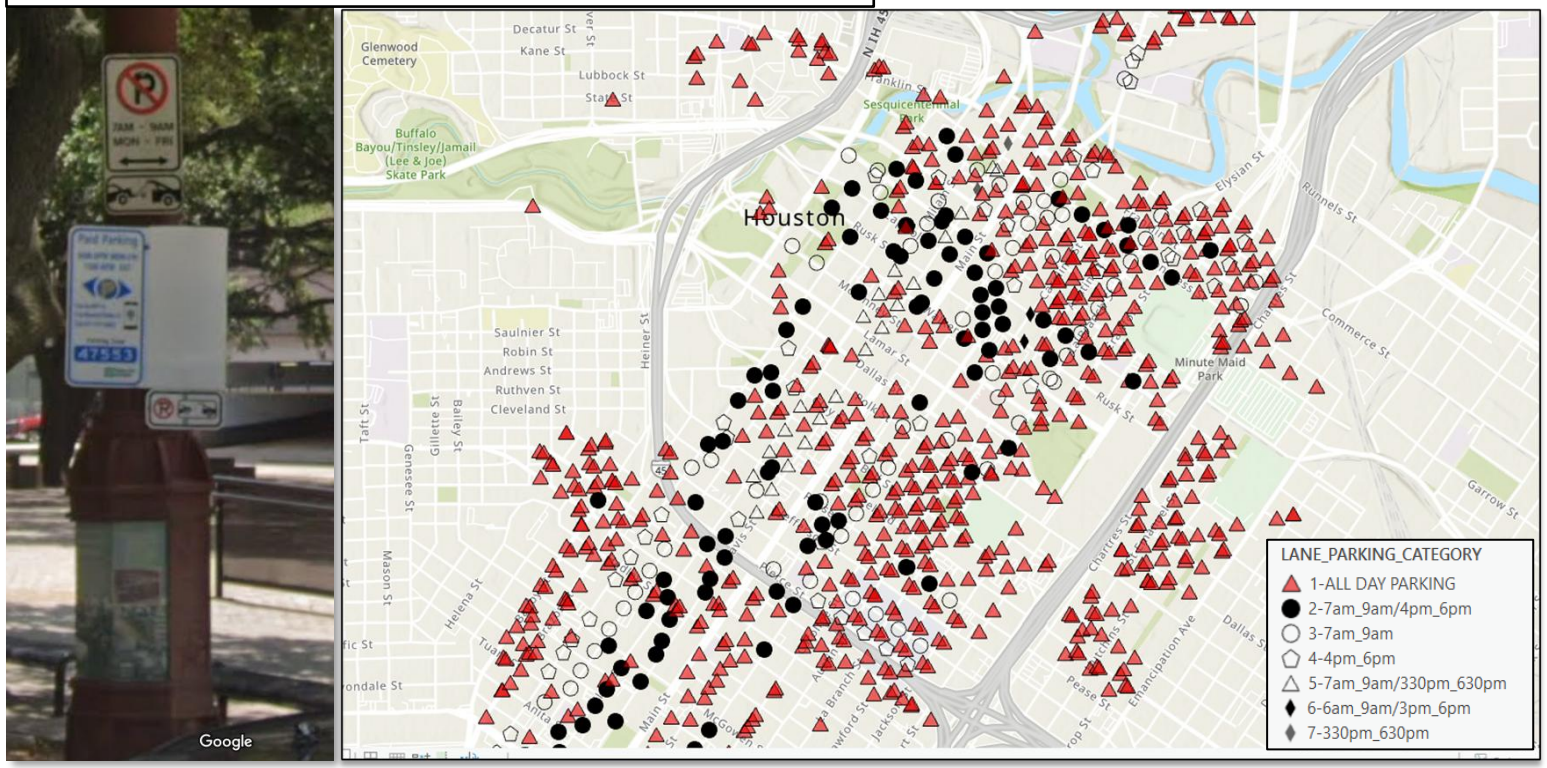
Challenges

- Coordinating staff to perform peak-hour observations for 394 intersections
- Observation days are restricted
- Available Weekday ADT data didn't match well with the collected TMCs
- Collected TMC + StreetLight Data ~~> TMCs (274 intsctns x 4 peaks x 3 mvmnts)
- Major sinks & sources (parking facilities)
- GPS data was spotty for some of the TTRs

Other Data

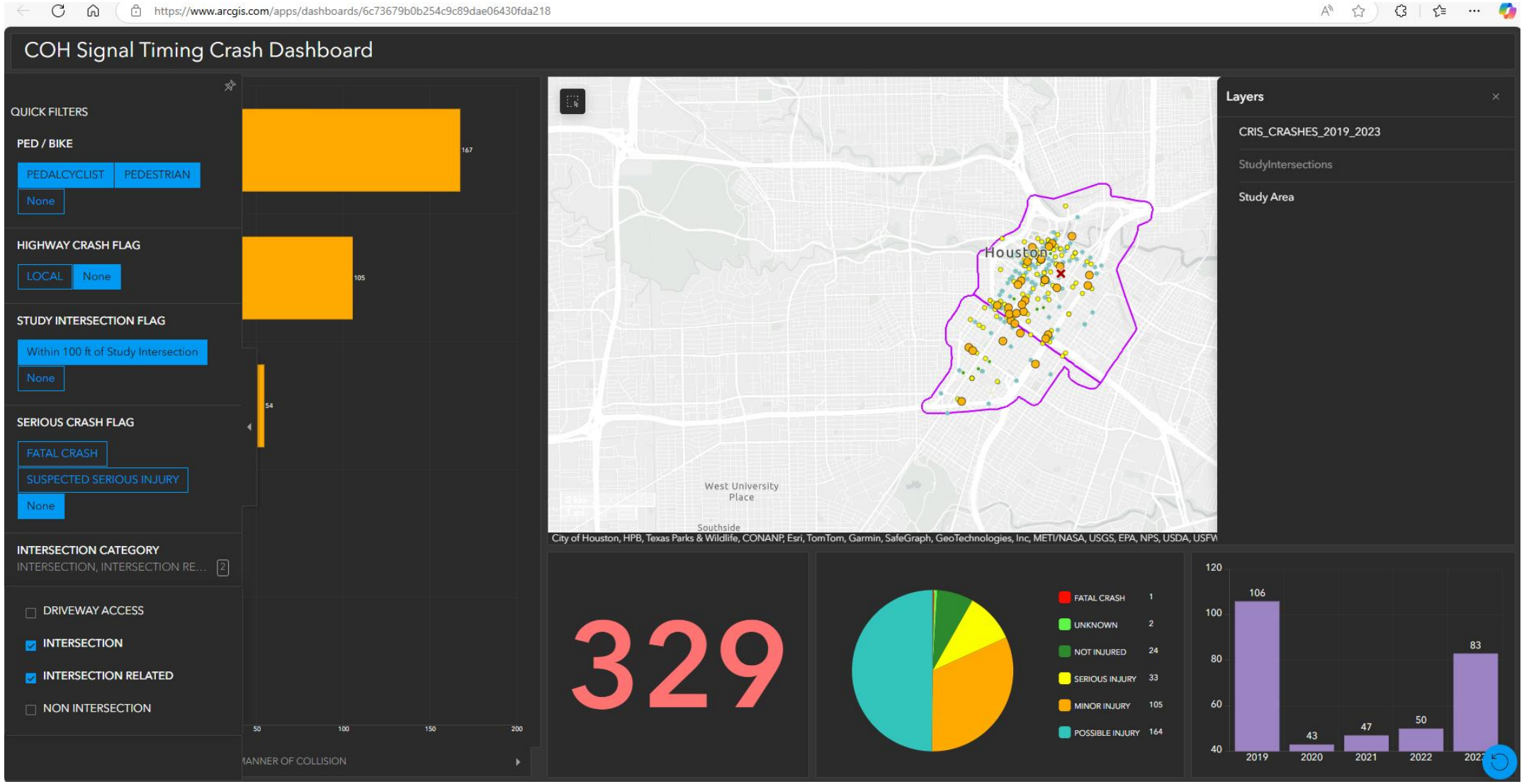
- **Signal Timings**
  - City of Houston ATMS system
- **Crash Data**
  - 5 Yr TxDOT CRIS data (2019-2023)
- **Bus-Stopping Rate**
  - Peak hour Ave bus-stopping rates calc from General Transit Feed Specification data (https://gtfs.org/).
- **Preemption Data**
  - 10 days of preempt data from ATMS
- **Dynamic Parking Lanes**
  - TOD restricted parking info from ParkHouston and verified in StreetView.

