A GIS Based Analysis of Vulnerable Areas and Communities in the Event of a Medical Emergency

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Abstract

This investigation focuses on determining areas that are underserviced by emergency response hospital in Puerto Rico. Using drive time distances from hospitals of 5, 10, and 15-minutes, perimeters are created. Once these areas are created, the investigation analyzes the areas found outside of these regions. Further investigation is done on these areas of lower accessibility to determining their demographic profiles. The results of the analysis found that 14.07 of block groups in Puerto Rico are outside of the service areas totaling to 13.82 of the population. The demographic profiles found areas of potentially high health risks within these underserviced areas.

Introduction

Emergency preparedness is a crucial aspect of any society and it is important for the safety of the population to understand their geographic proximity to health centers. This research is focused on the island of Puerto Rico and will use Geographic Information Systems (GIS) as a tool to analyze distances between communities and the nearest emergency response hospital. The goal of this investigation is to highlight communities that are at higher risk based on service areas created using isochrone driving distances from hospital geolocations.

Further analyses will be done on the areas deemed high risk. Using census data, demographic profiles will be created to monitor key aspects of the populations. This investigation is crucial because based on the profile of the communities outside of a hospital's service area there could be serious implications for the people living in those areas.

Background

In 1969, the Puerto Rico Medical Emergency Corps (*Cuerpo de Emergencias Médicas de Puerto Rico* or CEMPR) was implemented as a division within Puerto Rico's Department of Health. The purpose was to create a unified center for receiving emergency phone calls and dispatching the necessary response needed. Today, when an emergency call is placed and an ambulance is required, according to the CEMP's official Dispatch Chart, either a private or public ambulance will be called according to the closest available option. The CEMPR's dispatch flow chart provides a summarized version of how emergency response calls are handled. Different types of services are called upon depending on distance from the location of the emergency.

Puerto Rico is divided into four regional dispatch offices across the island which is separated into the Northern, Eastern, Southern, and Western dispatch center. These regions are further divided into operational zones. These zones are of particular interest because this investigation seeks to analyze if these zones are ideally distributed based on drive time to nearest hospitals. Other spatial analysis will be conducted to determine if the operational maps are ideal for the present demographics in Puerto Rico.

Methodology

Data Sources

The census data acquired for this investigation was downloaded directly from the American Census Bureau data base. The specific census surveys being utilized are the 2019 and 2014 ACS 5 Year Estimates Profile. The data is aggregated at the block group level. Previous investigations looked at variables such as: age, gender, percentage unemployed, population density, amongst others [1]. Additionally, this investigation will look at percentage uninsured and percent population with disability.

The location of the hospitals in Puerto Rico were acquired by georeferencing a combination of various lists of hospitals available online. The list was then converted into a geographic shapefile file using the longitude and latitude of the hospitals. Once in the GIS software, the layer was compared to the Google Earth base layer to check the precision of the coordinates for each hospital. A map illustrating the location of the hospitals used in this investigation was created (figure 1).

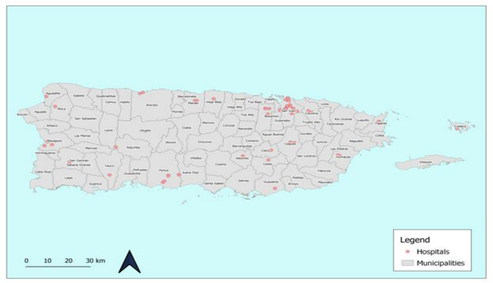

Figure 1. Emergency Response Hospitals

Network Analysis Framework

This investigation was done using QGIS, a free and open-source GIS platform, to conduct the network analysis for the hospitals. Specifically, the plug-in ORS Tools which provides access to OpenStreetMap functions was implemented. The service areas were determined by creating perimeters of 5- and 10-minute drive times around the hospitals. Overlap between service areas happened in different areas but for the purpose of this investigation they were ignored. Areas of overlap signals that the block group is highly likely to be properly serviced and this investigation seeks to highlight and determine how to best service areas that fall outside of drive time radiuses.

