# Review of the City of South Bend Fire Service using GIS

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## ABSTRACT

The City of South Bend is expanding. As of 2021, the city has a population of 103,353 (US Census Bureau, 2021). This is a gain of 2,400 more people than in 2010. Due to growth, some of the city's resources may be over-extended, or citizens may be underserved in certain areas. The South Bend Fire Department (SBFD) answers many types of calls in a day. Some are actual fires; most are not. The project's scope was an evaluation of the 11 City of South Bend Fire Response Areas to determine if the stations were being over-extended and if there was a need for a new fire station. If one was required, assess an optimal location for it and the creation of another Fire Response Area. The data was a random combination of alarm calls related to the individual Fire Response Areas. The project used Spatial Analysis tools and Map Algebra to spatially analyze the data to determine if there were clusters of events and indicate more activity in a specific area. The approach to the local modeling utilized a geographically weighted scheme where all the observations were weighted corresponding to their distance from the location of the fire stations. Both Euclidean Distance and Euclidean Allocation were used to visualize the data to determine response to alarm calls and to decide if some areas received more calls than others. The study considered obstacles when calculating distances. The Spatial Analysis tools were used to calculate significance-per-unit area from points or polylines. Once the analysis was complete, the findings were that the SBFD is not over-extended, nor is there a need for a new station.

## INTRODUCTION

The City of South Bend is expanding. Due to population growth, some of the city's resources might be over-extended, leaving areas underserved. The report from the National Commission on Fire Prevention and Control titled "*America Burning, the Report of the National Commission on Fire Prevention and Control"* discusses fire prevention in detail. The report covers the result of urbanization and how more people are moving to the cities, creating a strain on the fire services (National Commission on Fire Prevention and Control, 2003). The South Bend Fire Department (SBFD) answers many types of calls in a day. Some are actual fires, and many are not. The study assessed whether the SBFD was over-extended in some city areas. If so, was there a need for a new fire station? The Parrot and Stutz paper, "Urban GIS Applications," discusses how they used GIS to locate land and place a new fire station in San Diego. They assessed several criteria, such as topographic obstacles, roadways, land use, and population density, which became a basis for this study (Parrot & Stutz, 1991) by assessing the existing 11 Fire Response Areas and alarm call volume the study aimed to identify gaps in service or indicate where the services may be over-extended. *Figure 1* is a map of the City of South Bend City that divides the city into 11 Fire Response Areas, and it shows the location of the current fire stations.

Localized first-order variations, which may indicate trends in the study area, were initially seen in the spatial pattern across the study area (Blanford et al., 2020). The kernel density estimation

(KDE) tool in Spatial Analysis was utilized for this evaluation. Trends were indicated; therefore, second-order variation in the spatial pattern needed to be identified. For this analysis, the Nearest Neighbor tool was used to determine if part of the pattern is attributed to second-order effects or interaction effects among elements in the pattern (Blanford et al., 2020). Stated another way, are the EMS alarm calls clustered in certain areas indicating a trend?

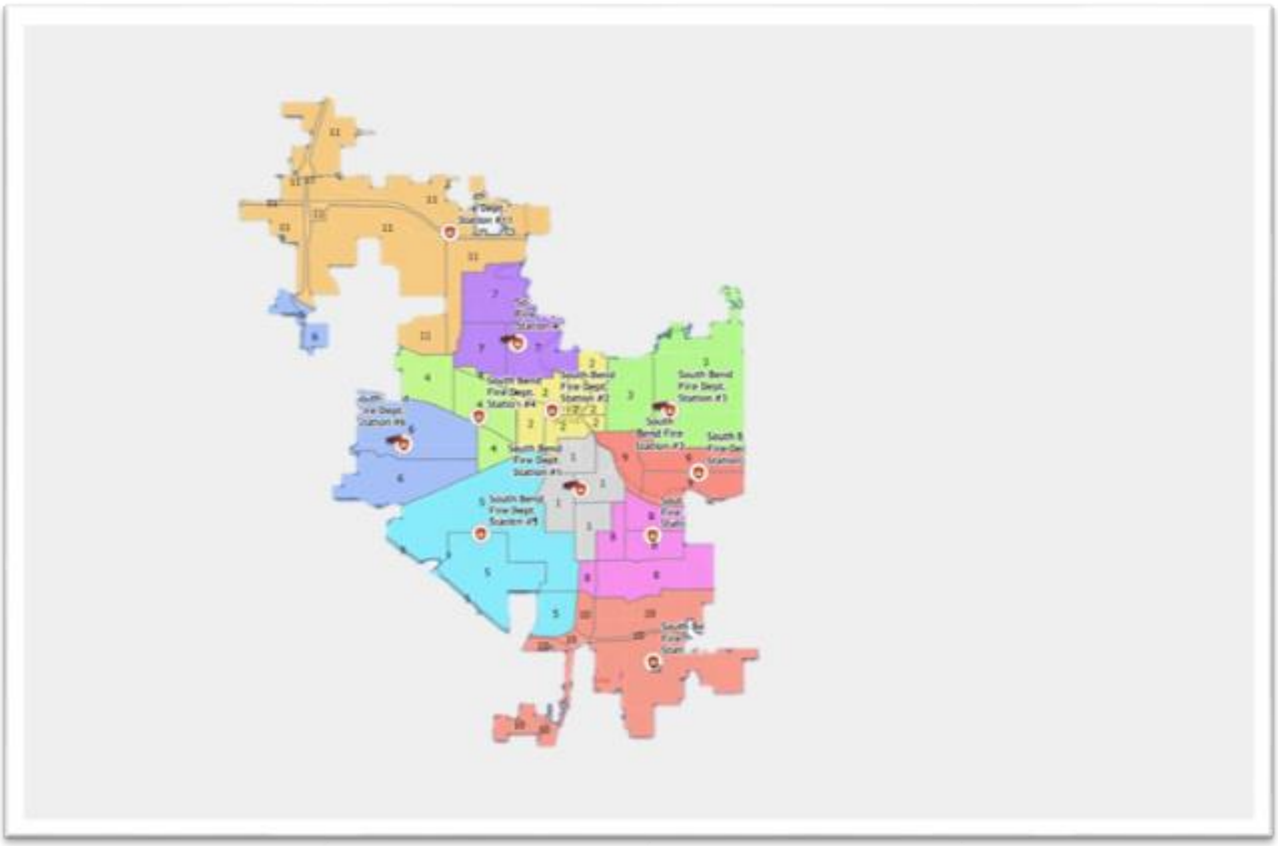

***Figure 1: The City of South Bend has 11 Fire Response Areas and 11 fire stations that service the city, as illustrated here. The current areas do not include the South Bend International Airport or the University of Notre Dame Campus, which their fire departments serve. Map Create using ArcGIS Pro 3.1.0.***

<u>Research Questions</u>:

- Is there an area of the city showing the SBFD being over-extended?
- If so, is there a need for a new fire station to be built?
- If yes, what is the optimal location for the new fire station?

Answering these questions required evaluating the 11 City of South Bend Fire Response Areas and evaluating Emergency Medical Services (EMS) call data. The volume and location of the calls were more important than whether the calls were fire or non-fire related. The alarm call information was sampled and spatially distributed to determine where clusters indicated a possible trend.

Description of the Problem

Determining if the SBFD is over-extended or if areas of the city are being underserved was the critical factor in the study. The alarm call data described in more detail under the Data Section for 2022 indicated that SBFD responded to 24,078 alarms. 11 fire stations and their crews responded to this call volume. That is 65.96 calls per day for the year if they were evenly distributed across the department. An evaluation of the type of alarm calls showed that only 560 of the 24,078 were fires (Coded 100). The codes are defined by the National Fire Incident Reporting System (INFIRS) reference numbers used by all fire departments in the United States and further explained in the Data section below (National Fire Data Center, 2015). Most alarm calls were Rescue and EMS Incidents (Code 321). These EMS calls were 17,712 of the 24,078 alarm calls answered (Indiana Department of Homeland Security, 2022). Conducting interviews with local South Bend Fire officials indicated that there was a need for this study. One fire chief (anonymous for their privacy) mentioned it was his understanding that there had not been a comprehensive overview of the fire department in possibly 20 years or more. This information made it clear that there was a need for the project. The project results may benefit the leadership at the SBFD and identify some previously undiscovered data. The project evaluates travel cost distance or how easy/hard it is to get to the alarms. It also considers the volume of calls per Fire Response Area using a simple random sample of 10% of the total alarm calls. This will indicate if any fire stations or areas have more incidents than others, illustrating the overall workload for each Fire Response Area. Then based on the findings, highlights areas that may be over-extended.

