Optimizing Police and Hospital Locations for High-Risk Roads:
A Geospatial Analysis Approach

A Project Paper for Introduction to Geospatial Analysis

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Abstract

Road accidents are frequent and regrettable incidents that can lead to severe consequences, such as injuries, damage to property, and even loss of life. For example, in Metro Manila alone, 17,257 recorded vehicular accidents occurred from August 2018 to December 2020. In such emergencies, the need for a faster response time from the local police authorities and emergency vehicles is critical to saving the lives of those who have incurred casualties during a road accident. This paper study aims to help improve the response time of police and ambulance services through Geospatial Analysis techniques. Using the maximum response time of eight (8) minutes at 15 kph speed, the results show that an additional one (1) police station and three (3) hospital locations are needed to fully cover the hotspot areas or areas with frequent road accidents. However, this analysis does not consider road networks, and other considerations can be made to improve the study further.

Keywords

Road Incidents, Response Time, Geospatial Analysis Techniques,

Introduction

Background

Vehicular accidents are an unfortunate and common occurrence on roads, and they can have severe consequences, such as injuries, property damage, and fatalities. For example, between August 2018 and December 2020, there were 17,257 recorded vehicular accidents in Metro Manila, most of which occurred on major thoroughfares like Commonwealth Avenue, Epifanio de los Santos Avenue (EDSA), and Circumferential Road 5 (C-5). Knowing what to do in such situations can save lives and prevent further harm.

If an individual finds themselves involved in a vehicular accident, the first step is to assess the damage and injuries sustained by everyone involved, including themselves and any companions. This assessment will help determine the accident's severity and whether immediate medical attention is necessary. It is crucial to remain calm and composed during this process to prevent further panic and chaos.

Prompt action is critical to saving lives in the unfortunate event of a casualty. The first action is to call 911 for police and medical response. Then, emergency responders will be dispatched to the accident scene as quickly as possible. The response time of emergency services, such as the police and ambulance, during a road accident is crucial in determining the outcome of the incident. **In many cases, the difference between life and death is measured in minutes, and a delay in response time can be disastrous.** Therefore, it is imperative to explore ways to improve the response time of emergency services during a road accident. **This study aims to highlight the significance of the problem and propose a Geospatial analysis approach to help improve the response time of police and ambulance services.**

Significance of the study

Improving the response time of emergency services during road accidents is crucial in preventing loss of life, injuries, and property damage. Delays in response time can lead to further complications or even fatalities, as victims may not receive the necessary medical attention in time. **Addressing this problem can help save lives and prevent further damage.**

Problem Statement

In this study, the research team delves into the issue of improving the response time of emergency services, specifically the police and ambulance, during road accidents. **The team seeks to answer the critical question of how to enhance the response time of these services to save lives and prevent further harm.**

Moreover, the team proposes a Geospatial analysis approach to improving the response time of emergency services during road accidents. This approach uses location-based data to analyze traffic patterns and emergency service station locations, among other factors, to optimize response time. The team believes this approach will help improve emergency services' response time during road accidents, reducing the risk of fatalities and severe injuries.

Overall, the team's research focuses on identifying ways to address the issue of delayed response time during road accidents and proposes a geospatial analysis approach as a solution. The team hopes that the study's findings will be useful in improving emergency services' response time during road accidents, ultimately saving lives and preventing further harm.

Assumptions

In this study, the research team has made several assumptions to explore how to improve the response time of police and ambulance during road accidents. The first assumption is that the **emergency response vehicle speed equals 15 kph.** This speed accounts for the worst-case scenario, such as during rush hour when traffic is heavy.

The team has also considered the **international standard response time to be eight minutes**.[1] This standard defines the maximum time emergency services should take to reach the accident site after receiving a distress call.

To determine the police response time, the team assumes that the police response originates from the police station. In addition, the **police station coverage area follows the city boundaries to respect the jurisdiction of each city police district**. This means that the police response time may vary depending on the location of the accident site and the distance from the police station.

On the other hand, the team assumes that the medical response unit originates from a hospital to determine the medical response time. However, the **hospital coverage area does NOT follow the city boundary**. This means that the medical response time may vary depending on the location of the hospital and the distance from the accident site.

Overall, the team's assumptions are a basis for analyzing the factors contributing to delayed response times during road accidents. The team aims to identify ways to improve emergency services' response time during road accidents and **propose a geospatial analysis approach to optimize response time, ultimately reducing the risk of fatalities and severe injuries**.