Vulnerability Index

The index is comprised of the various variables stated above: age, gender, percentage unemployed, population density, percentage uninsured and percent population with disability. A z-score will be determined for each variable within each block group by first determining the mean value of the variable, then the standard deviation. Then those values will be plugged into the formula for z-scores:

$$Z = (x - \mu)/\sigma \quad (1)$$

Once this is done for each variable the data has thus been normalized and can be used in computations along with other variables. The average of the z-score values for each block group will be calculated to determine which block groups have the highest vulnerability index.

Results and Discussion

Network Analysis Results

There are 360 block groups that are completely outside of the 15-minute drive time boundary of any hospital (figure 2). That is equal to 14.07 percent of block groups in Puerto Rico. The largest cluster of block groups outside of any hospital 15-minute drive time perimeter is found in the center of the island. The second largest cluster is found near the Northwestern corner of the island.

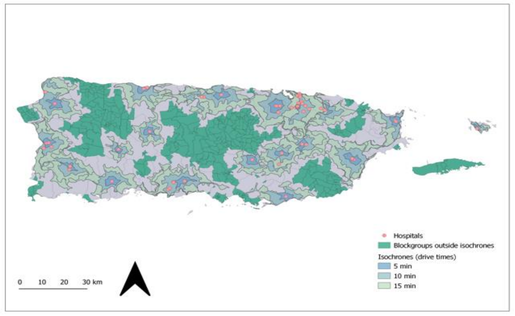

Figure 2. Block groups outside service areas

According to the 2019 5 Year American Census Survey, the total population of citizens living within these block groups equates to 13.82 percent of the population. Following a similar trend, the total population of people over 65 living in the block groups outside of the 15- minute drive time equates to 14.94 percent of the population.

Z- Score Results

Areas with higher z score averages tend to have above average values for each variable (figure 3). The cluster on the southeastern part of the island also is a particular area of interest. In total, 192 of 360 block groups have a z score greater than 0. This is to be expected when calculating for in comparison to the mean of the data. Similarly, 39 out of 360 block groups have an average z score greater than .5 which equals to 10.8 percent. However, in the southeastern region 22 out of 32 block groups have a z score above 0, which means equals to 68.75 percent. The variable that stands out the most in that region is when looking at aggregated household income.

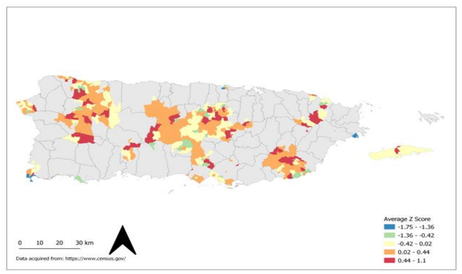

Figure 3. Z- Scores

Lower overall income can lead to serious barriers for getting medical attention. The regions were created using 15-minute drive time perimeters for hospitals but many people with lower incomes do not own a car and thus will have a harder time in the case of an emergency. That is just one of the many factors to consider when it comes to how income is connected to public health.

Conclusions

This investigation has shown how the use of Network Analysis can be implemented to aid in public health research. Drive time is a strong indicator of accessibility and creating isochrone distances based on a 15-minute drive radius from hospitals highlights areas that are underserviced. Overall, this investigation found 360 block groups that are completely outside of the 15-minute drive time boundary of any hospital, which is equal to 14.07 percent of block groups in Puerto Rico. This percentage is significant especially when considering the total population that lives within those block groups. For individual statistics, such as population and population over 65 years of age, this investigation found that nearly 15 percent of both categories live within those block groups in Puerto Rico.

Using a wide variety of variables chosen by researching previous literature's investigations into factors that determine areas that need more access to health facilities. Once the data was converted into z scores, the average for each block group was calculated. Z scores are a measure of tendency within a dataset, the closer to 0 a z score is the closer to the mean the data point is. This investigation found two general areas, one cluster of block groups on the Northwestern side of the island and another cluster on the Southeastern part of the island. Both clusters had a majority of block groups above an average z score of 0, notably the southeastern region has 68.75 percent above an average z score of 0. This is important to understand because it proves that these areas of lower accessibility are also of high potential risk of needing medical services.

Future Work

Future investigations can be conducted using Network Analysis tools to find the most optimal location for hospitals, thus ensuring that accessibility to hospitals in an emergency situation is guaranteed. Additionally, more in-depth analysis can be done on individual block groups of interest instead of looking at the block groups in clusters.

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