Parking Restrictions by Time of Day



05 Crash Analysis

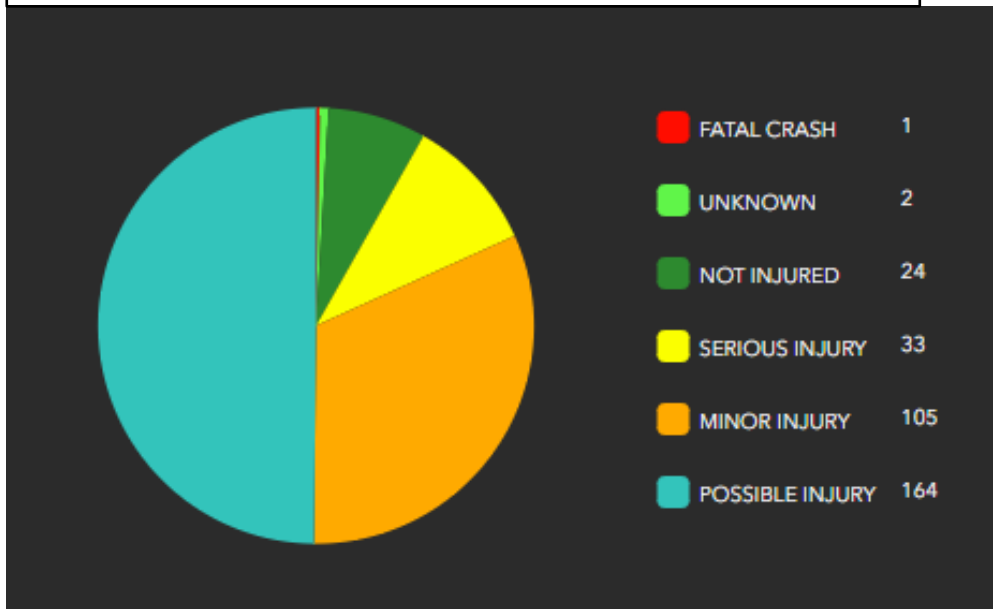
Crash Analysis Tool



Source: https://www.arcgis.com/apps/dashboards/6c73679b0b254c9c89dae06430fda218

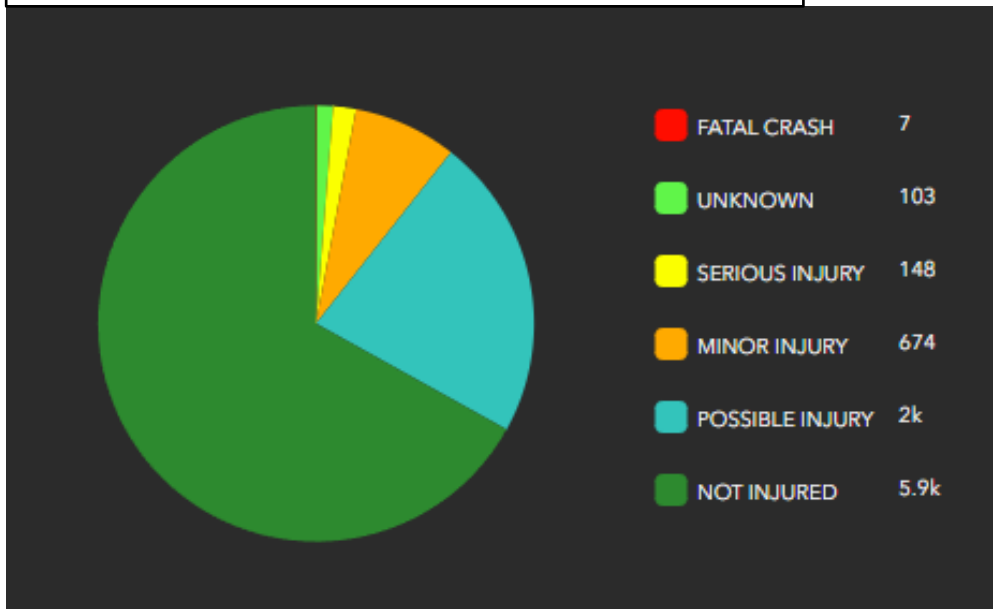
Crash Analysis Results

Ped/Bike Crashes – Total 329 Crashes



- Top Manner of Collisions: Single Veh Turning Left (>50%)
- Top Three Contributing Factors:
  - Failed to yield ROW to Ped/Bike (39%)
  - Disregard Stop & Go Signal (9%)
  - Pedestrian Failed to Yield ROW to Vehicle (7%)

