Optimizing Placement of Emergency Vehicles for the Houston Fire Department

Presented by
Ashwin Varma
Assistant Fire Chief Ruy Lozano

Optimize the placement of emergency vehicles to …

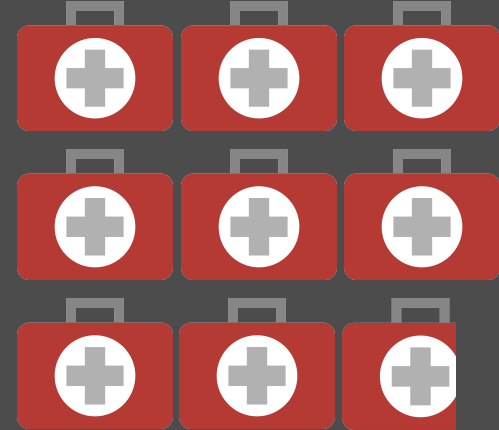**Maximize "efficiency" of dispatches**

Minimize time to respond to a call

Send only vehicles with resources to match the incident
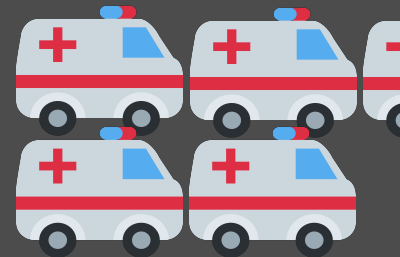
12% fire / rescue incidents

88% medical incidents

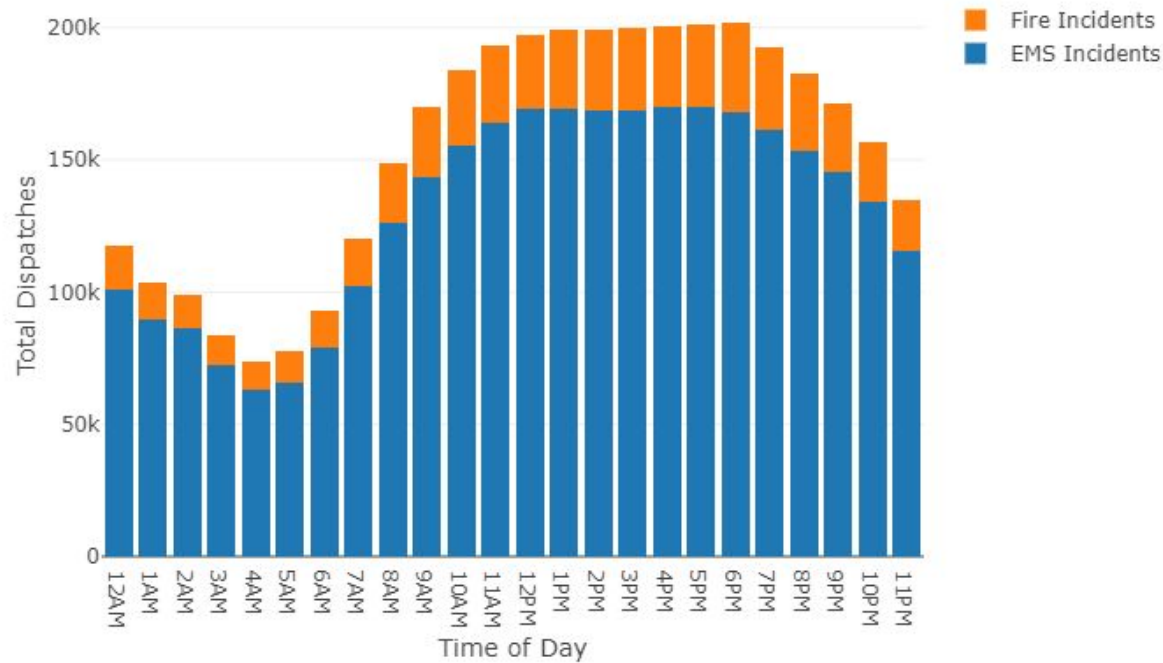**58% fire / ladder vehicles**

42% EMS vehicles

Call Volume increases overtime have been primarily driven by increases in EMS Call Volume

