Analysis of Emergency Response Times in Urban Environments

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This report analyzes emergency response times in Aberdeen, UK, focusing on ambulance travel times from a station to random destinations. The methodology involves obtaining a representative sample of addresses from postcodes for simulation. Response times are determined using Mathematica and Google Maps API via Python. The analysis includes travel time distributions, comparisons of potential ambulance station locations, and evaluation of average travel times. Optimal sites for a second ambulance station are determined as Bridge of Dee or Bucks Burn.

INTRODUCTION

Ambulances are a vital part of our emergency services and save millions of lives every year. Speed is key for these vehicles, and placing their stations in good locations is of the utmost importance to making sure they can reach patients in the shortest amount of time possible. The aim of our project is to find suitable locations to place new ambulance stations so that the average response time is minimised as much as possible.

METHODS

In the following sections, we explore the methods used to model ambulance station locations. We use two different programming languages. Python code can be found in the Google Colab notebook [7] while Wolfram Mathematica in Mathematica notebook [2].

FIG. 1. The map shows postal districts in Aberdeen [3].

Data

The analysis is based on a dataset containing 8147 postcodes in Aberdeen, scraped from the Postcode Area website [1]. Of these, 6144 were successfully converted to geographical coordinates. It is assumed that most incidents happen in densely populated areas, therefore the density of postcodes is representative of the density of incidents.

The postcodes are located on 11 different subpages of the website, one for each postal district of Aberdeen city, which are depicted in Figure 1. The first section of the Mathematica code [2] and a Python function `get_postcodes_for_Aberdeenshire` identify postcodes, and store them in a list. The coordinates are determined from the postcodes using the Mathematica built-in function `FindGeoLocation`. The second method uses Google Geo-Coding API [4].

The response times are then calculated from Aberdeen Royal Infirmary utilizing the Google Directions API [5] or Mathematica function `TravelTime`. But this function does not factor in the traffic. Mathematica code enables to calculate any number of points without financial expenses. Both methods will use significant runtime, that is the reason why we use only subset of all addresses.

It is important to note that we did not manage to conduct accuracy analysis of these models due to the reason we did not find data on real response times.

Second Station

Based on Figure 3 we have identified locations with high response times, five of them were chosen as possible locations for a second ambulance station: Aberdeen International Airport, Portlethen Retail Park, Bridge of Don, Bridge of Dee / Kincorth, and Bucks Burn. Three of these were considered in Python and all five in Mathematica. The response time was calculated by comparing it to the original station at Aberedeen Royal Infirmary and then taking lower travel time for each accident location.

Google API

In Python code response times from various ambulance station locations to emergency incidents, were calculated via Google's Geocoding and Directions APIs. The Geocoding API converts addresses into geographic coordinates. The Directions API calculate travel times taking into account traffic congestion and seasonal weather, These APIs typically incur a cost, but we accessed these services using a limited amount of free credits provided by Google using small enough sample size.

Data engineering

Data engineering is important when using API's as they are costly. Thus when we calculate response times for different models we save the data for further analysis in google drive [6] using `save_data` function. In Mathematica code, some data has to be filtered for duplicity before they are used for obtaining travel times. All data created also needs to be cleaned of unreasonable response times. This is due to addresses being interpreted in the wrong places in the map than originally intended.

RESULTS

The results outline the methodologies used to model ambulance station placement and their effects on response times. The assessment begins with visualizing emergency calls spatially, then analyzes response times over different times of the day and week, and concludes with a comparative study on introducing additional ambulance stations.

Modelling One Ambulance Station

In the initial scenario, we simulate the deployment of one ambulance station located at the Aberdeen Royal Infirmary. As depicted in Figure 2 generated by python code and in Figure 3 generated by Mathematica code, the green areas across the town reflects response times—typically under ten minutes—across most of the city. However, on the city's periphery, there are distinct pockets where response times exceed 20 minutes, as represented by the red zones.