All Crashes – Total 8800 Crashes

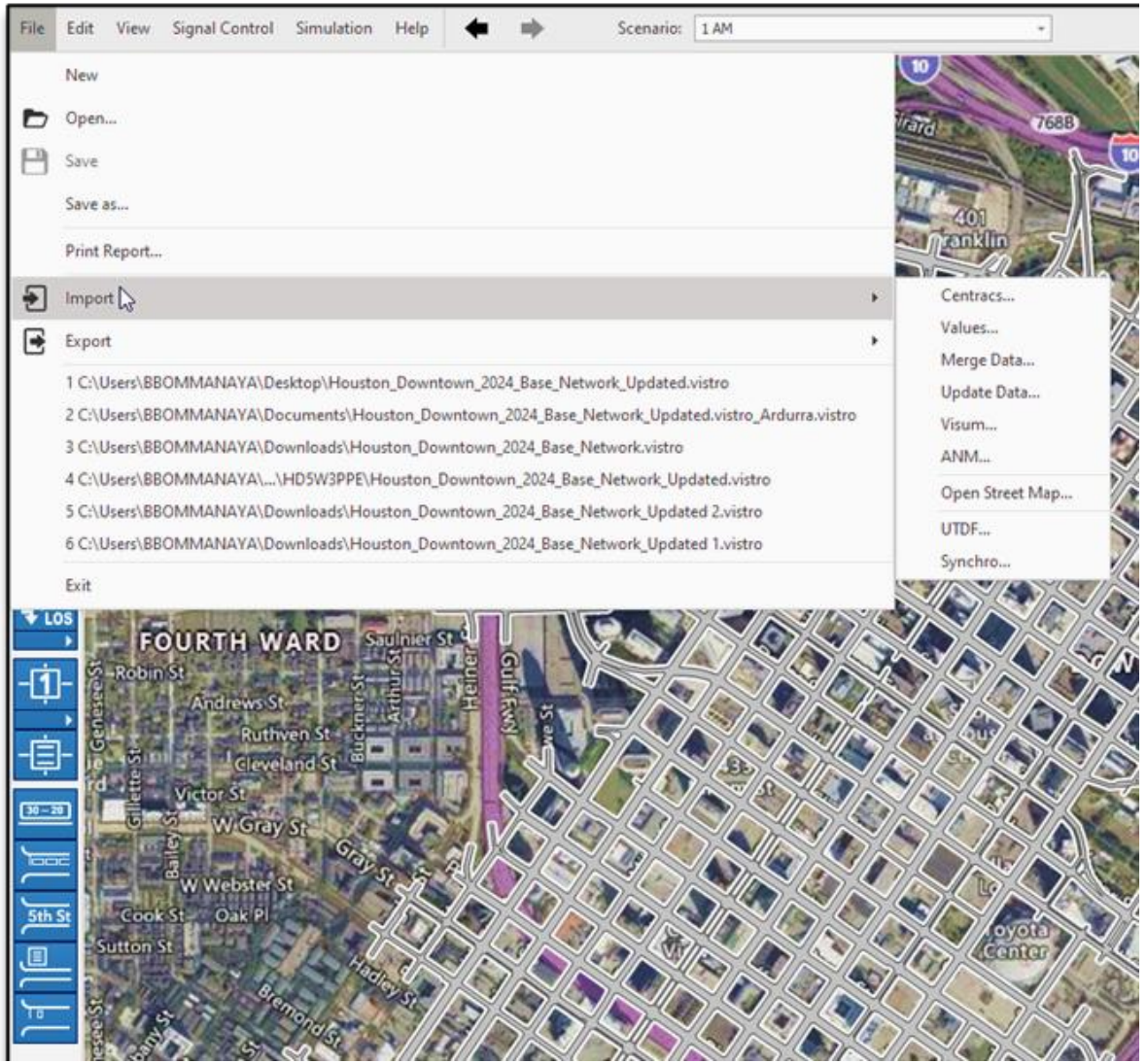


- Top Manner of Collisions: Angle - Both Thru Vehs (>14%)
- Top Three Contributing Factors:
  - Disregard Stop & Go Signal (43%)
  - Turned Improperly – Wrong Lane (11%)
  - Failed to Control Speed (6%)

06 Model Development

PTV VISTRO Modeling

- HCM Methodologies for Performance Metrics *(HCM 7th Edition Exhibit 19-11)*
  - Traffic Characteristics
  - Geometric Design Data
  - Signal Control Data
  - Other Data – Analysis Duration, Area Type
- Open Street Map for Starter
- Scenario Manager
  - AM, Midday, and PM Peaks
  - Saturday Peak



PTV VISTRO Modeling – Saturation Flow Rate Adjustment

- **HCM 7th Edition, Exhibit 19-11**
- **RTOR flow rate** – Input as a %
- **Platoon Ratio** – Input as Arrival Type
- **Lane Utilization Factor**
- **Initial queue** – Input as initial queue delay
- **Parking Maneuver Rate** – Parking on each side of the street separately
- **Local Bus Stopping Rate**

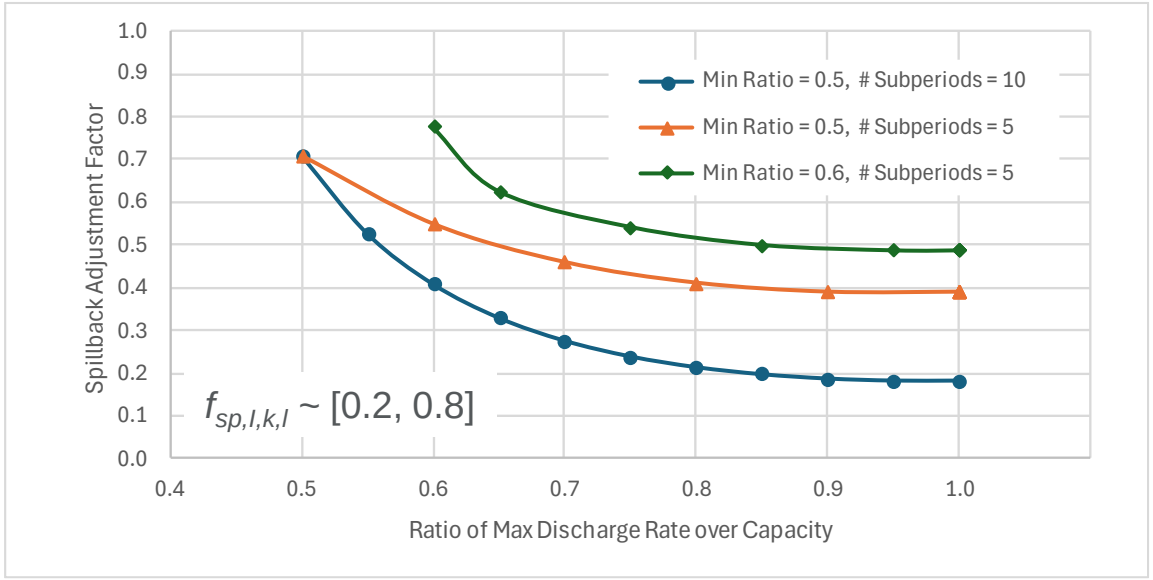
Adjustment Factors	Input Data and Parameter	Methodology of Identifying Input Values
Lane Width	Average lane width for a movement	Aerial image measurement
Heavy Vehicles	Percentage of heavy vehicles	Heavy vehicle volume divided by total volume of a movement
Parking	Presence of on-street parking and parking maneuver rate	Field visit or aerial image measurement of number of parking spaces in 250 ft upstream of stop line: 6 maneuvers/hr for 10 parking spaces on two-way street or 11 maneuvers/hr for 20 parking spaces on one-way street.
Bus Blockage	Bus stop rate	METRO Houston General Transit Feed Specification (GTFS) Data; vary by bus stop
Area Type	CBD	CBD for both downtown and midtown intersections
Lane Utilization	Number and volumes of exclusive lanes in a lane group	HCM Equation 19-7
Left Turns	Left turn volumes	Percentage of left turns in a shared left turn lane
Right Turns	Right turn volumes and right turn on red (RTOR) volumes, RTOR restrictions	Aerial image checking; percentage of right turns in a shared right turn lane.
Pedestrians and Bikes	Pedestrian (bike) flow rate in the pedestrian (bike) service time and that in the subject crossing (in both directions), pedestrian (bike) service time, and phase effective green time.	HCM Section 2 of Chapter 31, Equation 31-70 ~ Equation 31-74, and Equation 31-77. Pedestrians walk speed uses 3.0 fps.

Spillback Adjustment & Initial Queue Delay Estimate

- **Sustained Spillback observed in field**
  - Vertical queuing assumption in VISTRO
  - HCM spillback adjustment factor

$$f_{sp,i,k,l} = \left(\frac{dv_{u,i,k}}{c_{u,i,k}}\right)^{0.5} \times f_{ms,i,k} \times f_{sp,i,k,l-1}$$