Total Number of Incidents Responded to by the HFD
2012-2017

EMS Incidents
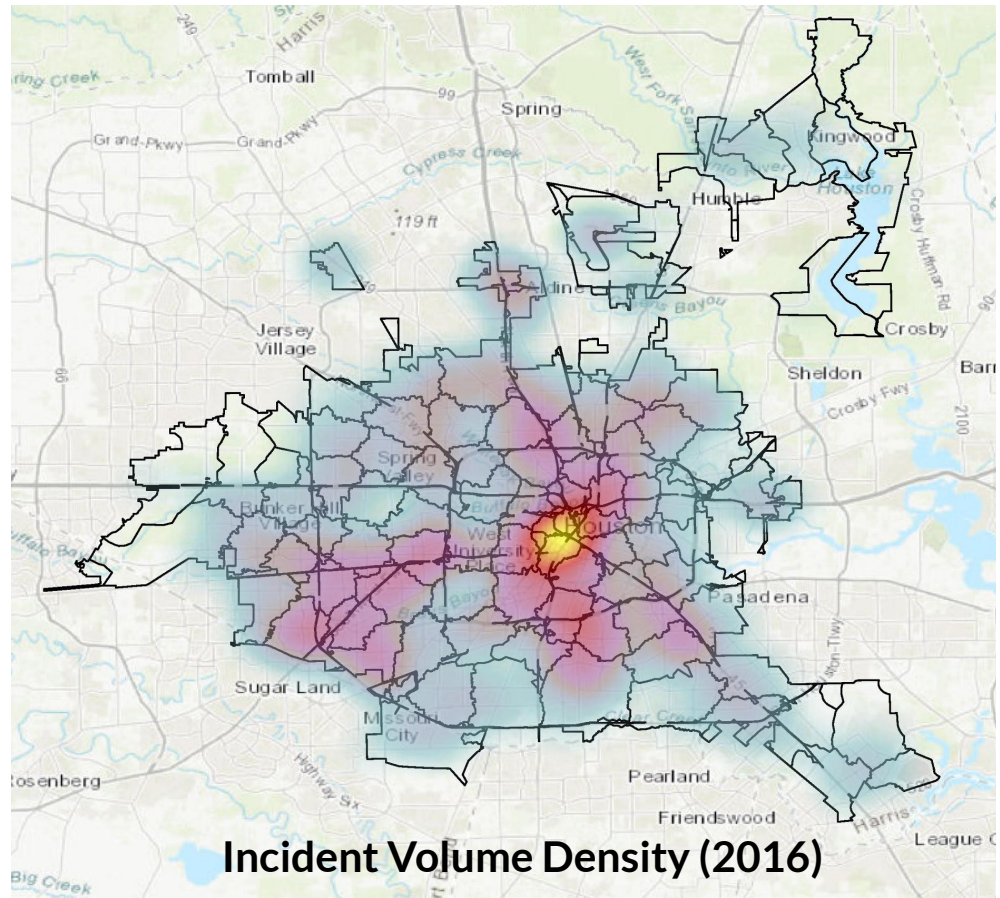Fire Incidents

Number of Incidents

Date

Call Volume spikes between the hours of 11AM to 6PM

The HFD Total Individuals Dispatches by Time of Day
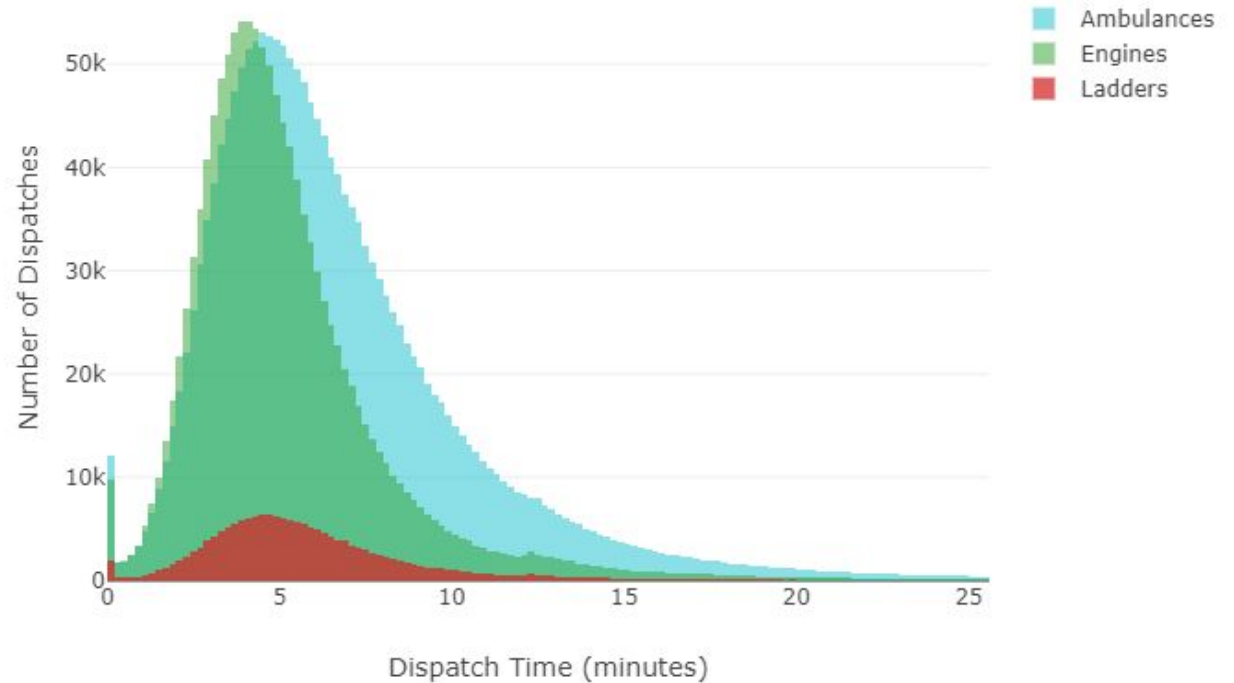2012-2018

Incident volume is concentrated in downtown Houston

Incident Volume Density (2016)

The delays to ambulance response times are due to disparity in ambulance demand versus capacity

Distribution of Dispatch Times among Ambulance, Ladder, and Engine Units 2012-2018

**In over 25% of incidents, HFD deploys a fire truck because the ambulance is unavailable**

Percentage of Incidents when the First Unit On-Scene was an Appropriate Unit
EMS Responses Only
2012-2018

Incident Volume vs. Response Time

Incident Volume by Stations (2016)

Median Response Time by Stations (2016)

No correlation between station incident volume and response time
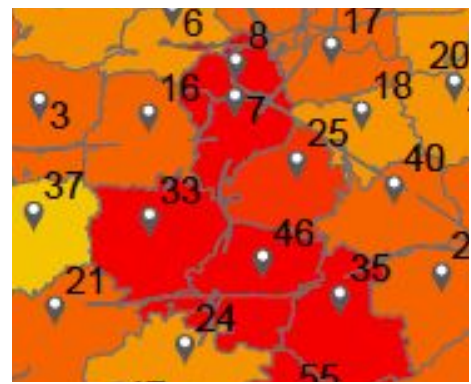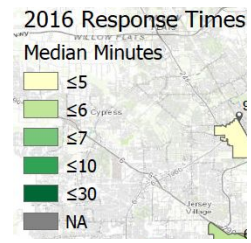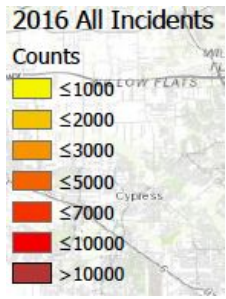
Incident Volume
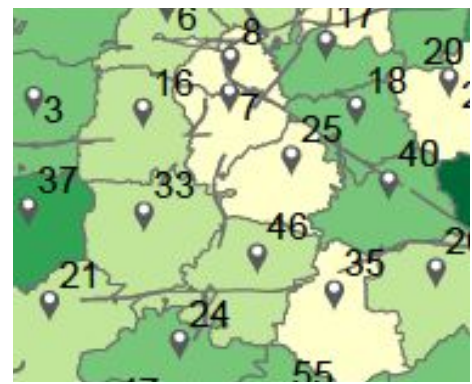
Average Response Time

Many slow responses are driven by out-of-territory responses

Frequency of Archetypes among Correct Dispatches
EMS Dispatches Only
2011-2018

Most response delays are driven by out-of-territory responses

Normalized Distribution of Times
for Within/Outside Territory Responses
(2011-2018)