Methodology

Data Collection

The data used for the paper is a combination of the traffic accidents in Metro Manila and the Global Administrative Areas (GADM). The traffic dataset serves as the determining factor in recognizing the hotspot location and which areas different amenities should cover. The GADM projects the accidents in the Philippine shape file's city and barangay boundaries.

Traffic Accident Dataset

The dataset is a list of tweets of incidents (accidents, vehicular breakdown, etc.) in Metro Manila that is scraped from the official MMDA Twitter page. The data was gathered through the Twitter API and parsed through the tweet text to get the relevant data. It contains information about a particular incident, including the date and time of occurrence, location (with coordinates), type of incident, vehicle type involved, and the source link of the tweet. The period of the dataset is from August 2018 up to December 2020. [2]

GADM

Global Administrative Areas (GADM) is a comprehensive database that contains boundary information on administrative areas worldwide. The database encompasses various types of administrative units, such as countries, counties, and departments, covering every country across the globe. Each administrative area in the database is accompanied by attributes, with the name being the primary information provided and other relevant details, such as variant names in some cases. [2]

Data Preprocessing

The data was prepared to analyze the traffic dataset by cleaning and handling missing values to ensure data consistency and accuracy. Additionally, the longitude and latitude accident data were converted to a GeoDataFrame format through feature engineering for better data manipulation and alignment with the study's objectives. These steps were critical for generating meaningful insights and making informed decisions based on accurate analysis.

In the case of the GADM data, the shape file is limited to the Metro Manila region. First, the data was prepared to analyze the traffic dataset by cleaning and handling missing values to ensure data consistency and accuracy. Additionally, the longitude and latitude accident data were converted to a GeoDataFrame format through feature engineering for better data manipulation and alignment with the study's objectives. These steps were critical for generating meaningful insights and making informed decisions based on accurate analysis. Then the dataset is filtered to the amenities involved when a traffic incident occurs. In this study, the considered amenities were limited to police stations and outposts, responsible for law enforcement, and hospitals, which handle injuries to people.

Mapping

After cleaning and processing the data for the study's purpose, the next step is integrating the two GeoDataFrames and visualizing the selected amenities concerning all incidents. This visualization will provide insights into locating hotspots based on the density of incident points. The study will focus on the city with the highest number of accidents, and a coverage area will be selected that includes all incidents given the current number of amenities. This will serve as the baseline for optimization.

Next is to optimize the coverage area of the two amenity types by setting a constant speed considering the traffic dilemma of the region, which in the case of Metro Manila is 15 kilometers per hour. Given the international standard for the emergency response time of eight (8) minutes, a common circular coverage will be used to highlight the area coverage of each amenity.

The main difference between the police and the hospital is the granularity of how the study will deal with location boundaries. For the police, the analysis will be on a per-city level since there are jurisdiction boundaries for the different police districts. It is assumed that by law, neighboring district police cannot interfere with cases outside their jurisdiction, even if they are near the incident. The hospitals, however, do not have this limitation, so the analysis will consider Metro Manila when looking at the coverage area.

Site Optimization and Analysis

The paper will investigate incident areas not covered by the calculated radius of a specific amenity. Uncovered areas strongly indicate that additional police stations or hospitals must cover all incident points while ensuring the response time meets the standard. By identifying these uncovered areas, the study will provide insights into the current gaps in emergency services and inform decision-making on where to allocate resources to improve emergency response times and reduce the number of incidents.

The optimal location will be analyzed using the centroid of the incident points and grouping the points as needed for multiple sites. The centroid will serve as the starting point where the optimal location of the new amenity should be. **However, since the incident most likely occurred on the road, the location of the centroid may not be feasible. The solution for this is to locate nearby open space that will satisfy the space requirement of the amenity.**

Finally, the analysis will be extended to consider the road network the selected amenity locations cover. This approach will provide additional insights compared to using only boundary-shape files.

Results & Discussion

Accident Plot and Hotspot Areas

The processed accident dataset involves 17,257 incidents during the two years mentioned. It is worth noting that there are either zero or close to no reported accidents in the northern part of the region *(Navotas, Malabon, Valenzuela, and North Caloocan)* and the southernmost part *(Las Piñas and Muntinlupa)*. This insight leads the team to shift its focus away from these cities since insufficient data exists.