The National Health Service has a strategic goal to arrive in 8 minutes to serious health incidents [8]. The Mathematica code[2] calculates that around 30% of response times with one ambulance take longer than this and 3-4% take longer than 15 minutes. This does not include the time to call for an ambulance and the time lost in traffic.

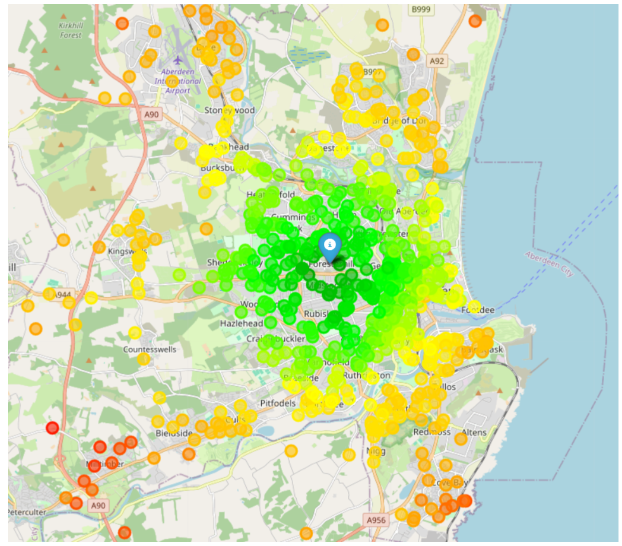

FIG. 2. The map shows response times to 100 addresses with a single ambulance station as produced by Python. The station is marked distinctly, with surrounding addresses color-coded to indicate the speed of response.

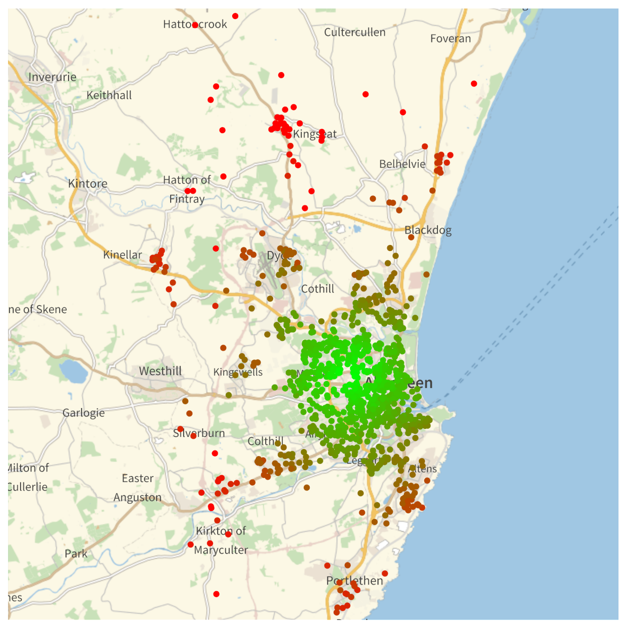

FIG. 3. The map generated by Mathematica code shows response times to 1000 random addresses with a single ambulance station in operation at the Aberdeen Royal Infirmary.

Time Analysis

First let us investigate the influence of times in the day to response time specifically intervals 3 AM, 9 AM, 3 PM, and 9 PM. As illustrated in Figure 4, the swiftest average response time occurs in the early hours of 3 AM, when traffic is minimal. Conversely, response times peak at 3 PM, which can be attributed to increased traffic congestion during the afternoon hours.