Legend: Outside Territory, Within Territory
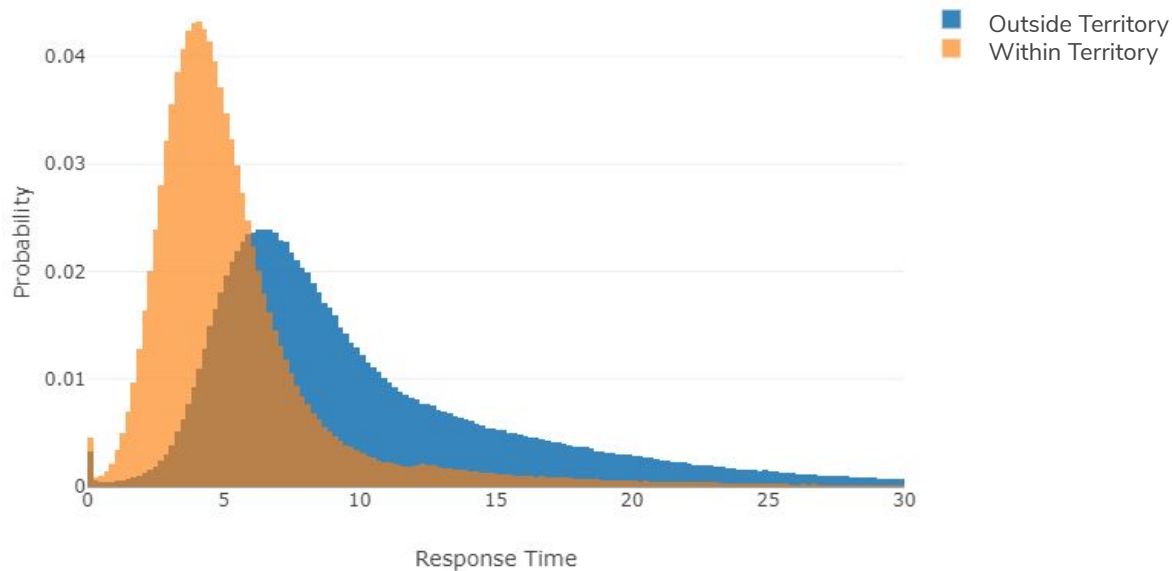
Understanding Chain Analysis:

A Case Study
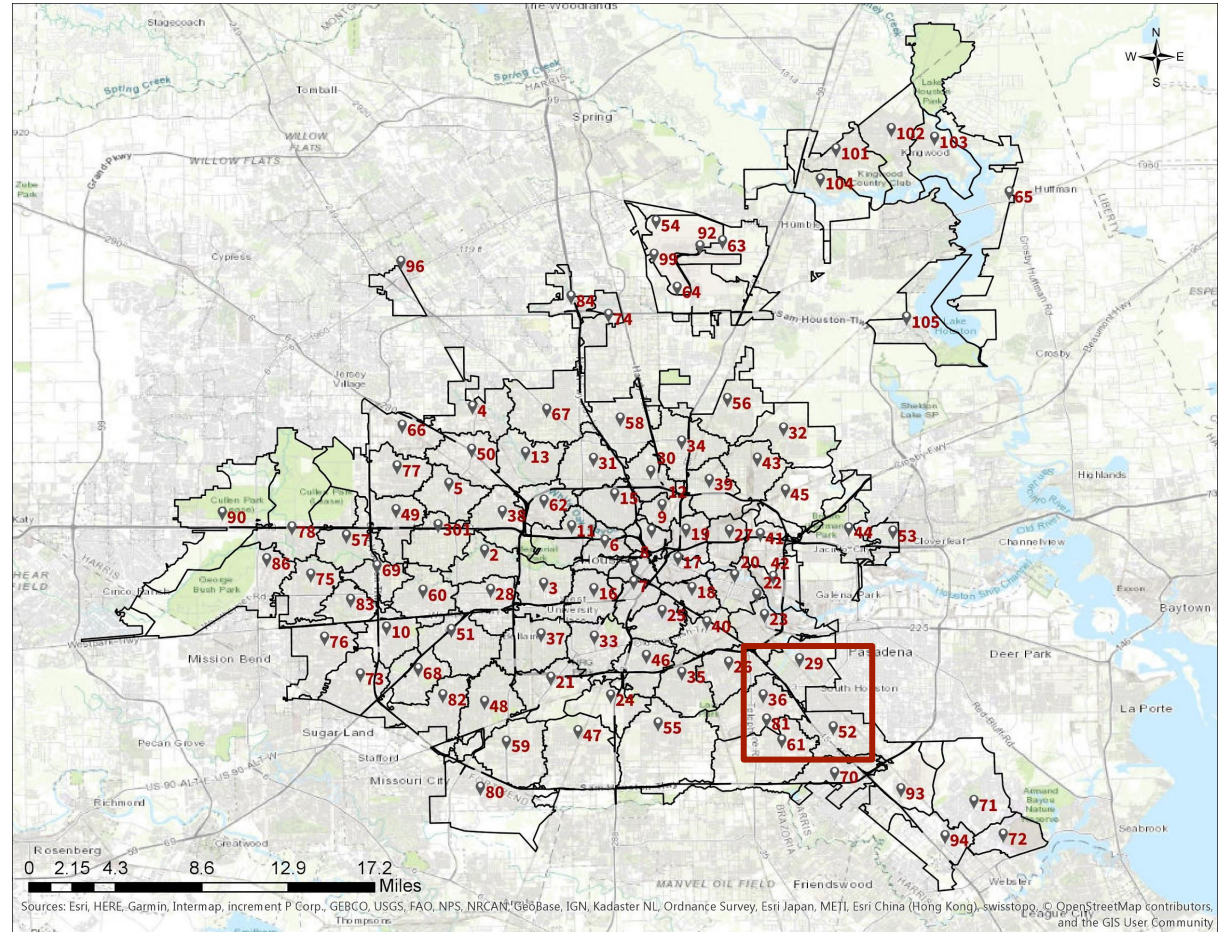
Case Study

On December 21, 2017, a call came in for **trouble breathing** in **Territory 29**, near Hobby Airport.
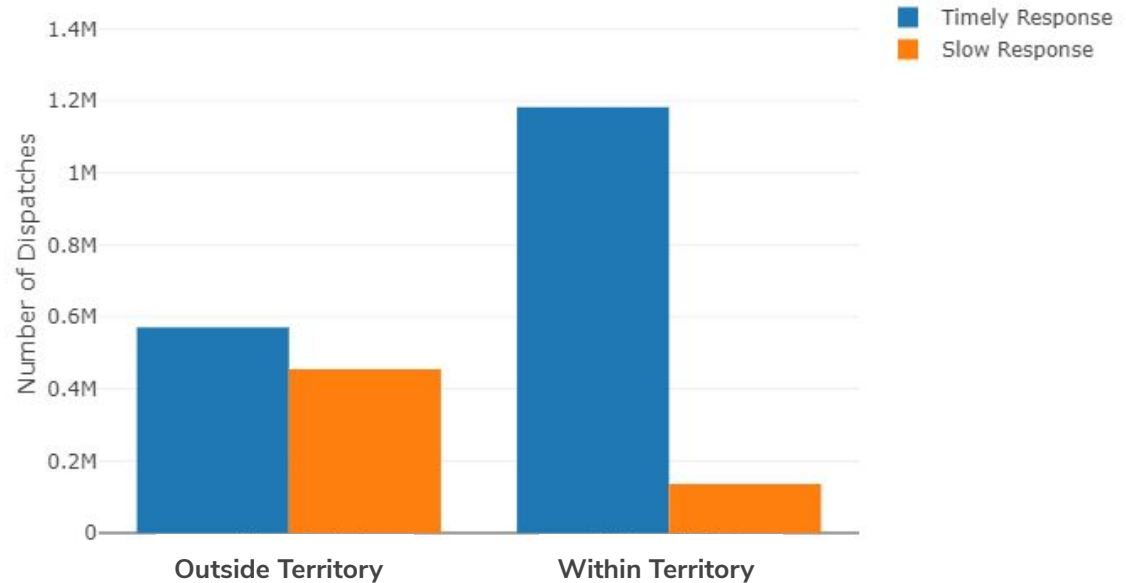
Houston Fire Department dispatched an **engine unit** from **Station 29** and a **medic unit** from **Station 70**.