Some things considered: Are some fire stations over-extended by call volume? Is there a need for a new station, and if so, where would it be best placed?

Literature Review

The following section reviews the publications and peer-reviewed journal articles used to frame the project. Some pieces also provided more in-depth knowledge of GIS and statistical analysis to solve problems. The argument for conducting the project was validated by the 1973 National Commission on Fire Prevention and Control (NCFPC) report titled "*America Burning.*" The report was updated in 2003 and highlighted vital information regarding factors influencing the nationwide fire services. Some of those topics are that increasing urbanization places more people in the city, creating a situation where citizens are closer to the firehouse; however, they are not necessarily responded to faster (NCFPC, 2003). Dr. Lori More-Merrell, Ph.D., describes in her blog for Lexipol.com how the current fire services are evaluated by measuring response times per the standards as recorded in the NFPA1710 (Moore-Merrell, L. PhD., 2019, July 17). It is noted that fire departments and EMS are not required to follow the standards. They have only suggested criteria, not mandates (Varone, 2012). Many fire departments and EMS do track their response times and evaluate their effectiveness using "*The Fire Community Assessment Risk Evaluation System*" (FireCARES) website maintained by International Public Safety Data

Institute (IPSDI). The site has information regarding SBFD EMS and fire service responses and evaluates their effectiveness. It also displays generic historical data from 2006 (International Public Safety Data Institute, 2022).

Much of the statistical analysis for this project was conducted using Lloyd's book "*Local Models for Spatial Analysis, Second Edition"* as a reference. This book made it easier to understand what needed to be assessed and what types of spatial analysis to utilize, such as kernel density to local model variances of the alarm calls. It helped explain the equations that the ArcGIS Spatial Analysis tools use. It was also the primary reference to describe the spatial analysis statistics when needed. (Lloyd, 2010). To supplement the information from Lloyd and to gain a further detailed explanation of geostatistics, the book "*An Introduction to Applied Geostatistics"* by Isaaks and Srivastava was referenced. The book is a case study and has an easier-to-understand explanation of the complex statistics used in GIS analysis. Glinka, Dudziński, & Glinka published a report described using kernel density estimation (KDE) in Warsaw, Poland, to evaluate the city fire department and EMS responses. Their findings concluded that using KDE was more precise at predicting the scale of magnitude of the investigated events (Glinka, Dudziński, & Glinka, 2022). This is very similar to the methods used for this project to evaluate alarm call volume. De Sanctis et al., also from Poland, discuss how fire services collect data and how that data is inconsistent. This identified what portions of fire service data should be focused on, such as travel time, turnout time, and alarm call volume (De Sanctis et al., 2015). Liu et al. used comparative statistics to evaluate response times during various times of the day to see how traffic impeded the fire response times and offered calculations for computing fire response areas based on travel time (Liu et al., 2020). This was important when calculating the SBFD fire response times. Using the busiest time for traffic added more time to the alarm response times to estimate the SBFD travel times.

The geographic information related to using geocoded fire incidents and how that can expose personal information was detailed by Anderson & Ezekoye. Their article is an in-depth look at the national fire response data collected. It separates data by population and describes the responsibility to protect personal information. Anderson & Ezekoye made it clear that there was an obligation to utilize a way to display the data that does not violate people's right to privacy (Anderson & Ezekoye 2018, January). However, only a tiny portion of the book, Parrot and Stutz, detailed how urban areas use GIS to improve their cities and towns. The methodology for locating a new fire station is outlined. Evaluation of response times and current fire station locations, parcel sizes, traffic conditions day/night, and crime statistics were all incorporated, as well as using a terrain layer because the topography of San Diego is restrictive when planning a fire station. (Parrot & Stutz, 1991).

## GOALS AND OBJECTIVES

The study assessed whether the SBFD was over-extended in some city areas. If so, was there a need for a new fire station? By evaluating the existing 11 Fire Response Areas and alarm call volume, the study was to identify gaps in service or indicate where the services may be over-extended. De Sanctis et al. discuss systematic data collection regarding the fire services. Their Fire Safety Journal article states, "Data collection is always related to costs and investments of resources." (De Sanctis et al., 2015, page number). The first objective was to use GIS Spatial Analysis Tools to evaluate the data, as Parrot and Stutz did in their article *Urban GIS Planning* from 1991. While dated material, the article explains how they used GIS to locate lots the City of San Diego owned to locate a site for a new fire station (Parrot & Stutz, 1991). Then compare the City of South Bend NFIRS data against the NFPA standard. Anderson, A., & Ezekoye state in their article in *The Fire Safety Journal*, "NFIRS database is one of the primary resources for data relevant to fire statistics in the United States" (Anderson & Ezekoye, 2018, p. 122). This will gauge how the city measures up to the standard. It is a quantitative measure to see if resources are being utilized effectively. Next, is to create an updated map showing the results of my research. Glinka, Dudziński, & Glinka discuss how they used a choropleth map to show areas of their city overloaded with emergency calls (Glinka, Dudziński, & Glinka, 2022). Finally, present the findings so that city officials can make an informed decision regarding their fire services.

## METHODOLOGY

To evaluate something, it is helpful to have a way to quantify the information. The quantitative data that sets the standard for many fire service professionals is the National Fire Protection Association (NFPA) Standard 1710 (NFPA, 2021). In the manual alarm call responses are broken down into three essential components, Availability, Capability, Operational Effectiveness:

Availability- The degree to which the resources are ready and available to respond.
Capability- The ability of the deployed resources to manage an incident.
Operational Effectiveness- A product of availability and capability. It is the outcome achieved by deployed resources or the ability to match resources deployed to the risks to which they are responding" (NFPA, 2021). The standard times as listed in the NFPA1710:

- Alarm Answering Time: 15 seconds for 95% of calls; 40 seconds for 99% of calls.
- Alarm Processing Time: 64 seconds for 90% of calls; 106 seconds for 95% of calls.
- Turnout Time: 60 seconds for EMS responses; 80 seconds for fire responses.
- First Engine Arrive on Scene Time: 240 sec (4 minutes) for 90% of responses with a minimum staffing of 4 personnel. (Moore-Merrell, 2019) & (NFPA, 2021).

Using all the minimum times adds up to 6.31 minutes. SBFD responded under the standard times per the 2022 data available, with an average total response time of 5.5 minutes (City of South Bend, 2023). For future analysis, the Business Analysis tool > Generate Approximate Drive Times tool was utilized to see how long it takes to drive to the farthest portion of the Fire Response Areas using the Fire Stations as the focal point and the polygons that make the Fire Response Areas as the boundaries. The time of day was set to daytime for the most traffic activity. As can be seen in *Figure 2*, the hatch mark areas are the assessed distance. Note that the large blank areas in some Fire Response areas are due to open space and lack of roads. The Generate Approximate Drive Times tool incorporated the roads layer into the equations. Where there is overlap or significant gaps is due to some of the Fire Response Areas being made up of multiple non-contiguous polygons.

