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

58% fire / ladder vehicles

88% medical incidents

42% EMS vehicles
Call Volume increases overtime have been primarily driven by increases in EMS Call Volume.
Call Volume spikes between the hours of 11AM to 6PM
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.
In over 25% of incidents, HFD deploys a fire truck because the ambulance is unavailable.
Incident Volume vs. Response Time

2016 All Incidents
Counts
- ≤1000
- ≤2000
- ≤3000
- ≤5000
- ≤7000
- ≤10000
- >10000

Incident Volume by Stations (2016)

2016 Response Times
Median Minutes
- ≤5
- ≤6
- ≤7
- ≤10
- ≤30
- NA

Median Response Time by Stations (2016)
No correlation between station incident volume and response time
Many slow responses are driven by out-of-territory responses.
Most response delays are driven by out-of-territory responses.
Understanding Chain Analysis:
A 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

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?
Case Study

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

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Total Chain Starters</th>
<th>Total Front-Line Vehicles</th>
<th>Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulances</td>
<td>341024</td>
<td>56</td>
<td>6090</td>
</tr>
<tr>
<td>Medics</td>
<td>206567</td>
<td>35</td>
<td>5902</td>
</tr>
<tr>
<td>Engine</td>
<td>186288</td>
<td>88</td>
<td>2117</td>
</tr>
<tr>
<td>Ladders</td>
<td>44978</td>
<td>38</td>
<td>1184</td>
</tr>
</tbody>
</table>

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

- 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)

- Outside Territory
- Within Territory

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

- Outside Territory
- Within Territory
Despite broad similarities to real HFD performance, simulator results suffer in some areas.

<table>
<thead>
<tr>
<th></th>
<th>Actual HFD Performance</th>
<th>Simulation Performance</th>
<th>Historical Dispatch Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance Median</td>
<td>5.67</td>
<td>5.71</td>
<td>5.60</td>
</tr>
<tr>
<td>Ambulance 90th Percentile</td>
<td>18.16</td>
<td>11.24</td>
<td>17.38</td>
</tr>
<tr>
<td>Medic Median</td>
<td>7.02</td>
<td>6.77</td>
<td>6.83</td>
</tr>
<tr>
<td>Medic 90th Percentile</td>
<td>17.97</td>
<td>13.11</td>
<td>17.04</td>
</tr>
<tr>
<td>Engine Median</td>
<td>4.77</td>
<td>4.63</td>
<td>4.52</td>
</tr>
<tr>
<td>Engine 90th Percentile</td>
<td>9.52</td>
<td>9.29</td>
<td>9.23</td>
</tr>
<tr>
<td>Ladder Median</td>
<td>5.33</td>
<td>5.38</td>
<td>5.24</td>
</tr>
<tr>
<td>Ladder 90th Percentile</td>
<td>10.83</td>
<td>11.81</td>
<td>11.47</td>
</tr>
<tr>
<td>Incorrect Response Fraction (%)</td>
<td>25.41</td>
<td>18.67</td>
<td>11.17</td>
</tr>
</tbody>
</table>
Accounting for delayed dispatches accounts for substantial fraction of “long tail” behavior for ambulances and medics.

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

<table>
<thead>
<tr>
<th></th>
<th>HFD Allocation</th>
<th>“Infinite” Capacity</th>
<th>5 Ambulance Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance Median</td>
<td>5.71</td>
<td>5.16</td>
<td>5.63</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>11.24</td>
<td>9.62</td>
<td>10.92</td>
</tr>
<tr>
<td>Medic Median</td>
<td>6.77</td>
<td>4.98</td>
<td>6.54</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>13.11</td>
<td>8.19</td>
<td>12.96</td>
</tr>
<tr>
<td>Engine Median</td>
<td>4.63</td>
<td>4.38</td>
<td>4.62</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>9.29</td>
<td>7.83</td>
<td>9.33</td>
</tr>
<tr>
<td>Ladder Median</td>
<td>5.38</td>
<td>4.46</td>
<td>5.33</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>11.81</td>
<td>7.33</td>
<td>11.35</td>
</tr>
<tr>
<td>Incorrect Response Fraction (%)</td>
<td>18.67</td>
<td>12.26</td>
<td>18.67</td>
</tr>
</tbody>
</table>
Targeted Ambulance Additions Substantially Improve 90th Percentile Response Times

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Current 90th Percentile Response (Minutes)</th>
<th>5 Ambulance Injection Response (Minutes)</th>
<th>Improvement (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>9.57</td>
<td>9.06</td>
<td>30.6</td>
</tr>
<tr>
<td>73</td>
<td>11.11</td>
<td>10.17</td>
<td>56.4</td>
</tr>
<tr>
<td>33</td>
<td>11.67</td>
<td>10.94</td>
<td>43.8</td>
</tr>
<tr>
<td>46</td>
<td>10.33</td>
<td>8.23</td>
<td>126</td>
</tr>
</tbody>
</table>
Targeted Ambulance Additions in Troubled Jurisdictions Can Reduce Distress Fractions
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
Acknowledgements

Special thanks to the following for their assistance and expertise on this project:

Dr. Tasos Kyrillidis
Rice University Department of Computer Science

Dr. Genevera Allen
Rice University Department of Statistics

Leonard Chan
Houston Fire Department

Assistant Chief Ruy Lozano
Houston Fire Department

Assistant Chief Rodney West
Houston Fire Department

Patrick Brown
Houston Fire Department

Station 16
Houston Fire Department

Houston Emergency Center
Houston Fire Department