Case Study 4
Incorrect Jurisdiction, Slow Response

- Jurisdiction Ambulance Location
- Location of Incident
- Responding Ambulance Location
- Responding Engine Location
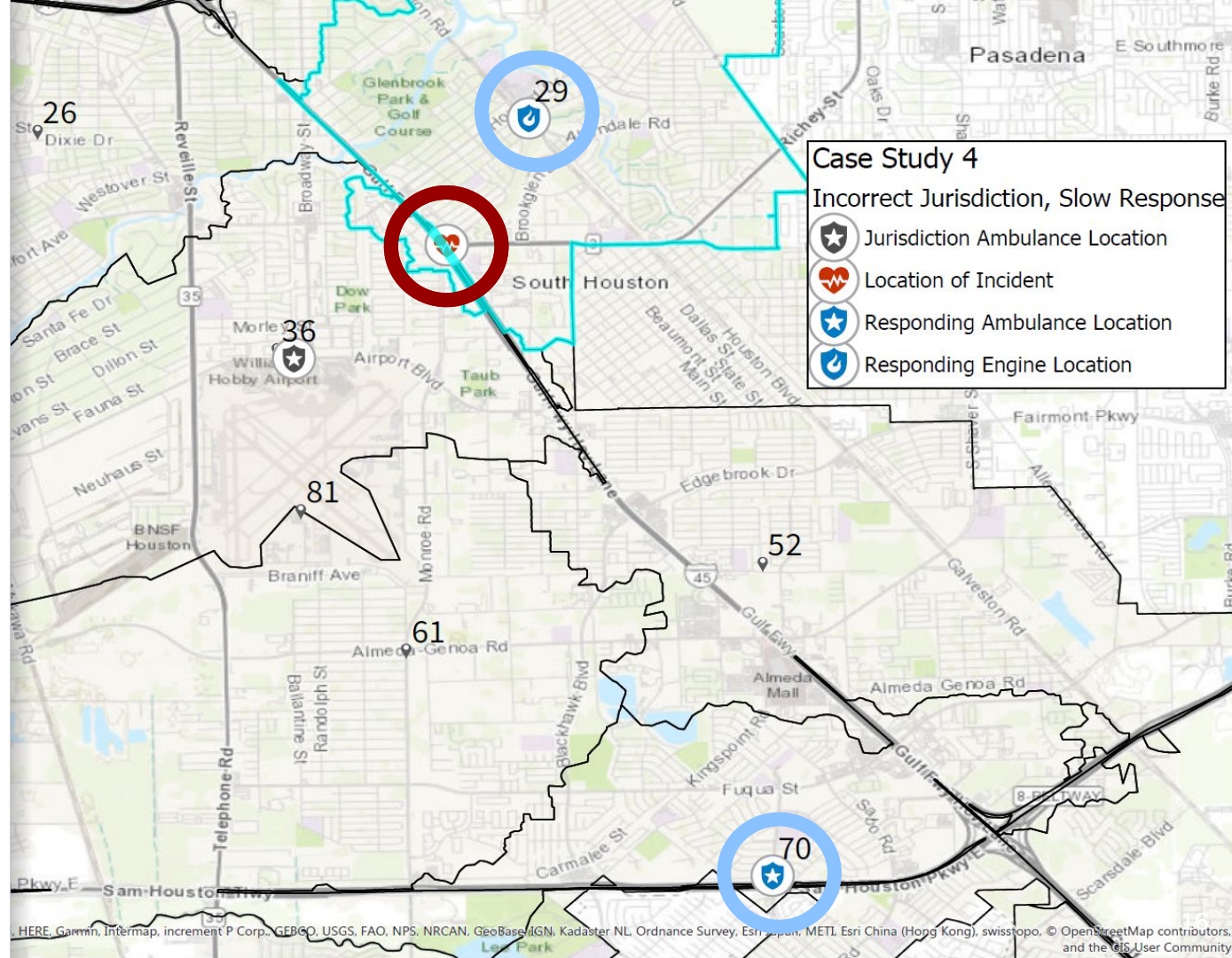
Case Study

Station 29
Engine Response Time:
7.43 min

Station 70
Medic Response Time:
12.45 min

Why didn't the medic unit stationed at Station 29 respond?

Case Study

Station 29's medic unit was **busy** responding to an **out of territory incident** in Territory 36.

Why couldn't **Station 36**'s medic unit respond?