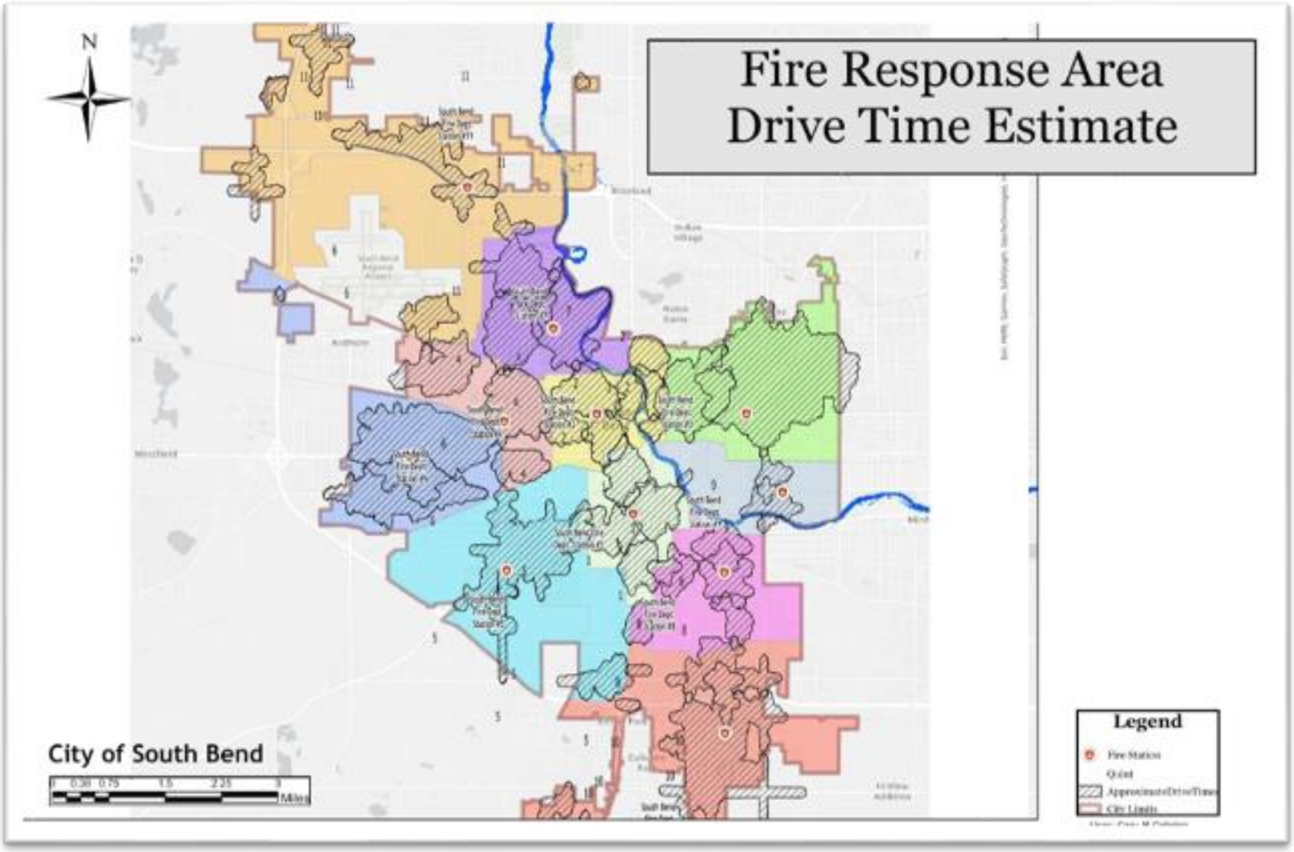


***Figure 2: The colored areas represent the 11 Fire Response Areas. The hatched marked areas represent drive time from the fire stations. This was created using the ArcGIS Pro Business Analysis tool > Generate Approximate Drive Times tool. The time of day is set to daytime, allowing for most traffic. None of the stations are projected to take more than the 6.31-minute minimum time to get to an alarm call.***

A hotspot map with the approximate drivetimes layer shows that most alarm calls are answered under a minimum of 6.31 minutes. (See *Figure 3*). The density of alarm calls is discussed more under the Analysis Conducted section.

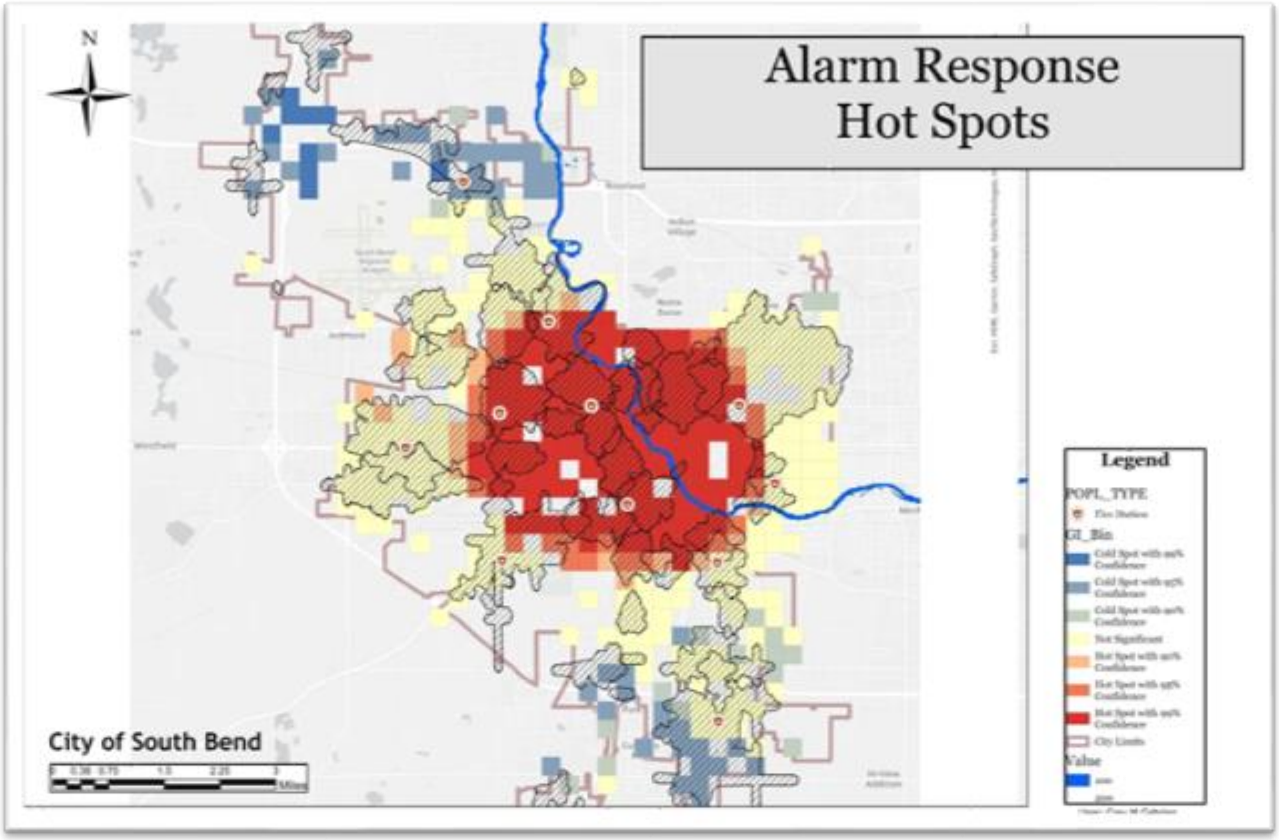


*Figure 3: The illustration displays the alarm calls layer using the GeoAnalytics Desktop Tool > Find Hot Spots. The hotspots were defined by bins that were 1320 feet square. The hatch marked area is the approximate drivetimes layer.*

None of the maximum drive times indicated in *Table 1* exceed the 6.31-minute minimum response time.

*Table 1: Drive Times as estimated by the ArcGIS Pro Generate Approximate Drive Times tool.*

| Max Approximate Drive times per Fire Response Area | |
|---|---|
| **Area** | **Drive Time** |
| **Fire Response Area 1** | **1.53 minutes** |
| **Fire Response Area 2** | **1.75 minutes** |
| **Fire Response Area 3** | **3.19 minutes** |
| **Fire Response Area 4** | **2.06 minutes** |
| **Fire Response Area 5** | **3.07 minutes** |
| **Fire Response Area 6** | **2.80 minutes** |
| **Fire Response Area 7** | **4.85 minutes** |
| **Fire Response Area 8** | **1.97 minutes** |
| **Fire Response Area 9** | **1.10 minutes** |
| **Fire Response Area 10** | **4.23 minutes** |
| **Fire Response Area 11** | **4.66 minutes** |
| **Average Reported Response Time in 2022** | **5.5 minutes*** |

*Note: The calculated statistical mean (average) is 2.87 minutes for the Approximate Drive Time Tool.