The mapping of the accidents can also show the difference between a major and minor road since the latter has little or no overlaps for its incident points. As a result, some incidents are spread out along parts of the minor roads. On the other hand, major roads will normally have a high volume of cars traversing the road, resulting in more incidents occurring in the area. Given this, the team was able to locate the roads that can be considered critical areas of the hotspots where the analysis will focus on. The top three identified hotspots are Commonwealth Avenue, Epifanio de los Santos Avenue (EDSA), and Circumferential Road 5 (C-5). The only city that encompasses all three roads is Quezon City, where the focus of the analysis will be, especially for the police section, since jurisdiction boundaries are involved.

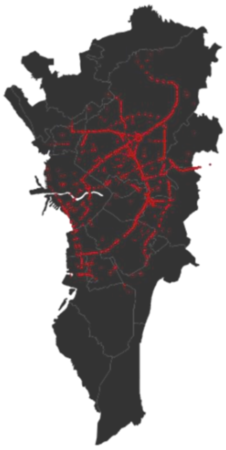

Figure 1. Traffic Incident Points of Metro Manila.

Police and Hospital Coverage

The GADM dataset included 149 police and 128 hospital points across the metro area. By integrating the incident and police/hospital points and setting a constant coverage area for all the amenity points, the interaction between the points can be observed. The plot highlights points of interest for areas not covered by an amenity's coverage area, particularly if the coverage area is set low. Additionally, many overlaps between the coverage areas can be observed, which is a positive interaction because alternative points can cover the incident location if the nearest police station or hospital is unavailable. These insights can inform decision-making on allocating emergency resources in areas with coverage gaps and improve overall emergency response times.

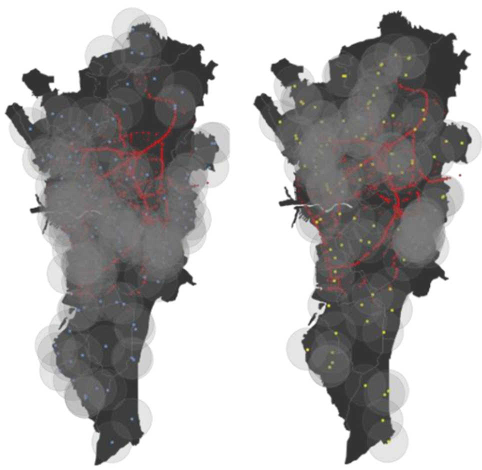

Figure 2. Police and Hospital Coverage Points with the Traffic Incident Points.

As noted above, the analysis for the police points will be focused on Quezon City. To cover all the incidents in Quezon City, the team adjusted the coverage area of the 20 police stations. By doing so, the maximum response time to reach a traffic incident was calculated to be 14 minutes. **This is way beyond the international standard for the response time of 8 minutes.**

By adjusting the assumed speed to at least 26 kph, all incidents can be covered within the maximum response time of 8 minutes, representing the best-case scenario. However, for the study, a speed of 15 kph will be assumed to account for and prepare for the worst-case scenario. This approach will help ensure that the analysis and recommendations are realistic and practical, given the traffic conditions in the area.

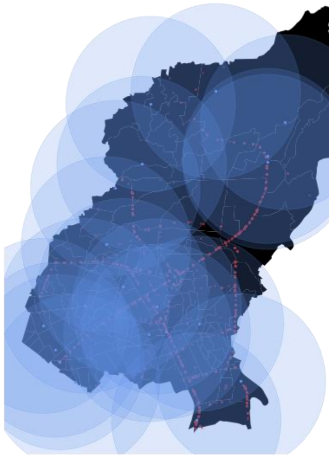

Figure 3. Police Station Coverage Area is set to cover all Traffic Incidents in Quezon City.

Next, the team tried adjusting the coverage area of the police station to make the maximum response time well within the international standard of 8 minutes. From the calculation, the team found that the coverage area should be 2 kilometers. As a result, the following plot shows the coverage area of police stations in Quezon City.

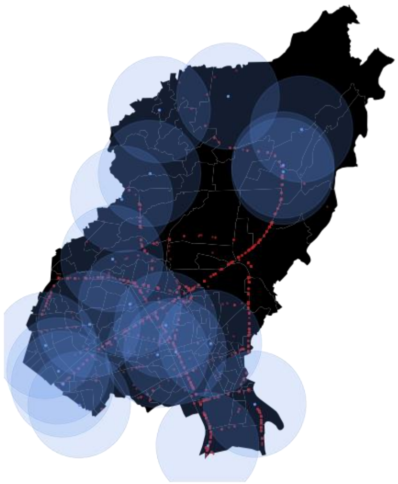

Figure 4. Police Station Coverage Area is set to have a maximum response time of 8 minutes in Quezon City.