9.93 min

Case Study 4
Incorrect Jurisdiction, Slow Response
- Jurisdiction Ambulance Location
- Location of Incident
- Responding Ambulance Location
- Responding Engine Location
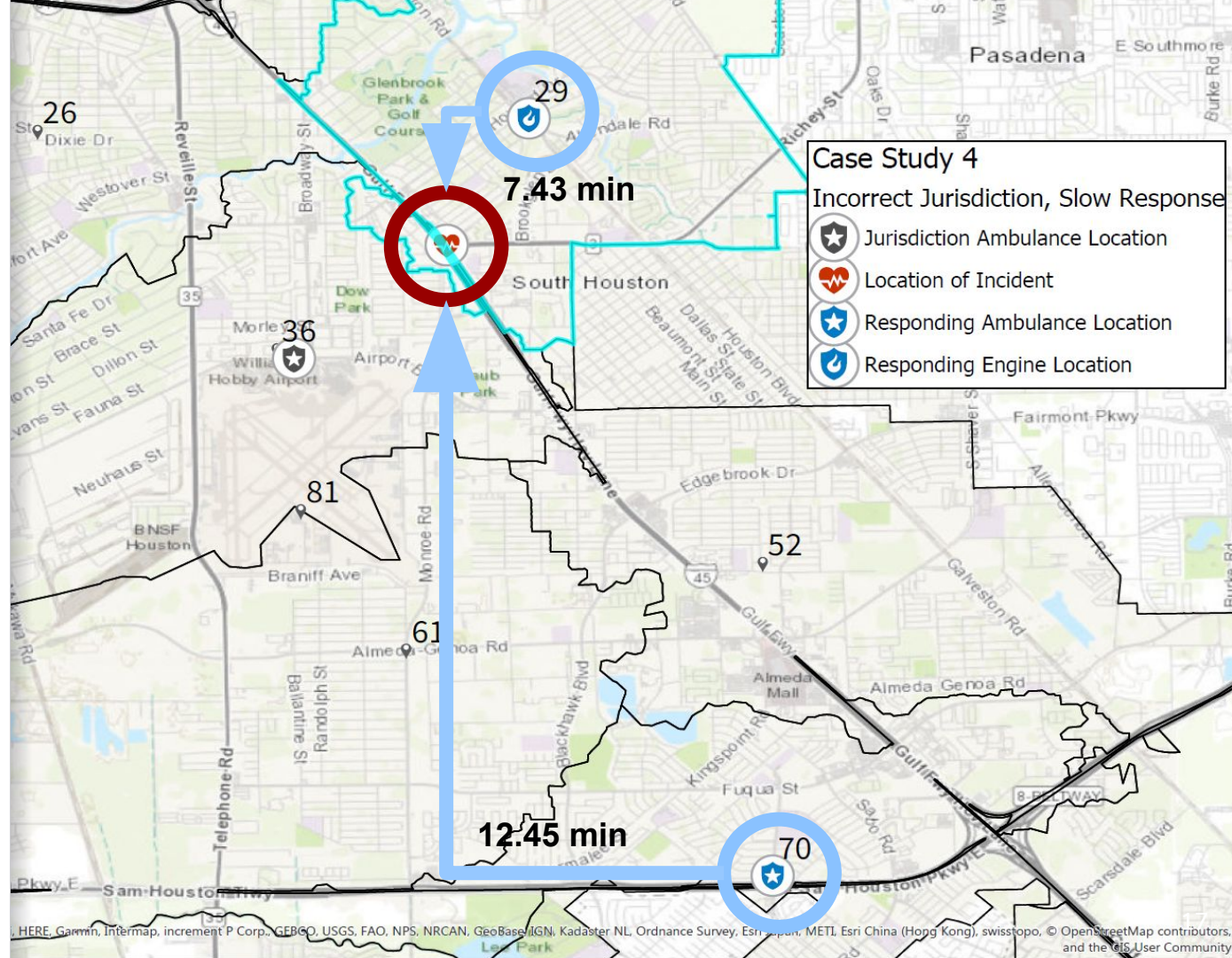
Case Study

Station 36's medic unit was **busy** responding to an **out of territory incident** in **Territory 52**.

Case Study 4
Incorrect Jurisdiction, Slow Response

- Jurisdiction Ambulance Location
- Location of Incident
- Responding Ambulance Location
- Responding Engine Location

10.77 min
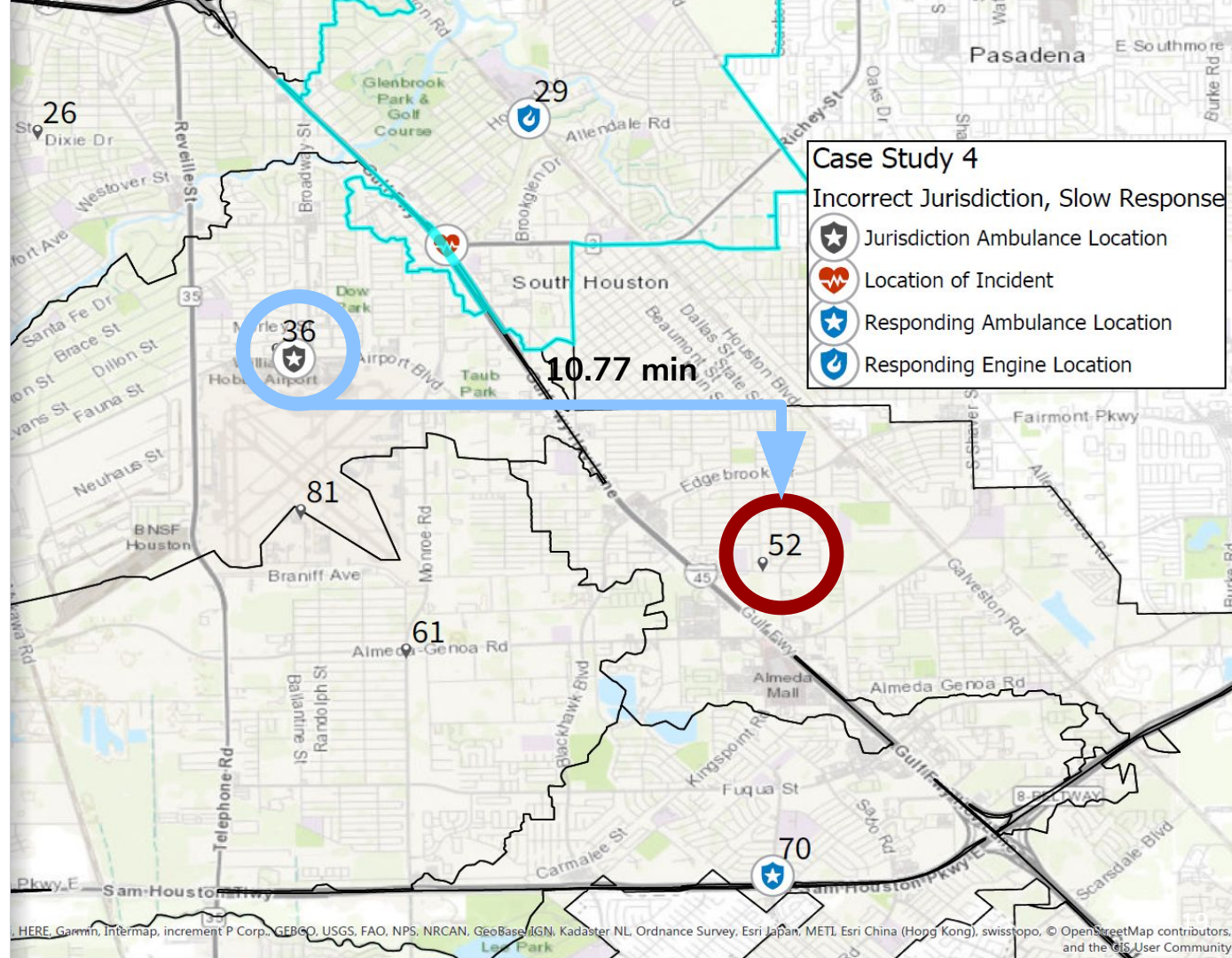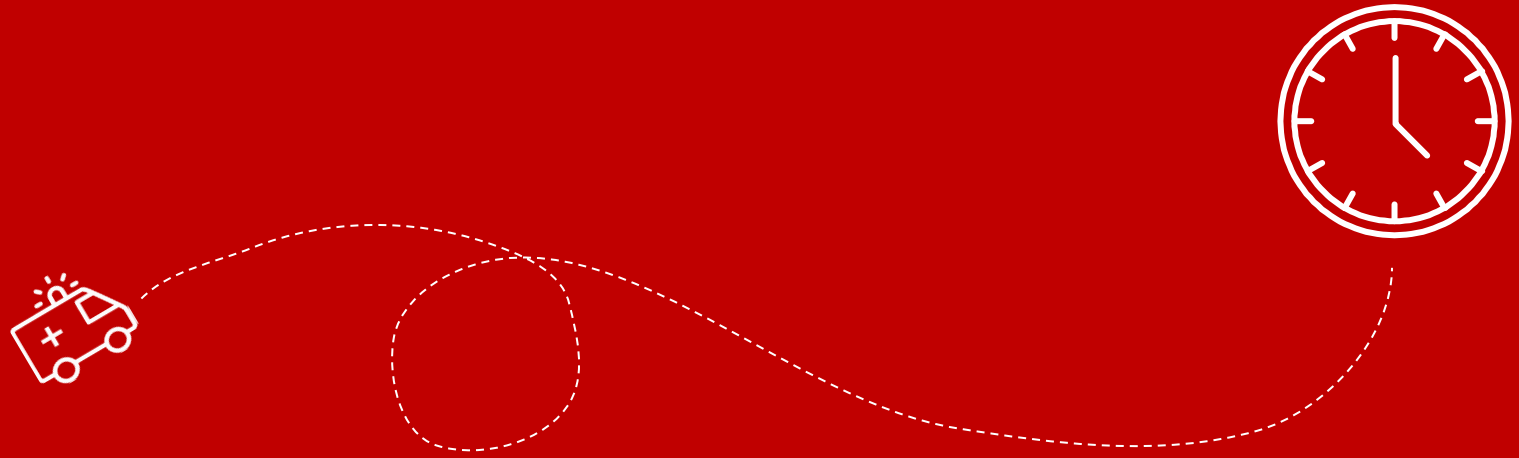
Chain Reactions ⚠

