# Optimizing London Fire Station Resources to Better Serve the Community

*BIA-650*
*Section A*
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# Agenda

- Motivation
- Project Description
- Simulation Methodology
- Optimization Methodology
- Results
- Sensitivity Analysis

# Motivation

- Simulating real-word emergency scenarios can have practical applications.
- We want to help fire stations by minimizing overall travel distance.
- Making fire stations more efficient will help them better serve the community.

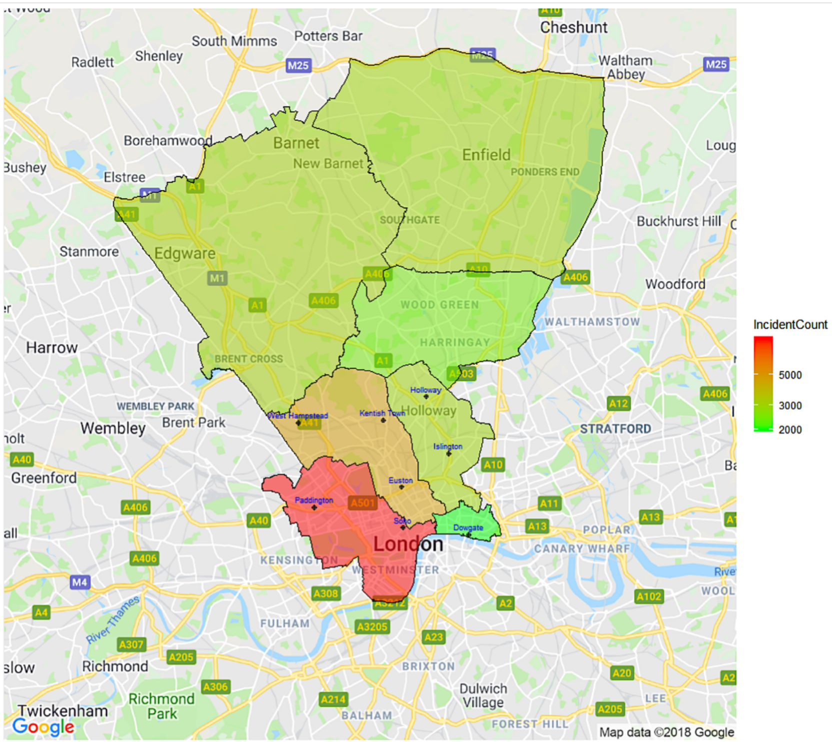
# Project Description

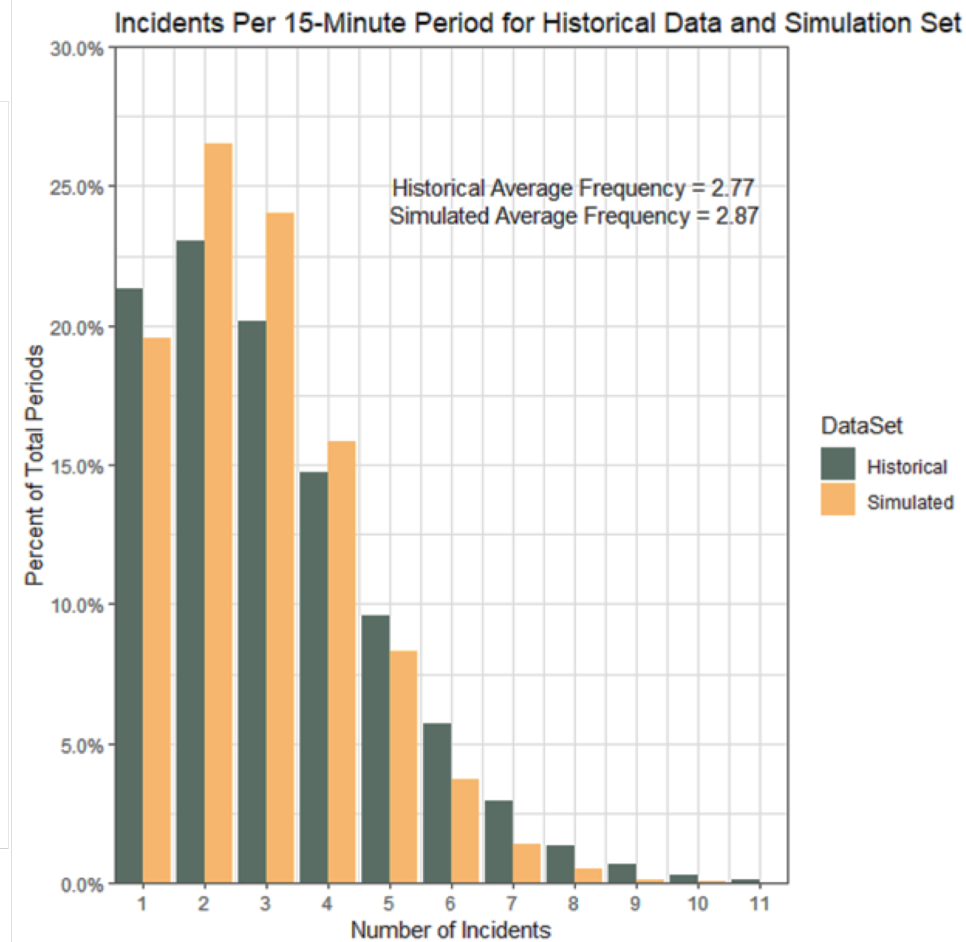
- We used over 85,000 fire incidents from 2017 (Jan to Oct).
  - This information came from Kaggle and the London Fire Brigade
- We used integer programming for optimization and found distances by using the great circle distance.
- We ran a simulation of our model using R.

# Simulation Methodology

- 9,600 simulated time periods (15-minute intervals over 100 days)
- Incidents for each time period were selected using a random draw of a subset of the historical data
- A zero-truncated Poisson distribution was used to determine the number of incidents in each simulation period
- The Integer Programming (IP) optimization model was applied to each simulation period

# Simulation Methodology



# Optimization Methodology

Inputs

Distance Matrix, D

$d_{ij}$ = distance between $i^{th}$ incident and $j^{th}$ fire station

Delay Factor Matrix, F

$f_{ij}$ = randomly generated factor (between 0 and 1) to simulate arrival delays

Effective Distance Matrix, E

$e_{ij} = d_{ij} + f_{ij}d_{if} = (1 + f_{ij})d_{if}$

Availability Vector, A

$a_j$ = number of fire engines available at $j^{th}$ station

# Optimization Methodology

Decision Variable, Constraints and Output

Decision Variable

Sent Matrix, S

$$s_{ij} = \begin{cases} 1, & \text{if fire engine is dispatched to incident i from station j} \\ 0, & \text{if fire engine is not sent to incident i from station j} \end{cases}$$

Constraints

$\sum_i s_{ij} = 1$, one fire engine is dispatched to each incident

$\sum_j s_{ij} \leq a_j$, the total number of fire engines dispatched from a station cannot exceed the available number