DATA

1. Files for the City of South Bend are included in Table 2.

***Table 2: Base Layer Information.***

| BaseLayers.lyr | | | | |
|---|---|---|---|---|
| **Name** | Type | Geometry Type | Used | Reason |
| **Addresses** | Feature Layer | Point | Yes* | Cluster analysis |
| **Centerline** | Feature Layer | Poly Line | Yes | Barriers/obstacles |
| **Structures** | Feature Layer | Polygon | No | N/A |
| **CityLimits** | Feature Layer | Polygon | Yes | Boundary |
| **Parcels** | Feature Layer | Polygon | Yes | Define property lines |
| **Hydrology** | Feature Layer | Polygon | Yes | Isolated the St Joseph River polygons only. |

*Note: Addresses are not identified for privacy. Source: City of South Bend 2022.

2. Files for South Bend Fire Department are included in Table 3.

***Table 3: SBFD Locations and Response Areas.***

| CoSBData.gdb | | | | |
|---|---|---|---|---|
| **Name** | **Type** | **Geometry Type** | **Used** | **Reason** |
| **CityLimits** | Feature Class | Polygon | No | Duplicate |
| **Fire_Response_Area** | Feature Class | Polygon | Yes | Define FD response areas |
| **FireStations** | Feature Class | Point | Yes | Locate current stations |
| **Source: City of South Bend 2022** | | | | |

3. Emergency Medical Services Calls:

The Excel spreadsheet, *Incidents Type w Address 2022*, was provided by SBFD, which retrieved it from INDHS. It is the EMS call center information regarding the fire and non-fire calls for 2022. It consists of the call type separated by INFIRS reference numbers (more details on this below), the addresses of the alarm calls, and the locations that the SBFD responds to. The physical addresses already existed in a .shp file geocoded to point data in ESRI ArcPro 3.1.0. This data was used to create a portion of the spatial aspect of the project. Specific fire call data spanning multiple years was requested from the SBFD, provided only the calls from 2022, which were quite significant; however, one year of data may not accurately represent the city over time.

4. NFIRS Reference Guide 2015

The guide uses a universally accepted set of numbers (Incident Numbers) to classify callout codes for the fire services in the United States. "These codes include the entire spectrum of fire department activities from fires to EMS to public service." (National Fire Data Center, 2015). The codes are divided into groups of like events. There are nine main category headings with multiple subcategories under each main one. The Incident Numbers begin at 100 and continue into the 900's. Detailed information can be found in Chapter 3, Section C: Incident Type of the *National Fire Incident Reporting System Complete Reference Guide*. For this project's scope, only the top nine fields are identified. These nine main categories are:

100-Fire. Includes fires out on arrival and gas vapor explosions (with extremely rapid combustion).
200-Overpressure Rupture, Explosion, Overheat (No Fire). Excludes steam mistaken for smoke.
300-Rescue and Emergency Medical Service Incident.
400-Hazardous Condition (No Fire)
500-Service Call
600-Good Intent Call
700-False Alarm and False Call
800-Severe Weather and Natural Disaster
900-Special Incident Type

Initially, the project would delineate between fire/non-fire calls; however, after evaluating the alarm calls, it seemed irrelevant to separate this information since the overwhelming number of calls are EMS medical alarms and not fire calls (INDHS, 2022).

## ANALYSIS CONDUCTED

Before conducting the analysis, the data collected needed to be cleaned and made acceptable for use with ESRI ArcPro 3.1.0

Data Collection:

The data was collected from as many sources as possible during the project. (See the Data section above for a detailed breakdown of data). The main criteria used to collect the data was a need for several spatially dispersed points (EMS call data) over a contiguous surface (Fire Response areas).

Data Cleaning:

The most complex data to clean was the EMS Call data. It needed to be organized in a way conducive to importing it into ESRI ArcGIS Pro. Also, to take a sample of the 24,078 alarm calls, an extra column was added and titled "Random Number." Then, using Excel's random number function, create a random number for every event. It sorted the column from smallest to largest. Then select the top 2,500 alarm calls, which were all now random. To ensure the sampling distribution of the sample size will represent the distribution of alarm calls at a 95% confidence level, there was a need to do some calculations. A sample of 2,500 alarm calls is taken from the population of the City of South Bend (103,353), for which the overall proportion that made alarm calls is 23.3% (0.223). The following formula determines the standard deviation to see if the Standard Deviation Rule applies.

$\sigma_{\hat{p}} = \sqrt{\frac{p(1-p)}{n}} = \sqrt{\frac{0.233\,(1-0.233)}{2{,}500}} = \sqrt{\frac{0.179}{2{,}500}} = 0.008$

$p = population\ proportion$

$\hat{p} = sample\ proportion$

$\sigma_{\hat{p}} = standard\ deviation$

$n = size\ of\ the\ random\ samples$

Since $np = 2{,}500(0.233) = 582.5$ and $n(1-p) = 2{,}500(1-0.233) = 1{,}917.5$ are greater than 10, so the Standard Deviation Rule applies. The probability is 95% that $\hat{p}$ falls within two standard deviations of the mean, between 0.233-2(0.008) and 0.233+2(0.008). Stated another way, there is roughly a 95% chance that the sample proportion will fall between 22.5% and 24.1% of the mean. The data still needed to be in a format that ArcPro recognized. The mighty Excel Spread Sheet was manipulated to easily import data as a comma-separated values (CSV) file and then converted into a table in ArcPro using the Conversion Tools > Excel > Excel to Table tool. The addresses still needed to be geocoded to point data. This was accomplished using the Geocoding Tools > Portal > Geocode Addresses.

The Fire Response Areas were converted to raster layers. The road layer was converted to a raster as well. The City of South Bend's centerline layer did not separate the roads into categories (e.g., major or minor). All streets would have the same value. The conversion was completed using the Conversion Tools – To Raster – Polyline to raster on the centerline layer. The river was not signally represented in a layer. The St. Joseph County GIS Department hydrology layer was utilized for the polygons that make up the St. Joseph River and then converted to a raster layer. The Reclassify Tool was then run, classifying the river with a value of 100 (difficult to drive across).

Then, the centerline and river layers were combined to make an "obstacles" layer. This was accomplished using the Combine Tool. Then once everything was combined, the Reclassify Tool was used, assigning the roads a value of 1 (very easy to travel), the river as 100 (very difficult to travel), and the land and all other data as 200 (impossible to travel) (Suárez, n.d.).

When the data was all clean and compiled, it was ready to begin analyzing. One of the first things to do was to determine if an area of the city showed that it was more challenging to serve than others. To do this, an evaluation of the Fire Stations concerning distance and driving time was conducted. For this task, the Spatial Analysis Tools > Euclidean Distance tool was used to make a layer for each of the 11 existing Fire Stations. The tool determines straight line distance concerning each cell's relationship to a Fire Station (ESRI, n.d.). Euclidean Distance operation gives the distance from each cell in a raster to the closest source. In *Figure 4*, the completed Euclidean Distance Map can be seen. The rings are in increments of 1 mile, and the 3D Analyst Tool > Contour List tool was used to show the distances better. There is an overlap at the one-mile point for nine of the eleven Fire Stations. This could indicate a gap in coverage for Stations in Fire Response Areas 10 and 11.