Out of territory responses result in both **delayed response times** and **downstream consequences** for the response times of future incidents

Average Chain Lengths 2011-2018
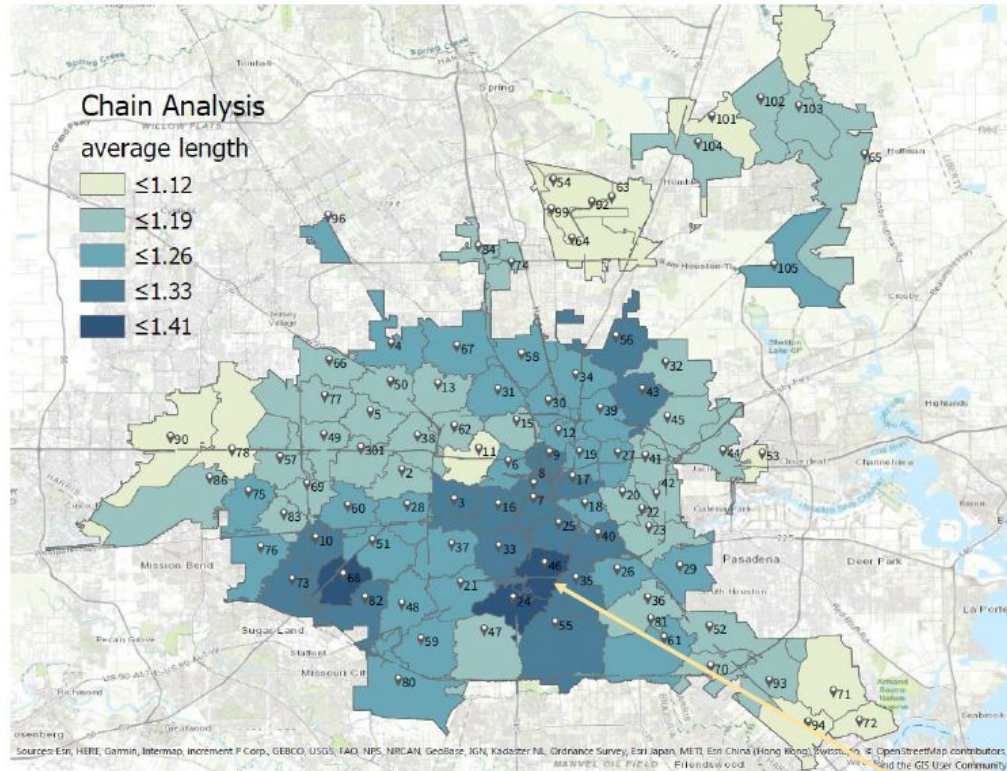
Vehicle Type	Total Chain Starters	Total Front-Line Vehicles	Ratios
Ambulances	341024	56	6090
Medics	206567	35	5902
Engine	186288	88	2117
Ladders	44978	38	1184

Station 46
Ambulances: 9752
Medics: 3390
Engines: 2816
Ladders: 425

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Helping Fraction:

HFD vehicles often respond to incidents outside their territories.

Distress Fraction:

HFD vehicles often require assistance from vehicles outside their territories.

Takeaways from Data Exploration

1 **Out of Territory Responses Make Up a Substantial Fraction of Delayed Response Times.**
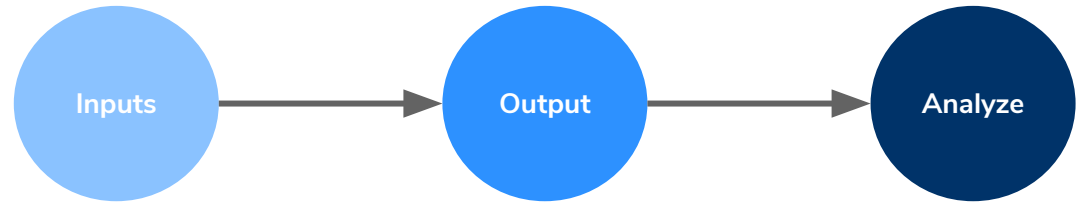
2 **Performance is driven mostly by response times in the "long tail" (>10 minutes).**

3 **Out of jurisdiction responses have "chain effects" which reduce performance system-wide.**

Building a Simulator

Inputs → **Output** → **Analyze**

Inputs
- A historic records of incidents
- A potential allocation of vehicles
- A distribution of out times: how long incidents occupy a vehicle
- Time matrix of times to demand points (obtained via Google Maps API)

Output
- Simulated results of dispatches, based on Houston Fire Department dispatching protocol

Analyze
- Does the changed allocation / number of vehicles improve the historical performance?