  - One fsp per approach allowed → **fsp ~ [0.55, 0.95]**



- **Initial Queue observed in field**
  - User input allowed one value per approach

$$d_3 = \frac{3{,}600}{v\,T}\left(t_A \frac{Q_b + Q_e - Q_{eo}}{2} + \frac{Q_e^2 - Q_{eo}^2}{2\,c_A} - \frac{Q_b^2}{2\,c_A}\right)$$

$$Q_e = Q_b + t_A(v - c_A)$$

If $v \geq c_A$, then

$$Q_{eo} = T\,(v - c_A)$$
$$t_A = T$$

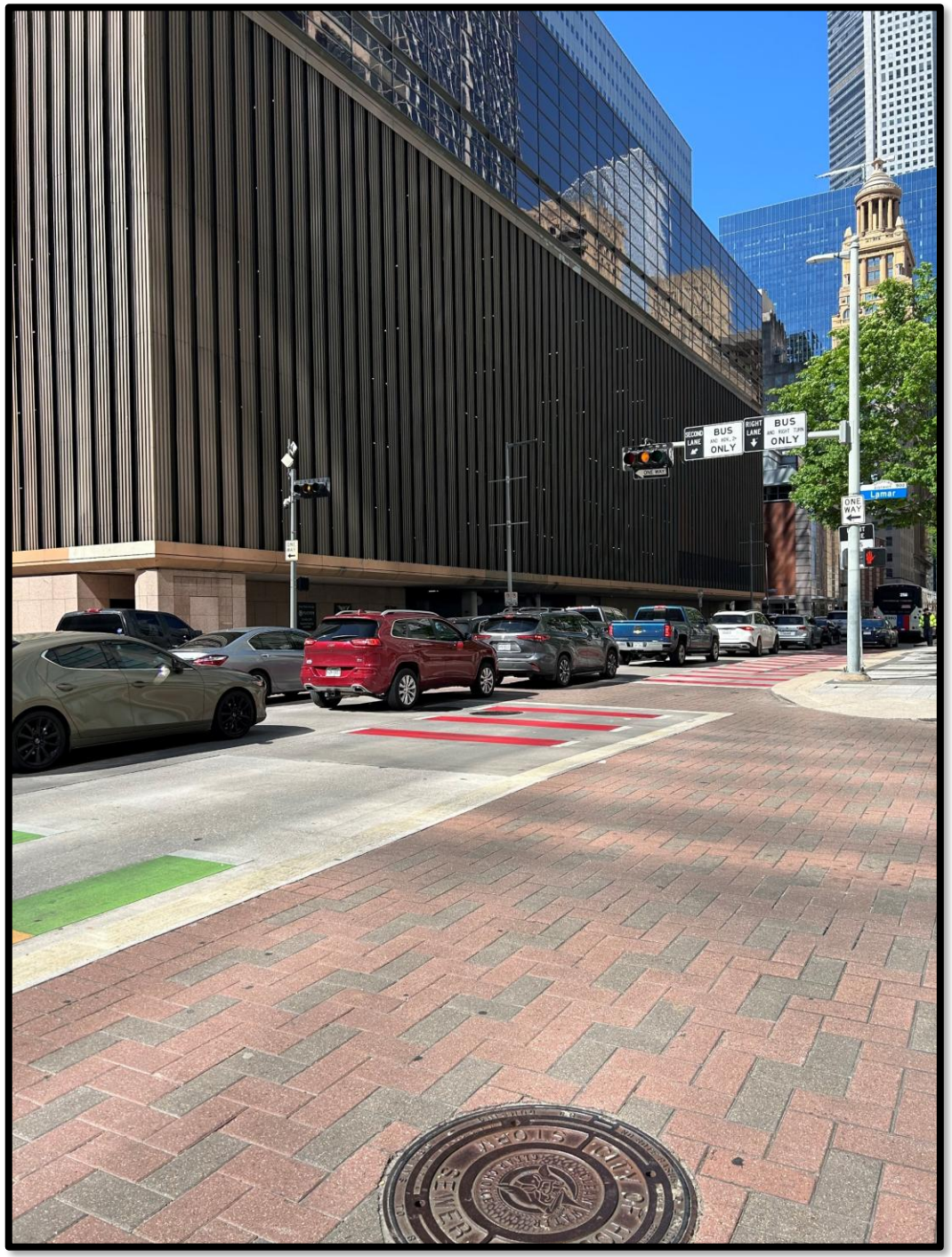
If $v < c_A$, then

$$Q_{eo} = 0.0 \text{ veh}$$
$$t_A = Q_b/(c_A - v) \leq T$$

07 Existing & Proposed Timings

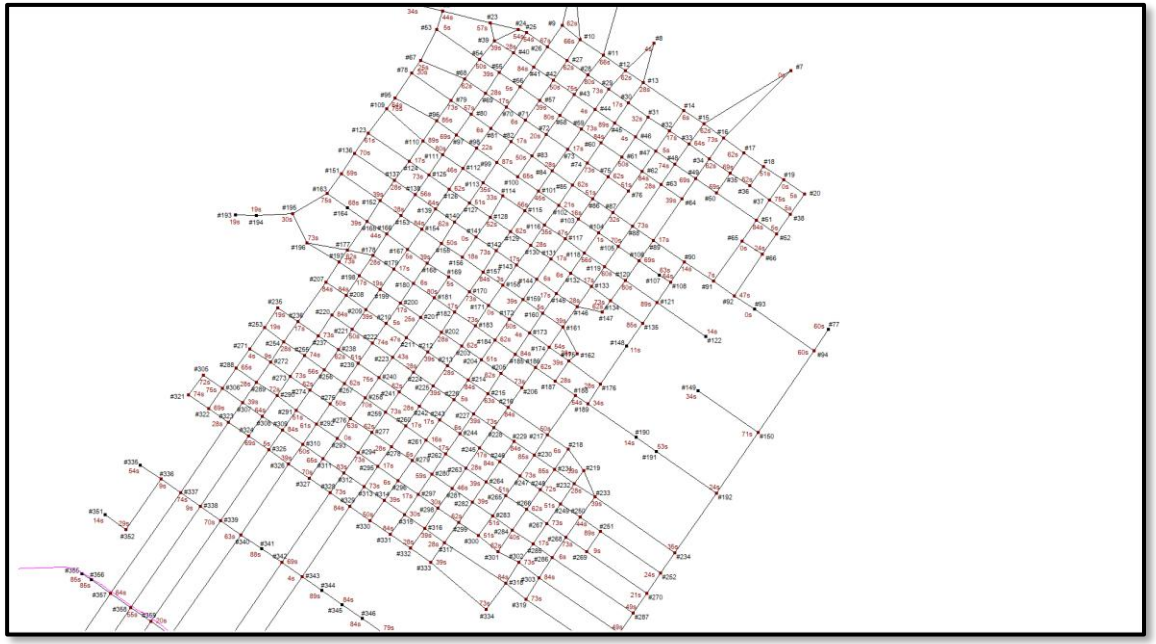
Existing Timings

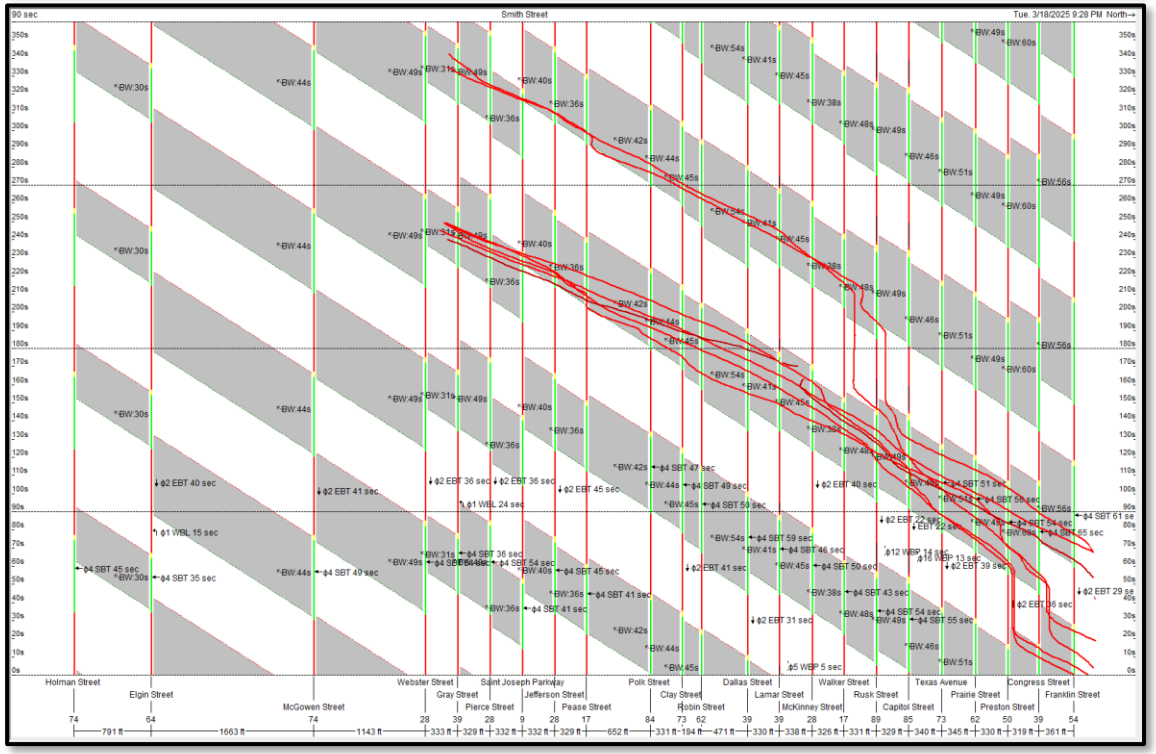
- The signals in Downtown and Midtown operate on a 90-second cycle and are pre-timed (No detection at most signals).
- Most of the signals have Ped Recalls and Rest-in-Walk active (No pushbuttons at most signals).
- The Time-of-Day schedule for most sites:
  - Weekday AM Peak Plan – 5:30 AM to 9:30 AM
  - Weekday PM Peak Plan – 3:00 PM to 7:30 PM
  - Off Peak Plan runs at other times on weekdays & weekends
- The existing coordination is primarily established for the N-S corridors and a few key E-W corridors.



Tru-Traffic Model