The analysis reveals several locations along Commonwealth Ave, Luzon Ave, and Tandang Sora Ave that are not covered by any police stations, as indicated in the plot below. Specifically, the plot shows only the incidents not covered by any police station, providing a clearer illustration of the coverage gaps in the area. This information can be valuable in identifying areas that require additional emergency resources to improve coverage and response times.

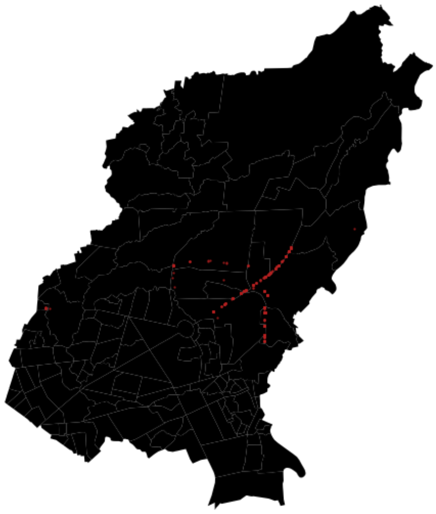

Figure 5. Uncovered traffic incidents by the police stations.

To ensure that response times remain within the 8-minute target, the team recommends constructing an additional police station to cover the incidents identified in the plot above. To determine the exact coordinates of this new location, the team utilized the centroid method, which involves placing the new police station at the center of the uncovered incidents, thereby providing optimal coverage. This approach can help improve emergency response times and enhance public safety.

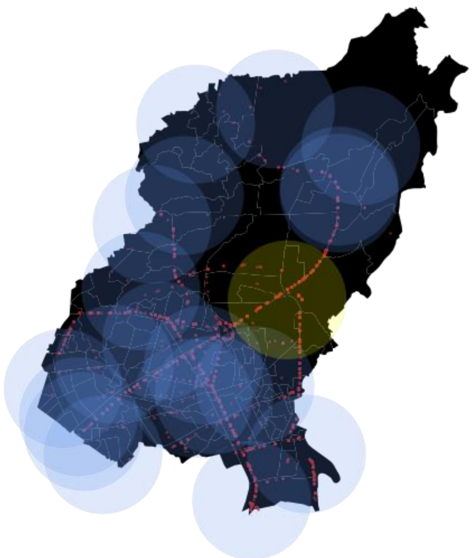

Figure 6. The coverage area of Police Stations includes the suggested area of an additional police station.

The graph illustrates the yellow-shaded coverage area of the new police station, which was recommended by the team to ensure a response time of within 8 minutes for all traffic incidents. The team used the centroid method to determine the location, which is at the center of the incidents, any existing police stations did not cover that. To assess the feasibility of the suggested location, the team used satellite images from Google Maps.[4] Initially, the suggested coordinate was 14.661660, 121.070399, located inside UP Diliman Campus. However, to improve accessibility, the team relocated the police station to coordinate 14.664651, 121.070271 along Commonwealth Ave. northbound near Tandang Sora, only 330 meters from the initial proposed location.

Figure 7. Proposed site location of an additional police station.

The steps mentioned above are also taken to optimize the potential hospital locations. But, again, the assumption is that the response vehicle will travel at a pessimistic rate of 15 kph, and the set maximum response time is 8 minutes. Since hospitals don't follow political boundaries when responding to a traffic incident, we will consider all traffic incidents and hospitals in Metro Manila.

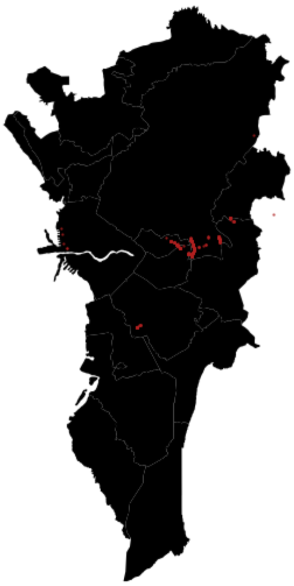

Figure 8. Uncovered traffic incidents by the hospitals.

Excluding the incidents covered by hospitals, the figure above shows the identified clusters of incidents that need to be covered by a medical response unit. These areas are Makati, Manila, and Quezon City-Mandaluyong-San Juan Area.

For Makati, the optimal location found by the centroid method is at 14.540310, 121.016898, in the intersection of South Superhighway (SLEX) and EDSA. However, this location is not feasible for the next hospital since the area is in the middle of the road. After searching for a possible location, the nearest area feasible to establish a hospital is 130 meters away, located in EDSA cor. SLEX with coordinate 14.539222, 121.016766.