HFD Simulator Generates an Accurate Representation of Real Performance

Distribution of Dispatch Times among Ambulance, Ladder, and Engine Units 2012-2018
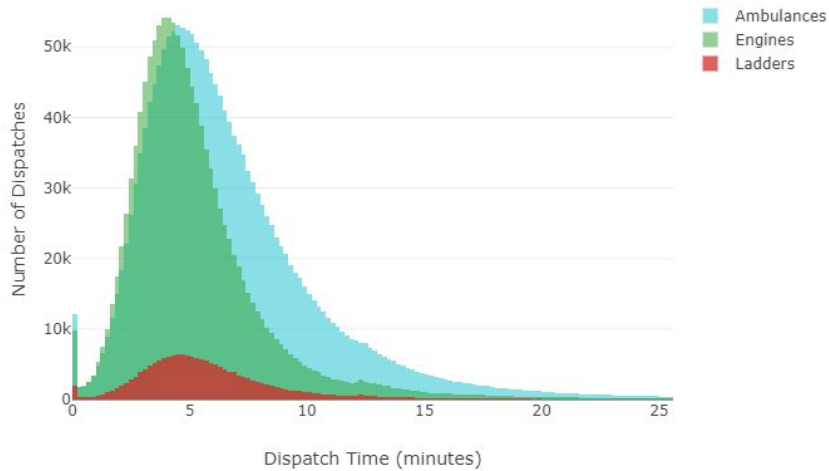
Distribution of Dispatch Times among Ambulance, Ladder, and Engine Units Simulated
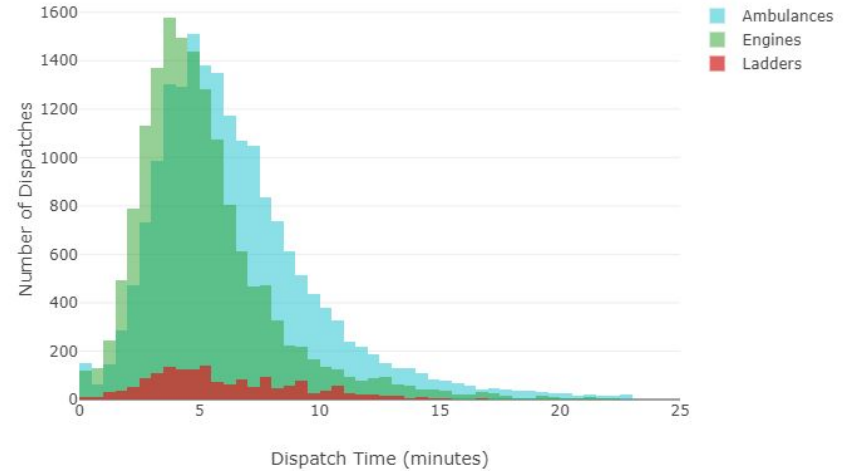
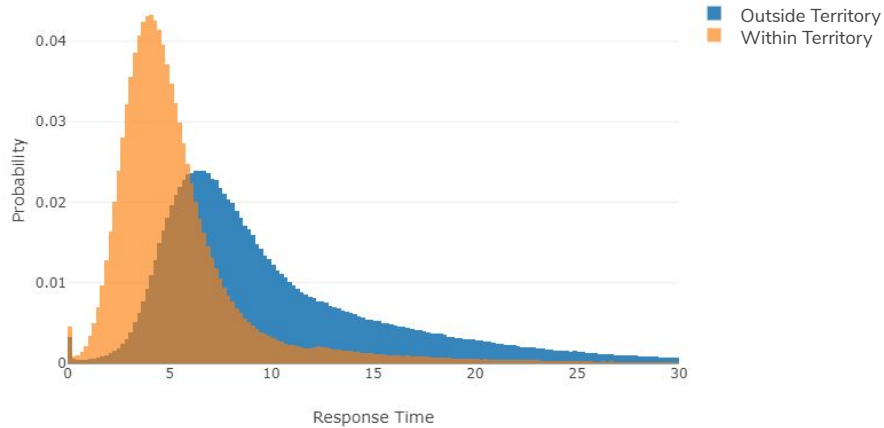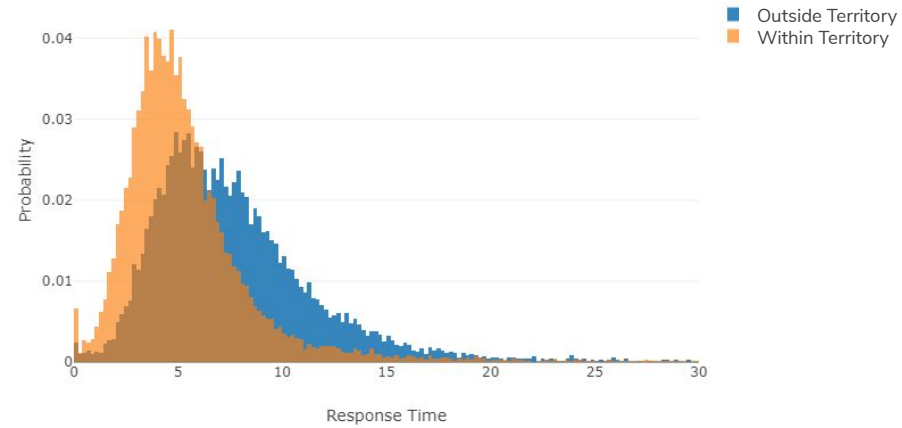# HFD Simulator Generates an Accurate Representation of Real Performance

Normalized Distribution of Times for Within/Outside Territory Responses (2011-2018)

Normalized Distribution of Times for Within/Outside Territory Responses (2011-2018)

Despite broad similarities to real HFD performance, simulator results suffer in some areas