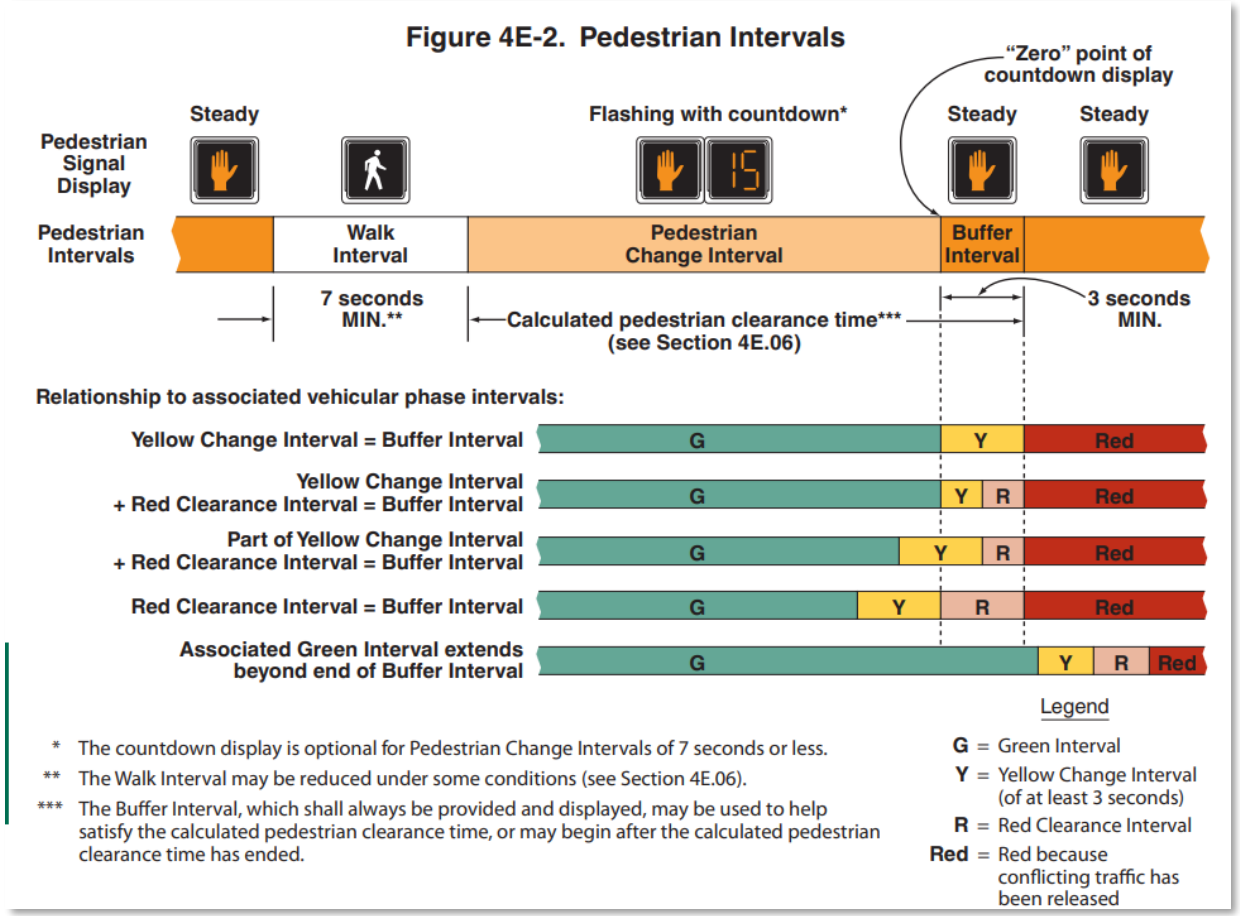
- Tru-Traffic is used to develop Time-Space Diagrams and optimize offsets to improve progression.
- Tru-Traffic was also used to collect travel time runs and plot the trip logs against the Time-Space Diagram.
- Utilized “Time-Shift” on Diagrams” function to line up the trip logs appropriately.
- Exclusive Train Phases were coded as “Exclusive Pedestrian Phases” in Tru-Traffic.
- Leading Pedestrian Interval (LPI) and Leading Bike Interval (LBI) were coded as increased All–Red in Tru-Traffic.





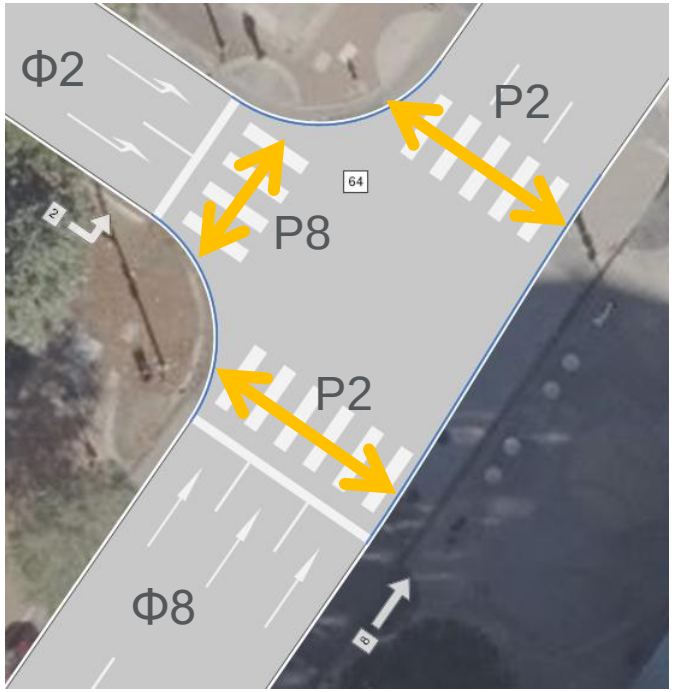
Proposed Pedestrian & Bike Timings Key Requirements

- A **pedestrian walking speed of 3.5 fps will be used** for developing the Walk phase timings.
- To improve pedestrian safety, **a Leading Pedestrian Interval (LPI) of 4.0 seconds** is proposed at select intersections, if deemed necessary.
- Based on City guidelines**, Yellow can be considered part of Pedestrian clearance**.
- Walk Time is between 4.0 sec and 6.0 sec for the entire grid.
- A **Leading Bike Interval (LBI) of 4.0 seconds** is proposed at intersections with bike signals, if deemed necessary.



