Optimizing London Fire Station Resources to Better Serve the Community

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Background

Using data provided by the London Fire Brigade as well as information from Kaggle, we were able to obtain a historical database for over 85,000 fire incidents for 2017 (from January to October).

Optimization Model

Inputs

Distance Matrix, D

d_{ij} = distance between ith incident and jth fire station

Delay Factor Matrix, F

f_{ij} = randomly generated factor (between 0 and 1) to simulate arrival delays due to traffic conditions, road blocks, etc.

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 jth station

Decision Variable

Sent Matrix, S

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

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 does not exceed the available number

Output

Minimize Total Effective Distance

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

Results

Sample Result Output for Select Simulation Periods

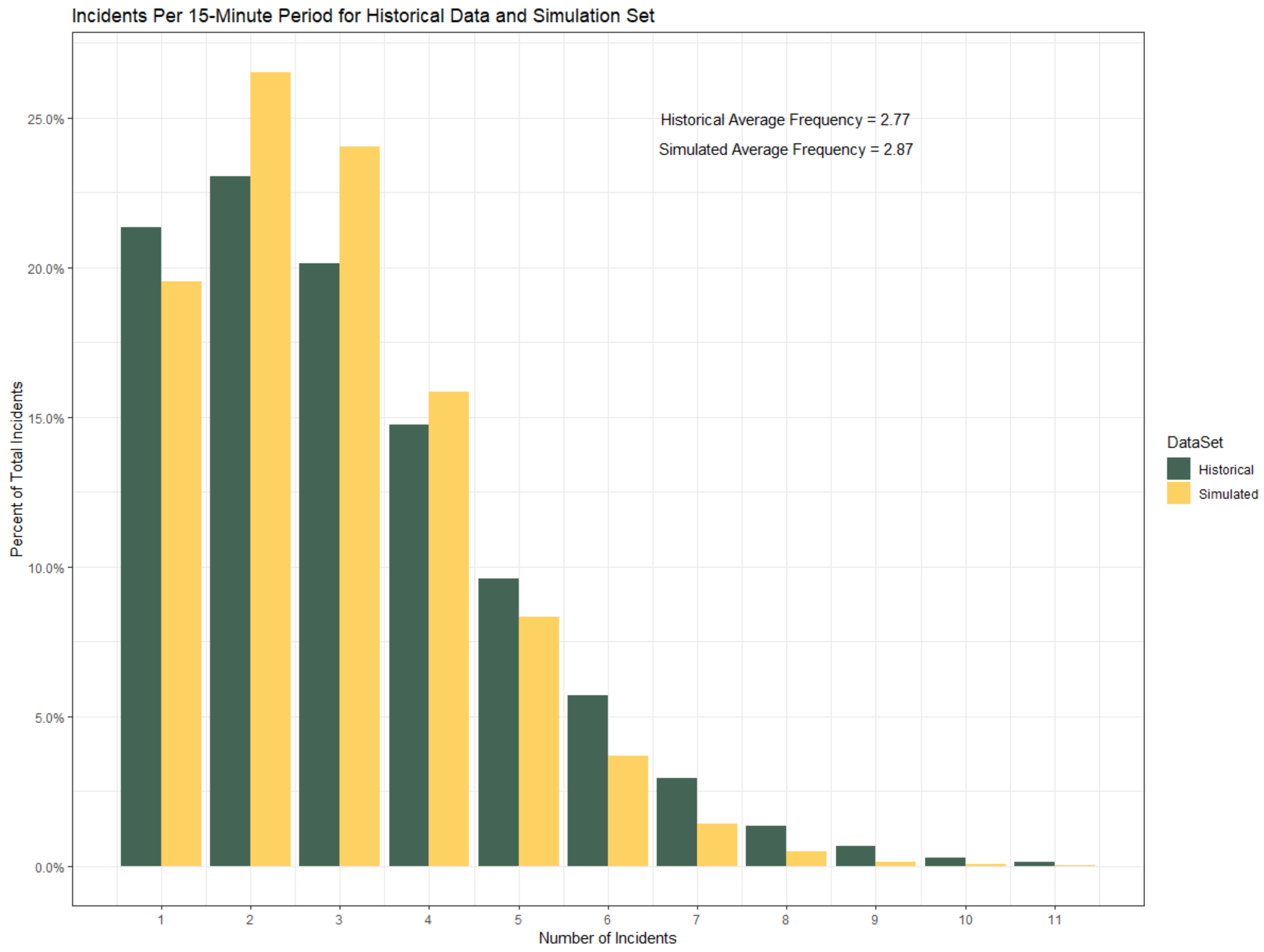
Period ID	Incident Number	Incident Fire Engine Deployment							
		Dowgate	Euston	Holloway	Islington	Kentish Town	Paddington	Soho	West Hampstead
26	071065-03062017	0	0	1	0	0	0	0	0
26	111710-18082017	0	0	0	0	0	0	0	1
26	079544-18062017	0	0	0	0	0	1	0	0
26	141792-21102017	0	0	0	0	0	0	1	0
27	061388-16052017	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