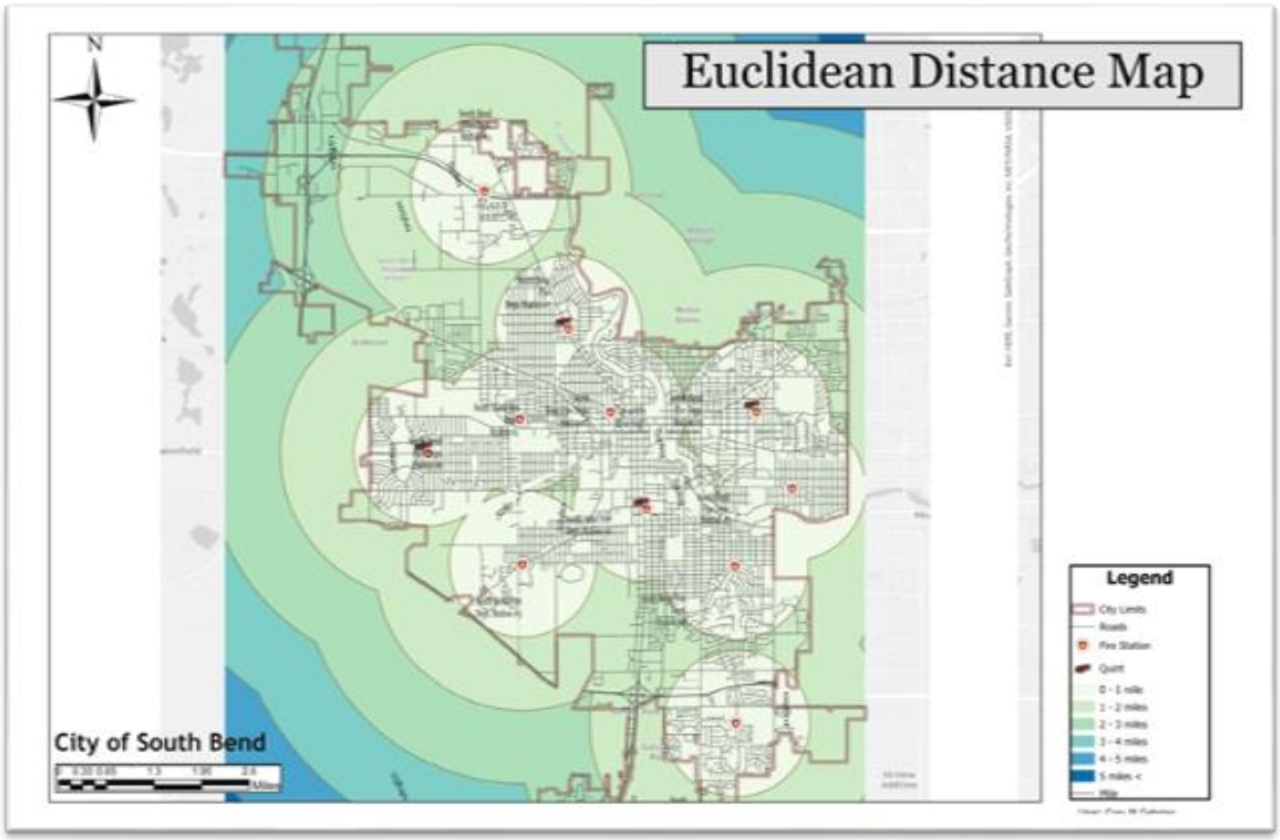


***Figure 4: The map above illustrates using the Cell Statistics Tool in the ESRI Spatial Analysis Toolbox. The Euclidean Distance is shown "as the crow flies" and does not assume any obstacles exist. The rings are in 6 equal interval concentric rings representing the distances from the sources. In this instance, the sources are the fire stations, and the rings are in 1-mile increments. Note that there is a gap for Stations 9 in the south and 6 and 11 in the north.***

While it is good to visualize the Euclidean Distance, other things can be gleaned using another Euclidean tool. Next, the Euclidean Allocation tool is used, which identifies the cells that are to be allocated to a Fire Station based on closest proximity (ESRI, n.d.). For this task, the Toolbox > Spatial Analysis Tools > Local > Lowest Position tool. This tool determined the effect of the Fire Stations on the other cells in the raster layer on a cell-by-cell basis. This observation shows what cells are spatially related to the Fire Stations. Looking at *Figure 5*, the information on the 11 known Fire Response Areas is overlaid on the Euclidean Allocation data to illustrate how they line up. Note that the Fire Service Areas align with the Euclidean Allocation in areas 1, 2, 3, 4, 5, 7, and 10. They are not a perfect match, but it is good to see that they closely resemble the existing boundaries. Some significant overlaps exist for areas 6, 8, and 11. This could indicate an area assigned too many or too few assets. There is not enough information yet to determine if this is relevant.

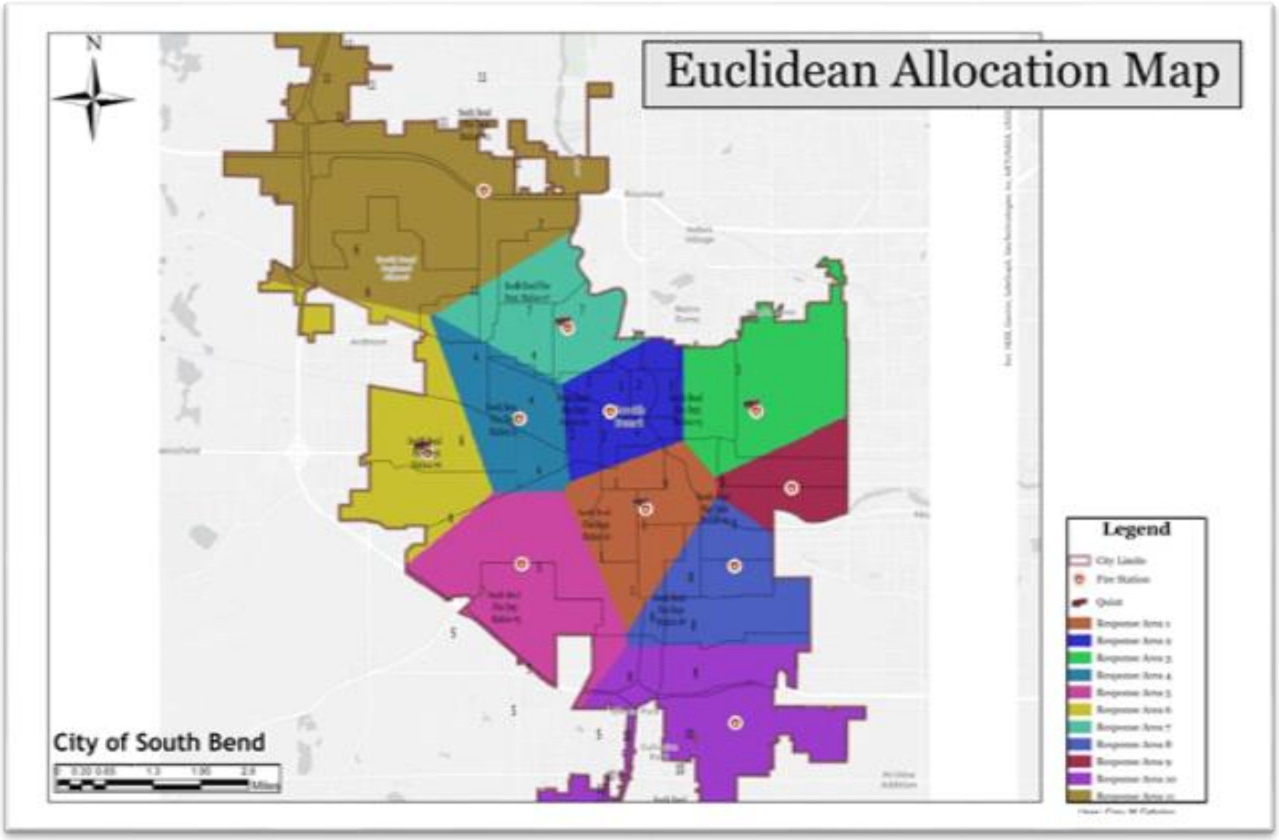


***Figure 5 shows a South Bend, IN map created using the Spatial Analysis > Lowest Position tool. The tool calculated the area that has the most influence on a point. The points used in this case represent the fire stations. The Fire Response Areas overlay this to show how closely (or not so closely) the allocation layer matches the existing areas*.**

CHALLENGES LIMITATIONS

As stated above in the Data portion, data was only available for the 2022 calendar year. Accessing other years of call data for a more accurate assessment would have been good.

Geocoding of the incidents costs ESRI Credits. Instead of trying to geocode 24,078 calls, some of which were duplicate addresses for calls made on different days or for other reasons, it was better to take the sample, import the sample data, then geocode that table. While doing the geocoding, the tool sorted out the duplications and had some addresses not inside the city limits boundary once plotted. The incidents outside any of the 11 Fire Response Areas were removed. This left a total sample size of 2,138 alarm calls.