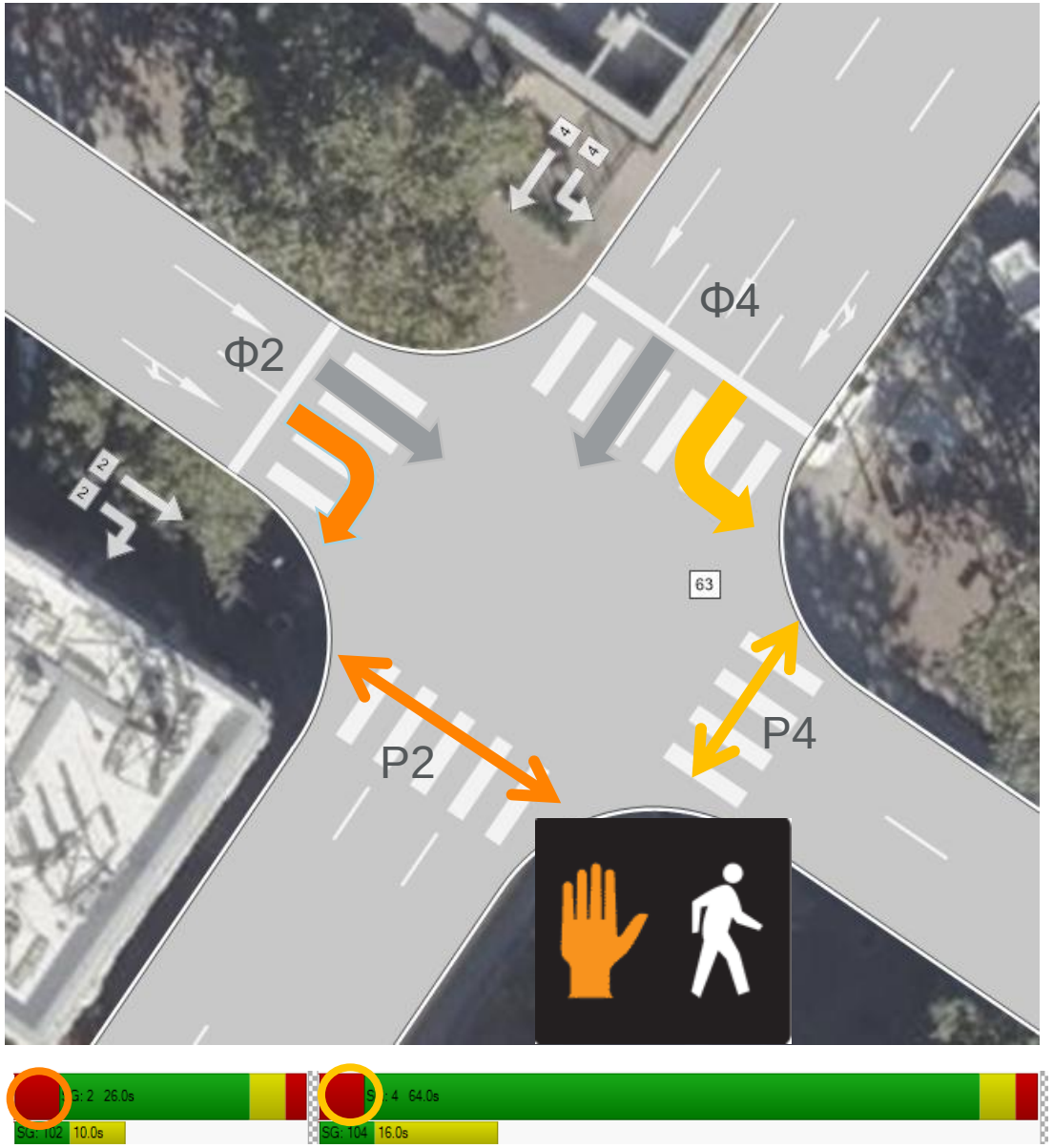
LPI/LBI Provision Conditions

- **Condition A**: Presence of a Ped/Bike Signal
- **Condition B**: Ped/Bike phase going concurrently with a vehicular phase that allows a turning movement in a conflict path
- Consider LPI or LBI when both A <u>and</u> B met



LPI for Φ2?

LPI for Φ8?



Proposed Timings Considerations – Cycle Length

- **First Iteration:** 90-sec CL with LPIs coded, and splits reallocated.
- **Additional Iterations:** Reevaluate Cycle length (adjust lower or higher) based on current traffic patterns.
- **Lower CL**
  - **Benefits**
    - Potentially reduce delays for minor streets
    - Lower probability of queue spillbacks
  - **Challenges**
    - Lower flexibility for split adjustment
    - At locations with LPIs, capacity reduction will be more than 10%
- **Higher CL**
  - **Benefits**
    - Minimize the impacts of incorporating LPIs
    - Higher flexibility for split adjustment
  - **Challenges**
    - Typical block spacing of 330’ in the Downtown grid

$Cycle\ Length = 90\ sec$

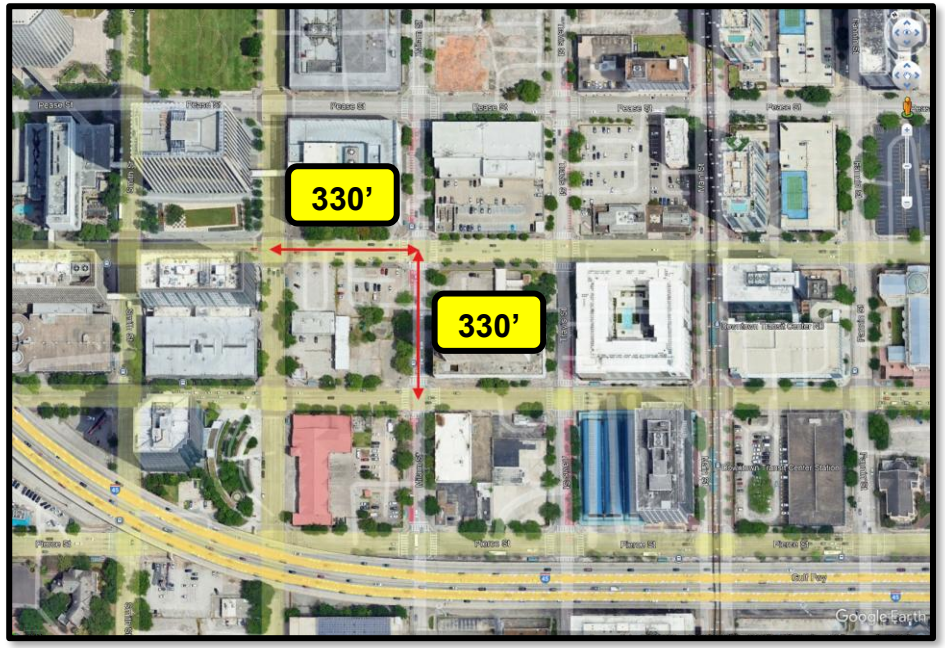
$Lost\ Time\ per\ Cycle\ (Existing) = 2 * 5 = 10\ sec$