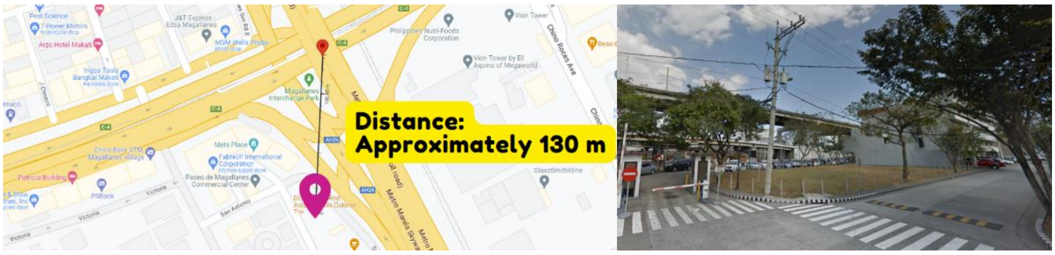

Figure 9. Proposed site location of an additional hospital at Makati.

In the case of Manila, the team used the centroid method to identify the optimal location for a new hospital. The resulting coordinate is 14.605239, 120.962401, situated in a highly dense residential area in front of the Port Area of Manila. However, this location is deemed not feasible due to accessibility issues for emergency vehicles. So instead, the team identified a location 160 meters away with coordinates 14.605589, 120.960920, situated inside the Port Area of Manila. With the Port Authority's support, this location is considered the most suitable for establishing a new hospital.

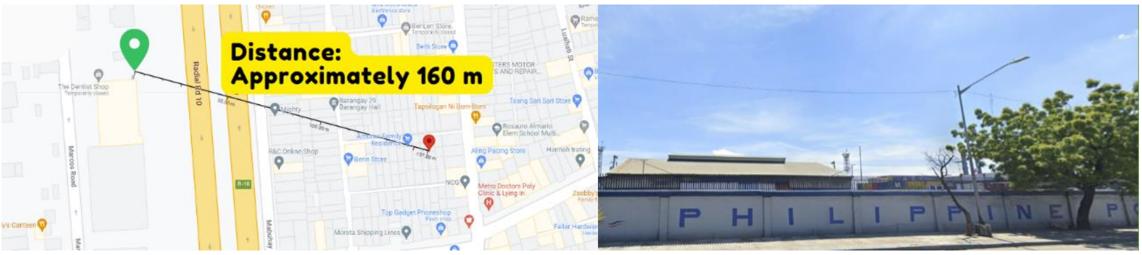

Figure 10. Proposed site location of an additional hospital in Manila.

Thank you for providing the information on the optimal location for the next hospital in the Quezon City-Mandaluyong-San Juan area. However, the suggested location inside Camp Aguinaldo is not feasible due to its status as a military camp, and other nearby areas like Camp Crame and Corinthian Gardens are also unavailable. As a result, the closest vacant and suitable land for the hospital's establishment is located 1.1 kilometers away at EDSA cor. Ortigas Ave. with coordinates of 14.593897, 121.058203. This location has been identified as a viable alternative and should be considered for further planning and implementation.

Figure 11. Proposed site location of an additional hospital at Quezon City – Mandaluyong – San Juan.

By establishing one police station in Quezon City, the city can cover all the traffic incidents and respond within 8 minutes, even in the worst scenario of traveling at 15 kph. Likewise, with the establishment of three additional hospitals in Metro Manila, the hospital can cover all traffic incidents and respond within 8 minutes, even in a worst-case scenario.

Analyzing the Road Network Coverage

The team has conducted an analysis of the road network in the proposed site location for the additional police station. Based on the results, it can be observed that the findings are nearly identical to the previous analysis when projected to the road network. The only slight difference is that incidents located close to the boundary are excluded from the road network analysis due to its utilization of road length as a basis, as opposed to the land area covered by the GADM data. Nevertheless, it's worth noting that both analyses cover a comparable amount of area provided that the roads are nearly straight. These findings suggest that the road network analysis can be a useful tool in evaluating the spatial distribution of crime incidents and identifying suitable locations for a new police station.