RESULTS

Initially, the data was divided into fire/non-fire related incidents; however, it became apparent that there was no need to separate the data, as the nature of the call was not considered relevant to the study. The study evaluated roughly 10% of the 24,078 fire and Emergency Medical Services (EMS) calls from January 1st to December 31st, 2022. This sample yielded a margin of error of 2% at the 95% confidence level after the adjustment for calls responded to outside the service areas were removed. The new sample size of 2,138 randomly selected alarm calls is input to calculate the margin of error. Recalculated Standard Deviation is 0.009. Z-Score for a 95% confidence level is 1.96.

The Margin of Error= $1.96 * \frac{\sigma}{\sqrt{n}} = 1.96 * \frac{0.009}{\sqrt{2,138}} \approx 2\%$

It was anticipated that the data would illustrate the efficiency of the current fire service assets and show any gaps or overlaps in fire service coverage that can be addressed in the future. As illustrated in *Figure 4*, the Euclidean Distance calculator shows some possible gaps, but the Euclidean Distance Tool only shows straight line distance. The roads and the river were used as obstacles to better evaluate distance and drive time. *Figure 6* shows the resulting raster layer depicting the combined roads and river layers. A road width of 12 feet was used to set the cell size since most roads in the United States are 11 or 12 feet wide (US Army, n.d.).


***Figure 6: Depicts the combined roads raster layer using Spatial Analyst Tools > Map Algebra > Raster Calculator. The roads are weighed as 1 (easy to travel), the river is weighed as 100 (very harder to travel), and the open spaces are all the remaining cells with a weight of 200 (extremely hard to travel). The cell size for the roads layer is 12sq ft resolution. Note the open areas in the west and southwest of the city.***

The roads and the river, now being "obstacles," are evaluated using the Spatial Analyst Tools > Distance > Distance tool. This allowed a new distance analysis, considering the roads and the river in the equation. The Parameters used: Input Raster- Fire Stations, Input cost raster- Combined Roads and River, Output- Cost Distance Analysis. The rest were left to their default setting. The output raster (*see Figure 7*) now considers the value of the roads and river and their effect on the distance calculation.

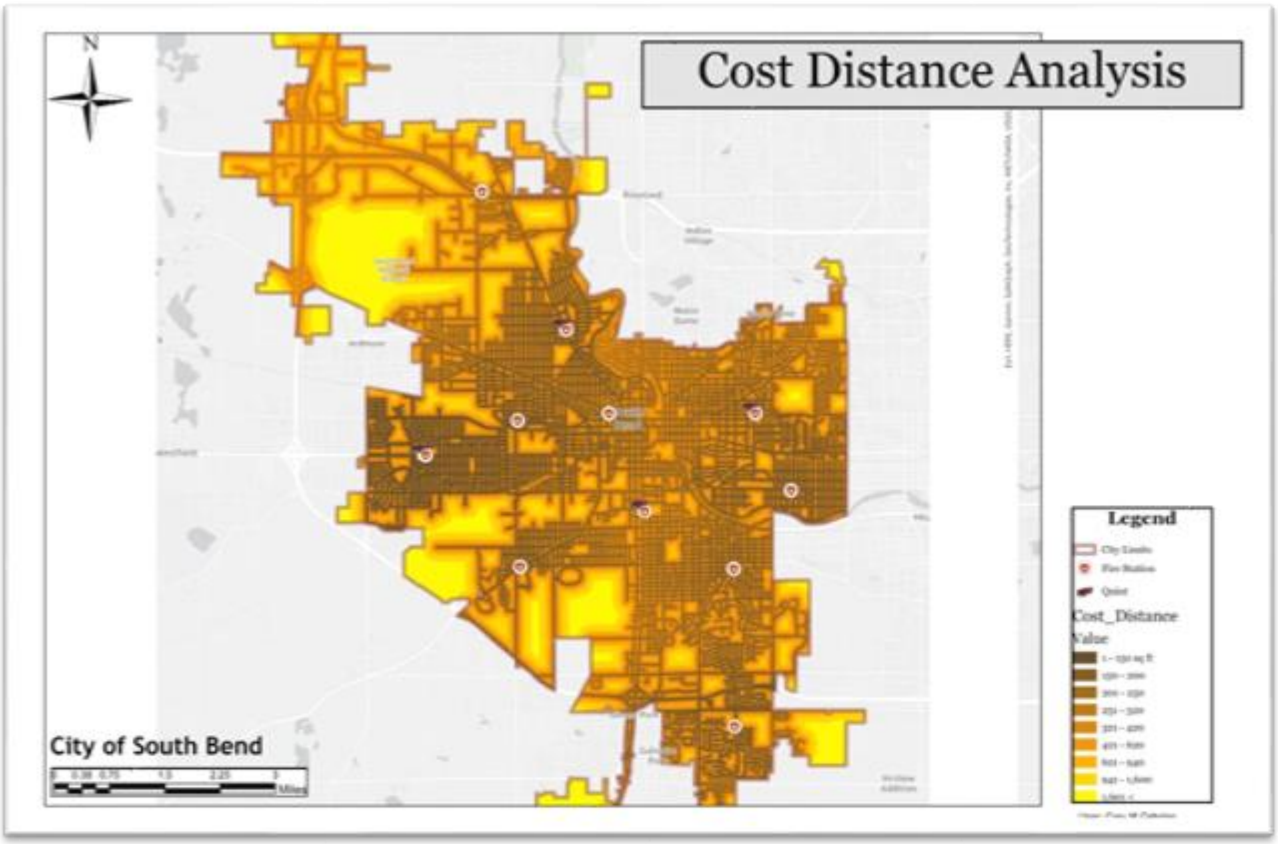


***Figure 7: Illustrates the combined roads and river raster layers using the Spatial Analyst Tools > Distance > Cost Allocation tool. The roads are weighted as 1 (easy to travel), the river is weighted as 100 (very hard to travel), and the open space is all the remaining cells weighed as 200 (extremely hard to travel). The cell size for the layer is set to 12 square feet. The Cost Distance is then shown in shades of brown through yellow. Darker brown is closer to the roads and quicker to respond to, bright yellow being the hardest to get to. The increments are 150 feet.***

The farther the fire department must travel from the station to an area, the more the travel cost. This is depicted in *Figure 7* as shades of brown (not much cost) to yellow (very high cost). This indicates a high travel cost in areas 5, 6, 10, and 11. The airport in Fire Service Area 11 is an anomaly and should not be considered because SBFD does not respond to calls at South Bend Airport.

According to what is known so far, Fire Service Areas 5, 6, 10, and 11 have the most cost burden on travel. Next, we need to see the alarm call volume in the identified areas.

CLUSTER ANALYSIS

First, since there were so many points in the EMS call data file (over 25,000), we made a random sample of 2,500 calls using the random number generation tool in Microsoft Excel. (See Cleaning the Data section above). The original locations (addresses) were geocoded and translated into x and y coordinates that will be used as control points. There were approximately 400 alarm calls that were outside the city limits; these were removed from the sample. The points were converted to a raster layer so they could be calculated. This data will be interpolated to generate approximations of the continuous phenomenon of the area.

Next, we applied the Spatial Analysis Tool > Kernel Density Tool to the alarm call layer. Kernel Estimation is a way to view the magnitude of events in a particular area as they occur over the surface. It provides a local estimate of the intensity of the alarm calls (Lloyd, 2010). The tools' Parameters were set to Input of the Random Alarm Calls layer. The population was set to None because we want each incident to be counted once. Since we are in standard units, square miles were used for the Area units. Output cells were left to Densities. The Input Barrier feature was the Fire Response Areas. This is because the focus should be on the areas that need a new fire station. The map in *Figure 8* depicts the magnitude of alarms in the Fire Response Areas. Note that of the Fire Response Areas looked at as possible candidates for a new fire station, Areas 5, 6, 10, and 11, only Fire Response Area 6 has significant alarm calls.