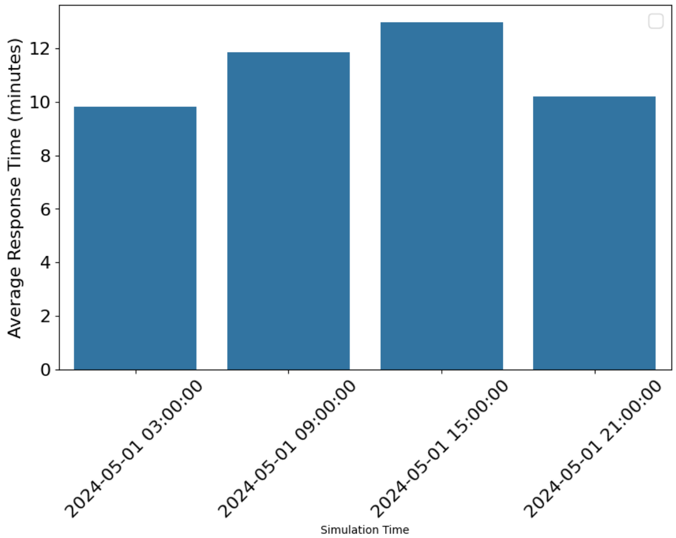

FIG. 4. The bar chart represents the average response time for emergency calls at different times of day.

Next let us look at response times which were recorded at a consistent time of 3pm over the span of a week. As Figure 5 illustrates, thursday afternoon emergencies tend to have the longest wait times, potentially due to peak weekly activities that could include higher vehicular and pedestrian traffic. Conversely, Sunday afternoons are marked by the shortest response times, possibly due to the reduced traffic.

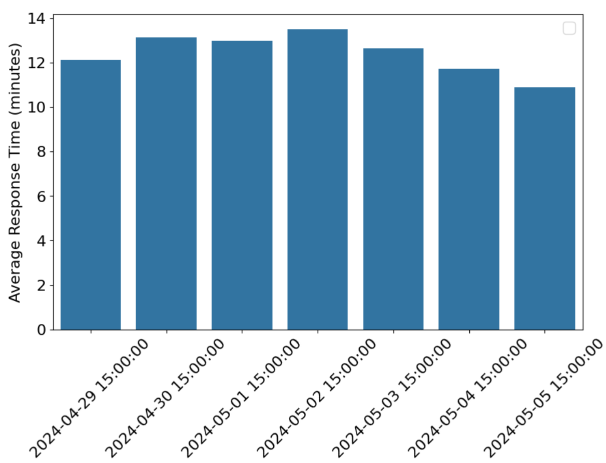

FIG. 5. The bar chart depicts the average response times for emergency calls at 3pm across different days of the week.

Results for alternatives for extra ambulance station

This segment explains the central finding: the addition of a second ambulance station lowers overall response

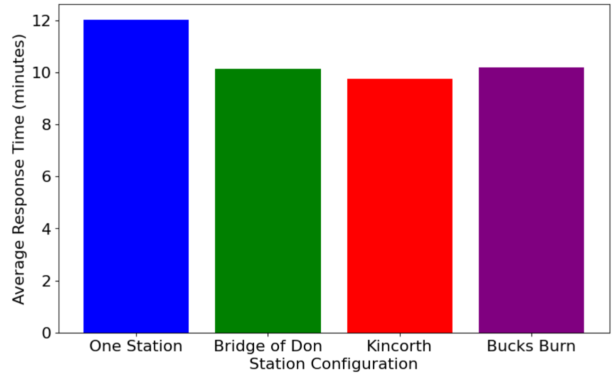

FIG. 6. Average response times across various station configurations are compared in this bar chart.

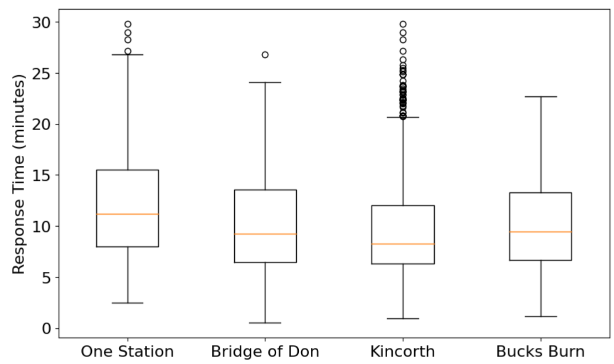

FIG. 7. Box plots contrasting response times across different station setups, revealing the range and distribution of response times for each configuration.

times by approximately two minutes, though the magnitude of improvement is station-dependent. From Figure 6, it is evident that the incorporation of a station in Kincorth yields the most significant reduction in response times. However, it is important to acknowledge that this configuration also results in greater variance in response times as seen in Figure 7. Further examination of Figure 8 reveals a bifurcated pattern: a cluster of rapid responses contrasted with a tail of delayed times. We believe when choosing station locations, it's important to consider not only the average response time but also its distribution.