$Effective\ Green\ Time = 90 - 10 = 80\ sec$

With a 4.0 sec LPI on both phases

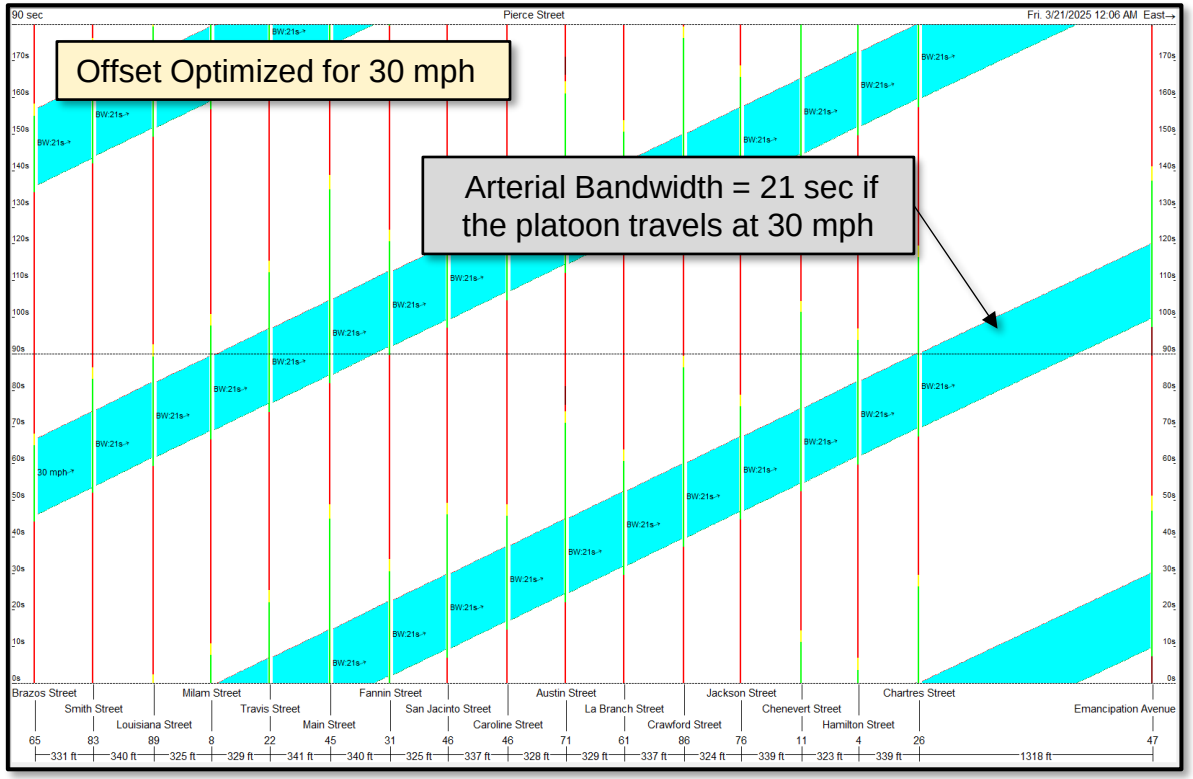
$Effective\ Green\ Time = 90 - 10\ - 2 * 4 = 72\ sec$

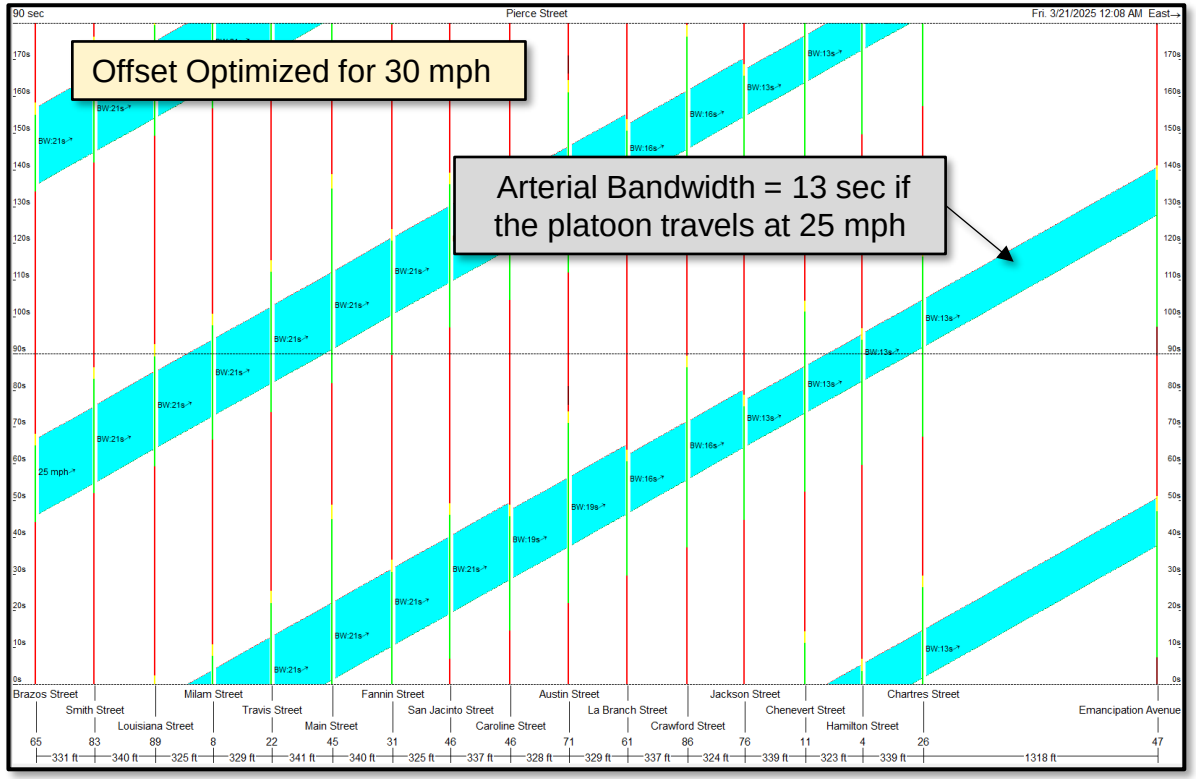
$\%\ Change\ in\ Capacity = \frac{72 - 80}{80} * 100 = \mathbf{-10\%}$



Additional Coordination Considerations

- **Coordination Speed:** A suitable coordination speed is crucial for efficient operations. **The offsets will be designed for a speed of 25 mph** in proposed conditions.
- Coordination will be **End-of-Green to End-of-Green** wherever feasible to ensure the block is clear for the side street vehicles to turn.
- Avoid platoons arriving in dilemma zones.