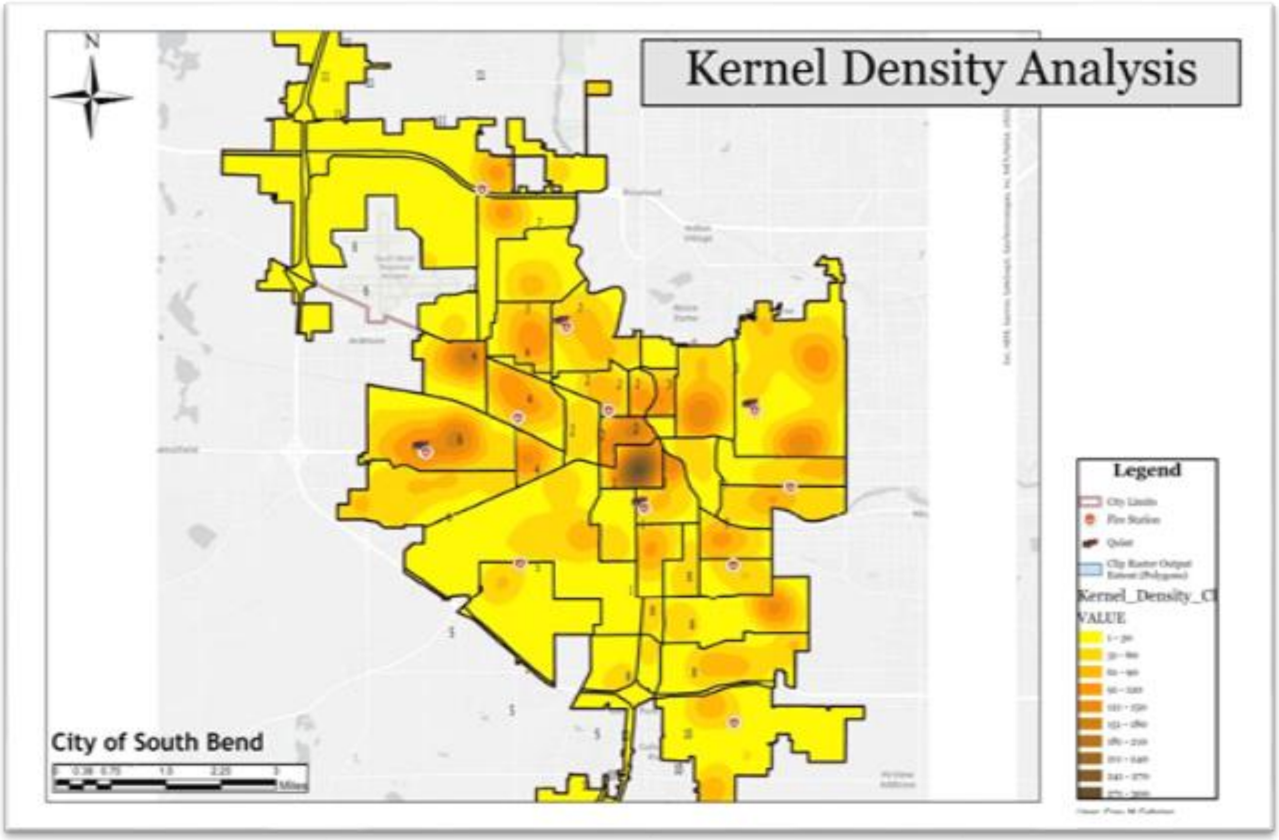


***Figure 8: The map illustrates the magnitude of alarm calls calculated using the Spatial Analysis Tool > Kernel Density estimation. It is divided into each Fire Response Area. The darker the color, the denser the alarm call volume. Yellow indicates 0 to 30 calls, and the color ramp advances in increments of 30 to the max is just over 300 calls in an area.***

This is good because now the focus is on Fire Response Area 6 as our candidate for a new Fire Station.

PUTTING IT ALL TOGETHER

According to the data, there appears to be a possible need in Fire Response Area 6. *Figure 9* illustrates Fire Service Area 6 with the current station and the Kernel Density Analysis. The incidents are overlaid to illustrate the pattern calculated from the sample. Observe the northwest noncontiguous portion where there were minimal alarm calls. Interestingly, the propensity of calls is near Station 6 and between 6 and Station 4.

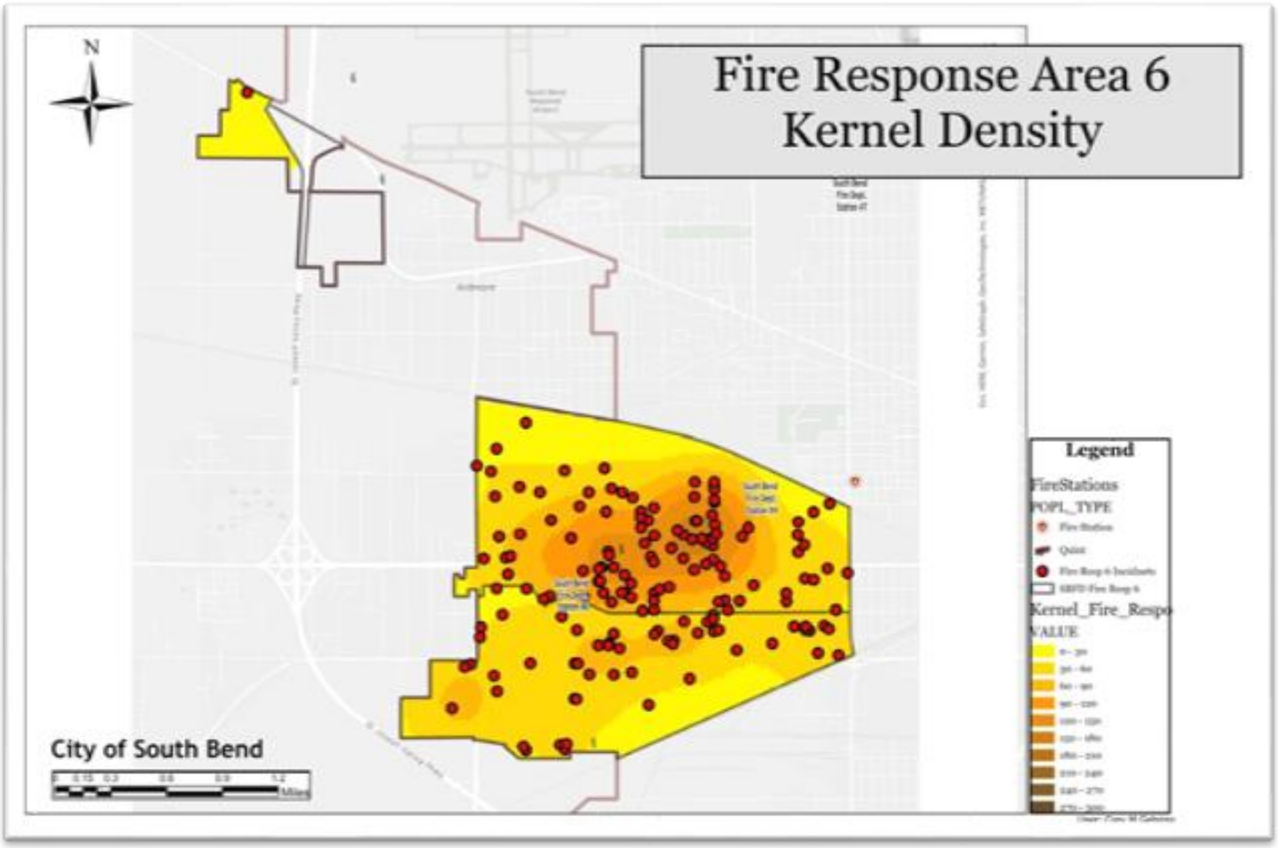


***Figure 9; The illustration shows the number of sample incidents (red dots) compared to the Kernel Density in Fire Service Area 6. The Kernal Density was calculated and displayed using increments of 30 alarm calls. The darker the color, the higher the call volume in that area. The cell size is set to 12'x12'.***

*Figure 10* depicts the Cost Distance Analysis for the same area. Since Fire Service Area 6 is divided into two separate areas, it was initially thought to benefit from a new station in the northern section; however, when assessed, the alarm call volume in that area was minimal.