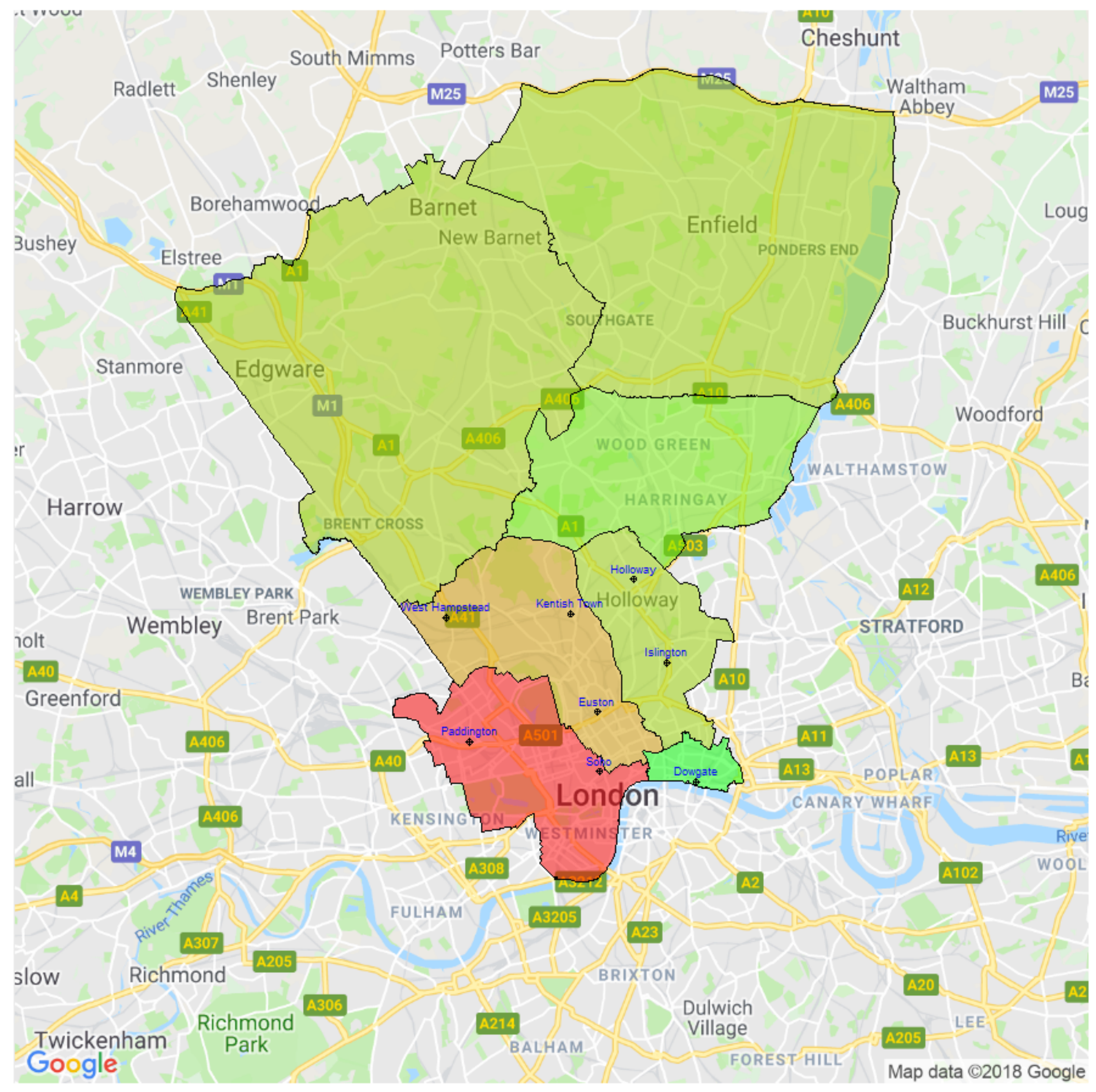
Simulation

- 9,600 simulated time periods (15-minute intervals over 100 days)
- A zero-truncated Poisson distribution was used to determine number of incidents in each simulation period were optimized using integer programming (IP)
- Incidents for each time period were selected using a random draw of a subset of the historical data
- The model assumes fire engines are deployed at the end of each 15-minute period and do not return for 30 minutes (i.e., a fire engine deployed in the previous two simulation periods cannot be used in the current period

Incidents Per 15-Minute Period for Historical Data and Simulation Set



Concentration of Simulated Incidents Over 100 Days and Fire Stations Included in Analysis



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Sensitivity Analysis

Fire Engine Availability

	Dowgate	Euston	Holloway	Islington	Kentish Town	Paddington	Soho	West Hampstead	Total Fire Engines
Base Model	1	1	1	1	2	2	2	2	12
Sensitivity +1	2	2	2	2	3	3	3	3	20
Sensitivity +2	3	3	3	3	4	4	4	4	28

- The base analysis was performed using actual fire engine counts from London Fire Brigade's fleet list (as of September 2017).
- Two sensitivity analyses were performed by adding 1 fire engine and 2 fire engines to the starting fleet of each fire station.
- For the base analysis, slightly over 400 simulation periods (about 4.4%) did not have a sufficient number of fire engines available to deploy to all incidents for that time period (i.e., there was no feasible solution for the optimization problem).
- When increasing the starting number of fire engines at each station by 1, there was only one simulation without a feasible solution.
- The sensitivity analysis with two additional fire engines per station had no infeasible solutions.

Simulated Incidents by Fire Station