The Figure 9 was produced by mathematica code. However, it gives similar result as the Figure 8. As Mathematica does not account for the traffic, the distributions are shifted to left. This shift is quite significant, about 5 minutes. The Kincorth configuration once again stands out by having lowest mean value. Additionally, table I suggest that both Kincorth and Bucks Burn models improve the number of response times within the 8 minute threshold by 10%.

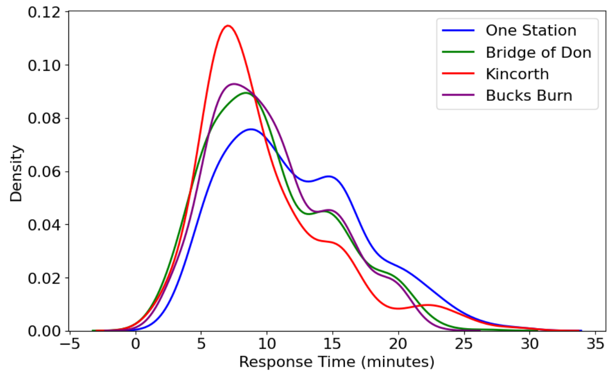

FIG. 8. Density plots illustrating the distribution of response times for three ambulance station configurations run in Python.

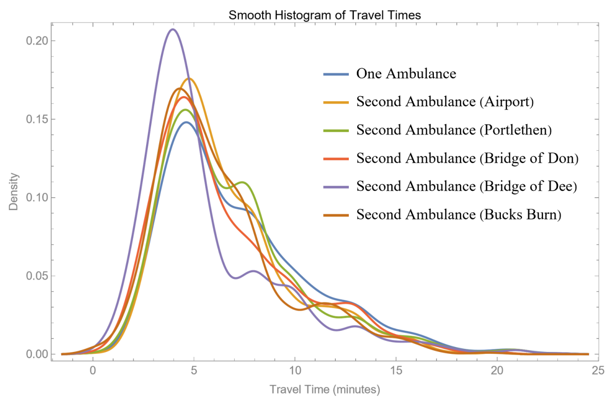

FIG. 9. Density plots illustrating the distribution of response times for five different ambulance station configurations run in Mathematica.

CONCLUSIONS

The simulations in this report suggest that having a second ambulance station in Aberdeen could aid in faster response to accidents. Both methods used - Mathematica and GoogleMaps API - show that by introducing extra ambulance location the mean response times and the longest response times are lowered. The best placements for the additional station of those considered are Kincorth and Bucks Burn.

We've also investigated how traffic affects ambulance response times. Traffic patterns vary throughout the day and week, significantly slowing down ambulance travel even in smaller cities like Aberdeen. This particularly impacts response times in the outskirts of Aberdeen. However, the challenge remains that the areas with the poorest access are dispersed in various directions around the city, making it difficult for one additional ambulance station to effectively cover them all.

Configuration	**Over 8min.**	**Over 15min.**
One Station	32.4%	3.4%
Airport (2^{nd})	24.5%	1.5%
Portlethen (2^{nd})	26.4%	2.9%
Bridge of Don (2^{nd})	26.4%	1.8%
Bridge of Dee / Kincorth (2^{nd})	20.6%	2.5%
Bucks Burn (2^{nd})	20.3%	1.1%

TABLE I. shows for each configuration the percentage of response times above the average threshold given by NHS [8].

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