Output

Minimize the Total Effective Distance

$$\sum_i \sum_j s_{ij} e_{ij}$$

# Project Results

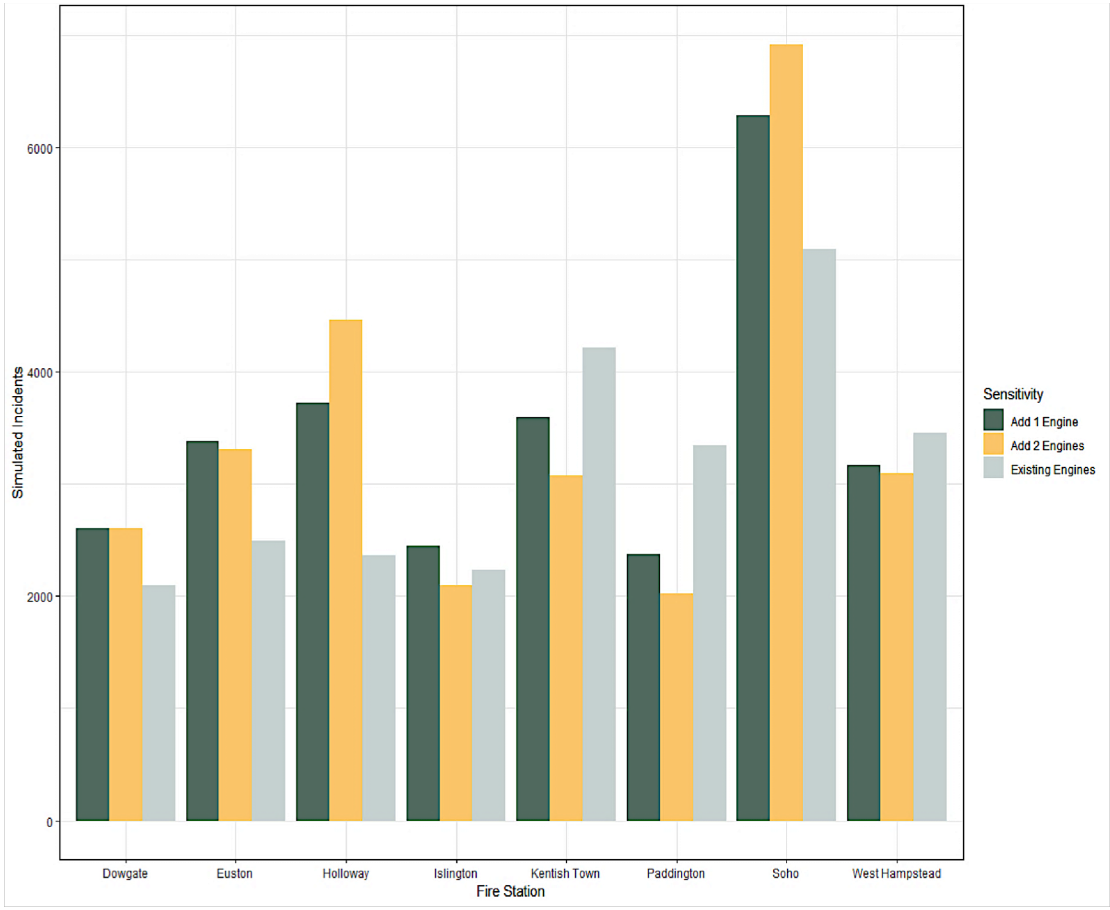
Result output for some selected Simulation Periods

| Period ID | Incident Number | Incident Fire Engine Deployment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Dowgate | Euston | Holloway | Islington | Kentish Town | Paddington | Soho | West Hampstead |
| 26 | 071065-03062017 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 26 | 111710-18082017 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 26 | 079544-18062017 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 26 | 141792-21102017 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 27 | 061388-16052017 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 024617-27022017 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 27 | 116856-29082017 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 28 | 026377-03032017 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 28 | 070188-02062017 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 039442-02042017 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 29 | 082627-23062017 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 29 | 142806-23102017 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 30 | 026696-04032017 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

| Period ID | Total Fire Engine Deployment | | | | | | | | Total Incidents | Total Effective Distance |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dowgate | Euston | Holloway | Islington | Kentish Town | Paddington | Soho | West Hampstead | | |
| 26 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 4 | 11.43 |
| 27 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 32.46 |
| 28 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 11.23 |
| 29 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 18.08 |
| 30 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.41 |

# Sensitivity Analysis

- Two sensitivity analyses were performed.
- For the base analysis, slightly over 400 simulation periods did not give us a feasible solution
- The second sensitivity analysis had no infeasible solutions



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