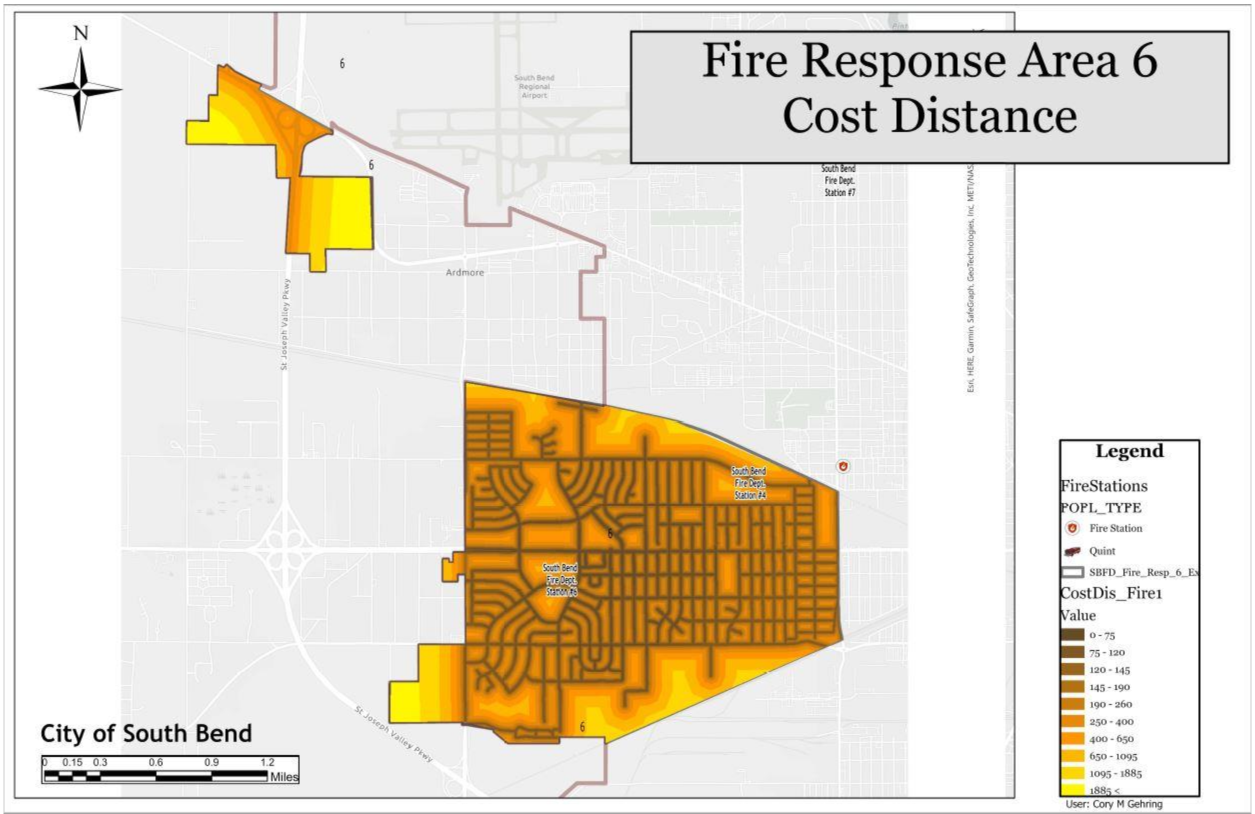


***Figure 10: This illustrates the Cost Distance Analysis. It can be noted that it is easier to travel on the roads. The more open areas or areas that are dense with structures are more challenging to get to. The cell size is set to 12'x12'. Note that it is still easier to get to areas close to the roads in the upper detached area than those out in the fields.***

## CONCLUSION

When the project was complete, the results did not identify any over-extended areas or indicate a need for a new station. While crude, the drive time analysis indicated that fire response times in all areas are predicted to be under the standards published by the NFPA in 95% of the calls. The data was limited to one calendar year, and that information initially indicated that Station 6 might be over-extended; however, once that area was focused on, it became apparent that Station 6 was not. The data does indicate a possible future need between Fire Response Areas 6 and 11. The maps in the figures above answer the questions proposed at the beginning,

- Is there an area of the city showing the SBFD being over-extended? No.
- If so, is there a need for a new fire station to be built? Not currently.
- If yes, what is the optimal location for the new fire station? Should one be needed, it should be located between Fire Response Areas 6 and 11, as the current information predicts.

This information, when presented, can help the city government decide if it needs to build a new fire station at this time or if it can wait to do it later. For a check on the analysis of the project, an inquiry was sent to the city fire service to indicate where they intended to build a new station when the time came. Interestingly, this analysis shows it would be built on the city's northwest side close to Response Areas 6 and 11. *Figure 11* indicates the parcel the city has picked out for the following station location though there are no plans to build it anytime soon.

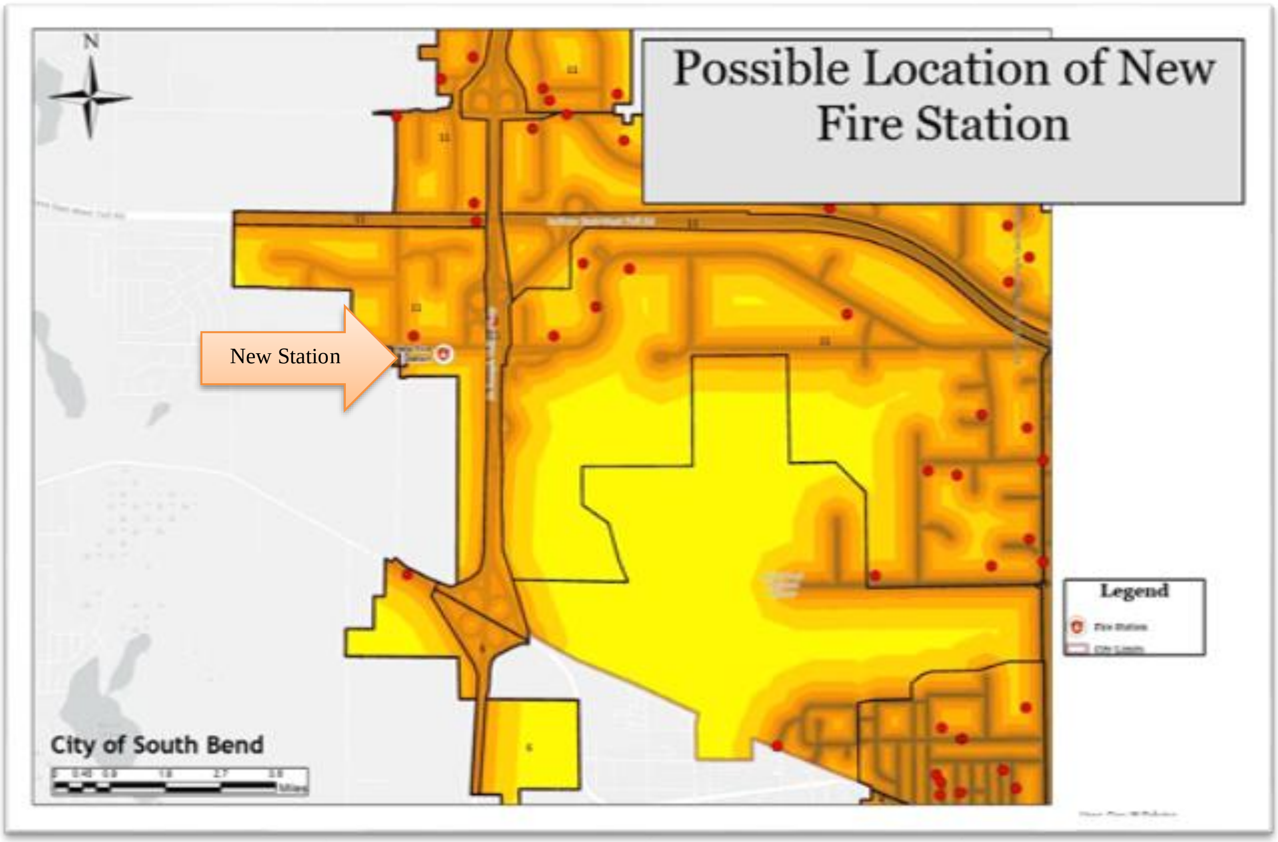


***Figure 11: The location of the proposed new station. This is very close to the area the data indicated had a possible gap in coverage. The bright yellow in the center of the map is the South Bend International Airport. SBFD does not respond to calls in that area.***

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