Figure 12. Proposed Site Location of the Additional Police Station

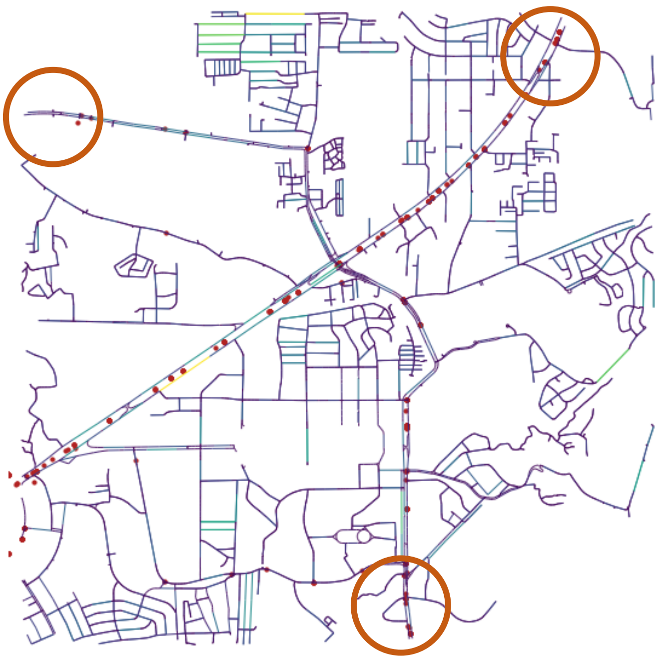

Figure 13. Road Network Plot of the Proposed Police Station Site

<u>Conclusion</u>

The objective of this study was to identify measures to enhance the response time of police and ambulance during road accidents. To achieve this objective, the team employed geospatial analysis techniques to map out the current police stations within its city-level jurisdiction and hospital locations within Metro Manila. By adjusting the coverage area of the stations, the team determined the critical locations in need of additional police stations and hospitals, based on the assumption of a maximum of 8 minutes with a 15kph speed from the station/hospital to the accident site.

To validate the findings, the team conducted a comparison between the analysis results and the road network, which showed minor differences between the two plots due to the straight path of major roads. Through this approach, the team was able to identify one (1) potential location for a new police station within Quezon City and three (3) prospective hospital locations within Metro Manila to cover the hotspot areas. This study demonstrates the usefulness of geospatial analysis in identifying areas for improvement in emergency response systems and provides valuable insights for policymakers and stakeholders to make informed decisions.

Recommendation

As with any study, there is always room for improvement and development. The following points to some potential future work that could be undertaken to create a more comprehensive report on optimizing police and hospital locations with respect to high-risk roads through geospatial analysis techniques:

1. **To estimate the coverage area of a police station/hospital using an expanded road network.** The team could only incorporate a basic road network in its analysis for one area. The coverage area of the locations would be very different once this is considered, as it could also consider optimal routes to take going to the incident sites. By analyzing the road network and calculating travel times and distances, future researchers can estimate the coverage area of a police station or hospital and optimize emergency response times more accurately.
2. **To conduct sensitivity analysis on assumed speed to determine the optimal speed for emergency response vehicles.** Considering this with the road network map, future researchers can simulate different routes at different speeds to support the optimal and more realistic speed for emergency response vehicles.
3. **To consider other features such as available workforce/capacity and population density of the police/hospital locations in estimating the coverage area.** While the road network is an essential factor in estimating the coverage area of a police station or hospital, other factors can influence the coverage area, such as the available workforce and capacity and population density. For example, a police station with more officers can cover a larger area than one with fewer officers. Similarly, a hospital with more beds and medical staff can serve a larger population. Additionally, population density can impact the coverage area, as areas with higher population density may require more emergency services than areas with lower population density. Therefore, future researchers may need to consider these factors when estimating the coverage area of a police station or hospital to ensure that emergency services can be effectively delivered to the population in need.

Reference

[1] Estember, R. (2019, March 7) An Optimization-based Approach Model for the Improvement of the Performance of Emergency Medical Service Ambulances. Retrieved March 22, 2023, http://www.ieomsociety.org/ieom2019/papers/293.pdf

[2] University of Waterloo (n.d.) Global Administrative Areas (GADM). Retrieved March 22, 2023, from https://uwaterloo.ca/library/geospatial/collections/us-and-world-geospatial-data-resources/global-administrative-areas-gadm

[3] Brotoisworo, P. (2020, December 28) Manila Traffic Incident Data. Retrieved March 22, 2023, from https://www.kaggle.com/datasets/esparko/mmda-traffic-incident-data/code

[4] Google. (n.d.). Google Sattelite Images. Retrieved March 22, 2022, from https://www.google.com/maps