	Actual HFD Performance	Simulation Performance	Historical Dispatch Performance
Ambulance Median	5.67	5.71	5.60
Ambulance 90th Percentile	18.16	11.24	17.38
Medic Median	7.02	6.77	6.83
Medic 90th Percentile	17.97	13.11	17.04
Engine Median	4.77	4.63	4.52
Engine 90th Percentile	9.52	9.29	9.23
Ladder Median	5.33	5.38	5.24
Ladder 90th Percentile	10.83	11.81	11.47
Incorrect Response Fraction (%)	25.41	18.67	11.17

Accounting for delayed dispatches accounts for substantial fraction of "long tail" behavior for ambulances and medics

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Optimization Models generate good theoretical performance, but marginal improvements in simulated performance

87.15%

of incidents **covered** in 6 minutes or less

5.71 vs. 5.65

Median percentile response times of **Ambulances**

Even with no vehicle limitations, with current station locations, there is a lower limit on response times.

|	HFD Allocation	"Infinite" Capacity	5 Ambulance Injection
Ambulance Median	5.71	5.16	5.63
Ambulance 90th Percentile	11.24	9.62	10.92
Medic Median	6.77	4.98	6.54
Medic 90th Percentile	13.11	8.19	12.96
Engine Median	4.63	4.38	4.62
Engine 90th Percentile	9.29	7.83	9.33
Ladder Median	5.38	4.46	5.33
Ladder 90th Percentile	11.81	7.33	11.35
Incorrect Response Fraction (%)	18.67	12.26	18.67

Targeted Ambulance Additions Substantially Improve 90th Percentile Response Times

Jurisdiction	Current 90th Percentile Response (Minutes)	5 Ambulance Injection Response (Minutes)	Improvement (Seconds)
8	9.57	9.06	30.6
73	11.11	10.17	56.4
33	11.67	10.94	43.8
46	10.33	8.23	126

90th Percentile Response Times for Ambulances
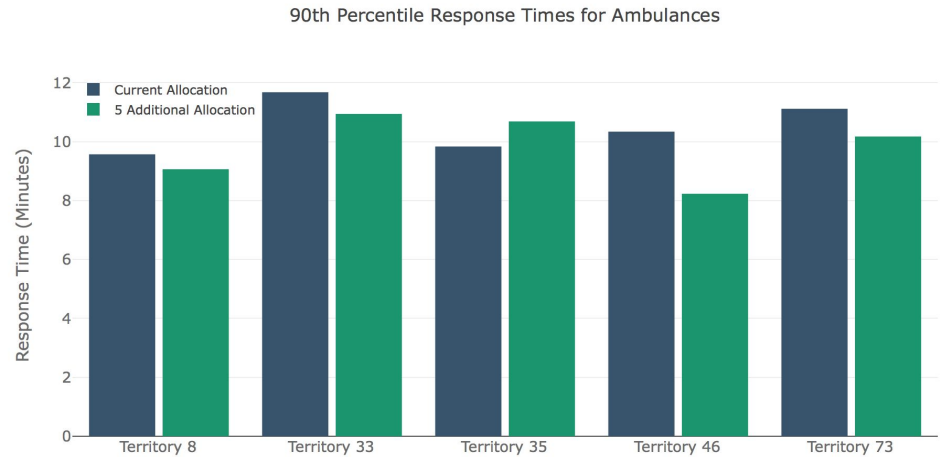
Targeted Ambulance Additions in Troubled Jurisdictions Can Reduce Distress Fractions

Distress Fractions under 5 Additional Ambulances
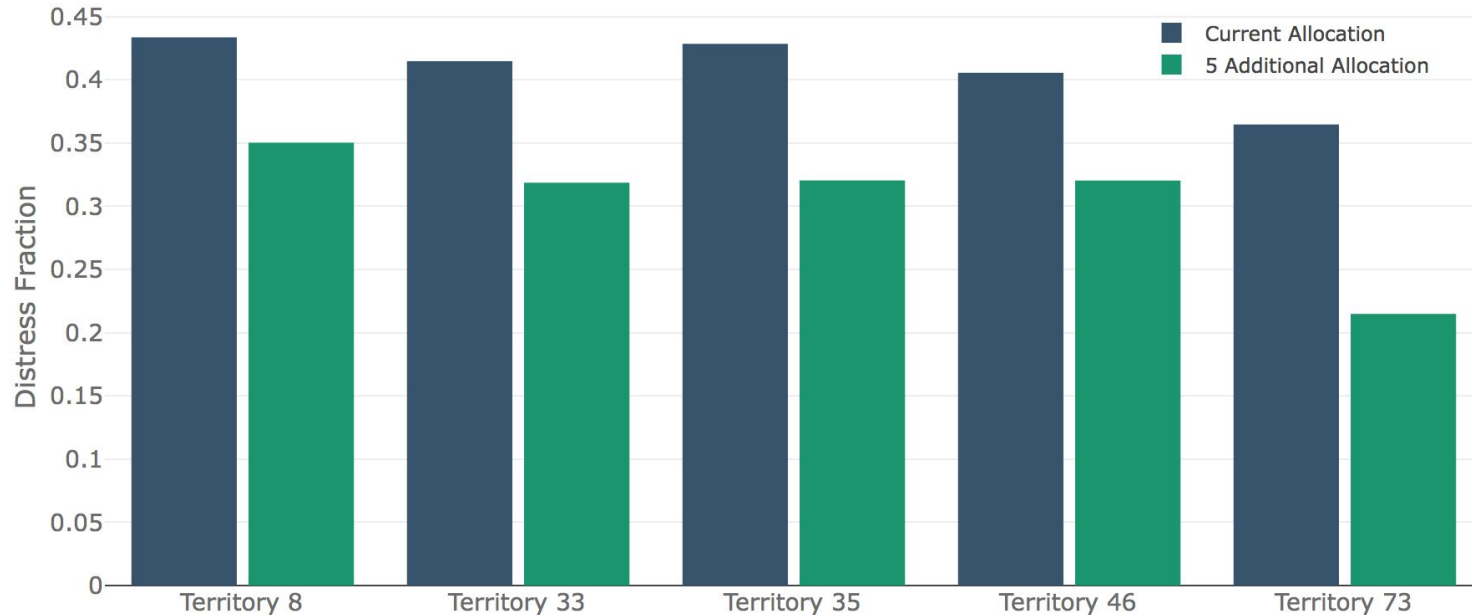
Moving Forward

Use Targeted Ambulance Additions to Improve Operating Performance

1 — **Modest System-Wide Improvements in Response Times for All Vehicle Types**

2 — **Substantially Improved 90th Percentile Response Times in Stations with Ambulance Addition**
- **Stations: 35, 46, 33, 73, & 8**

3 — **Dramatic Reduction in Distress Fractions in Stations with Ambulance Addition**

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Houston Fire Department

Houston Emergency Center
Houston Fire Department

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