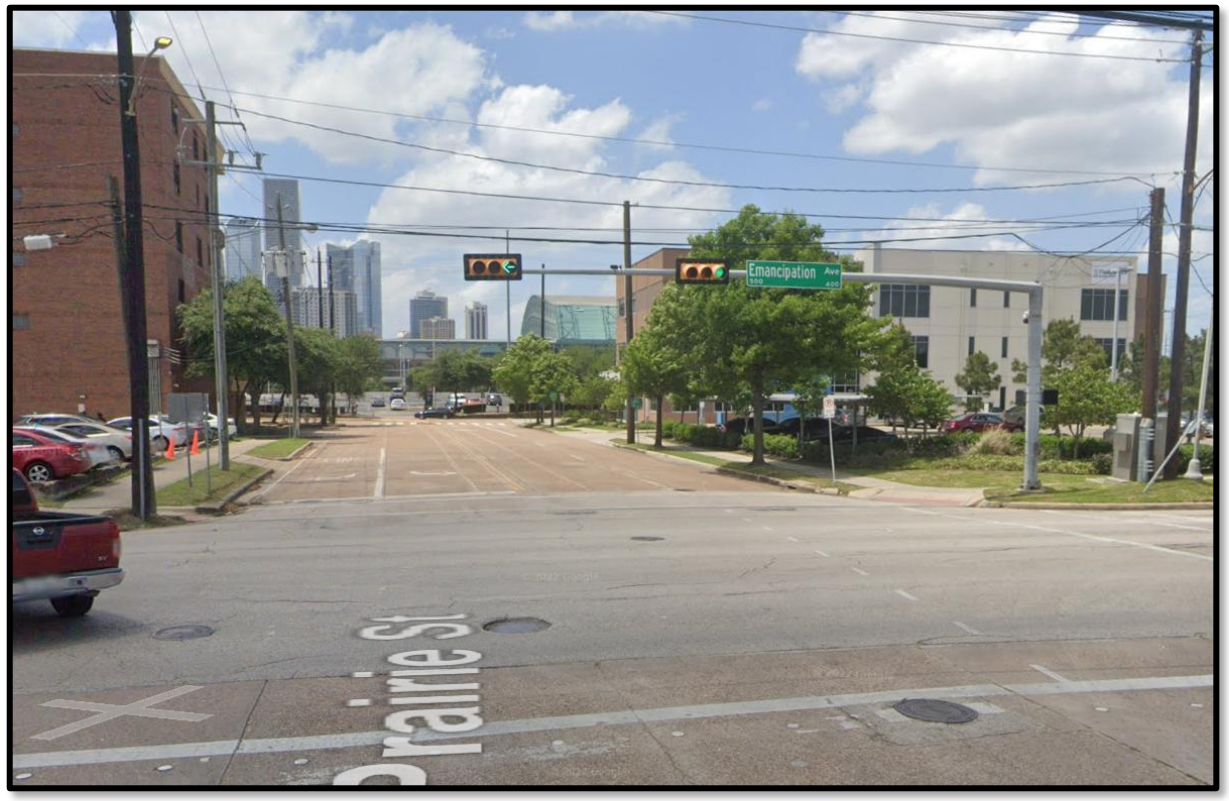


The proposed timings are under development and have not yet been implemented/fine-tuned in the field.

08 Other Recommendations

Other Recommendations

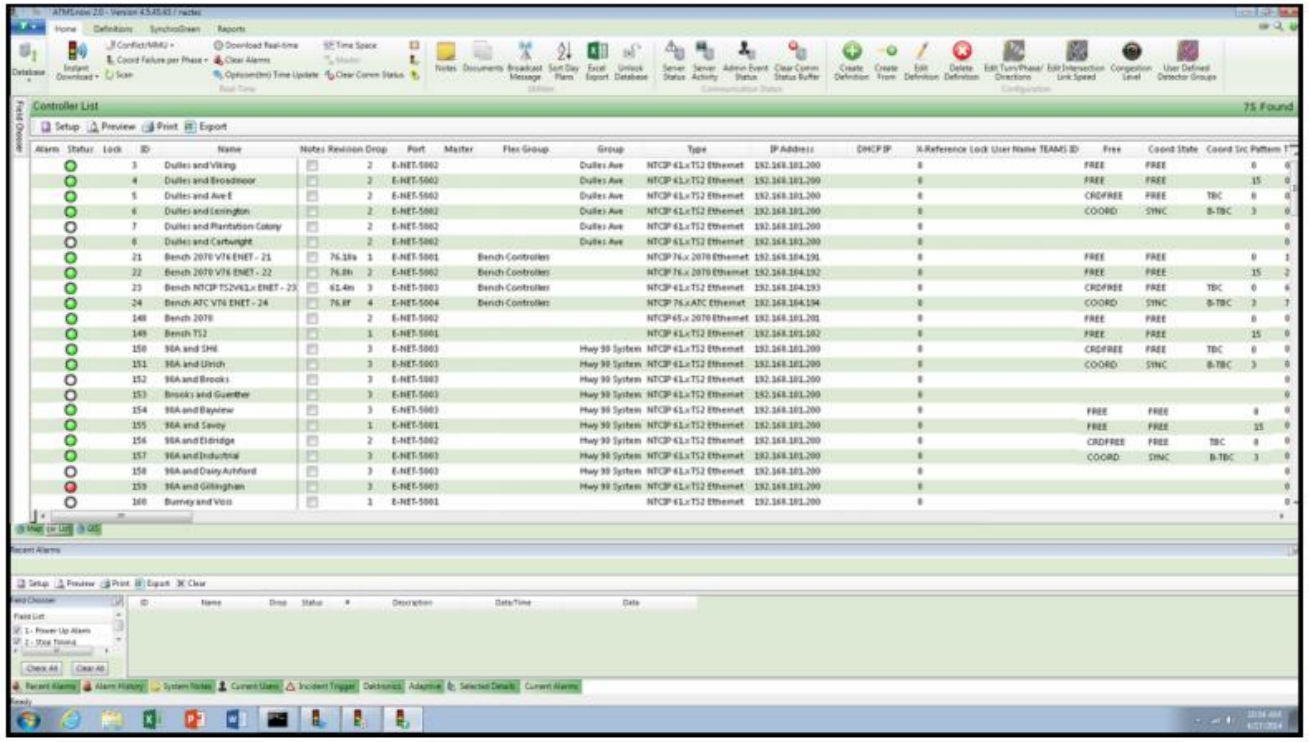
- Signal Head Upgrades
  - TMUTCD Compliance
  - Flashing Yellow Arrows to provide Prot + Perm left turn phasing
- Installing pedestrian pushbuttons to provide actuated pedestrian phases.
- Proposed new pedestrian overlaps at select intersections to satisfy the pedestrian split.
- Lane configuration changes proposing additional exclusive and/or shared turn lanes or removal of dual turn lanes.



09 Next Steps

Next Steps

- Finalize optimized timings.
- Timing implementation
  - Signals with ATMS connectivity vs Signals without connectivity
  - Implement timings in off-peak and overnight to minimize operations impacts
  - Activate the updated CL for one peak and evaluate its performance before activating it for other peaks
- Field fine-tuning of timings.
- Perform post-implementation travel time runs and compare the before-and-after timing implementation.



Contact Info

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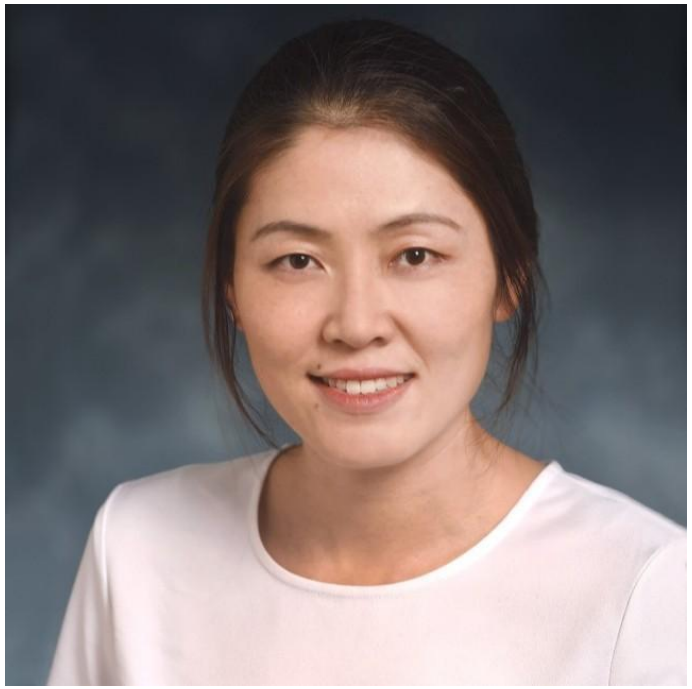

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Questions?