# Police Precinct Optimization: Using Distance as an Evaluation Metric

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***Abstract*—In 2017, Nashville metropolitan area experienced a 49% increase in Motor Vehicle Theft from the previous year. Prompt police response time is critical in the overall function of law enforcement agencies. Therefore, the location of a police precinct is a critical decision each local government must make. Using police incident data from Metro Nashville Davidson County, we evaluate the effectiveness of the current precinct locations based on how far each incident of crime is to its assigned precinct. We also explore the effect and possibility of relocating all precincts as well as redefining the precinct jurisdictions.**

***Keywords—crime analysis, Metro Nashville, K-means clustering, optimization***

## I. Introduction

Nashville, the capital of the state Tennessee, is one of the country's fastest-growing cities. In 2017, the Metro Nashville Police Department reported motor vehicle theft up 49.06 percent from 2016. Additionally, 33,848 incidents of crime were reported to the FBI Uniform Crime Reporting (UCR) program for 2017, resulting in an overall crime rate increase of 3.52 percent from the previous year.

| Incident Type | 2016 Incident Count | 2017 Incident Count | 2016-2017 Change (%) |
|---|---|---|---|
| Motor Vehicle Theft | 1,747 | 2,604 | 49.06% |
| Murder | 83 | 111 | 33.73% |
| Aggravated Assault | 4,934 | 5,072 | 2.80% |
| Robbery | 2,009 | 2,062 | 2.64% |

Table 1. Metro Nashville Davidson County Crime Rates - 2016 and 2017

Table 1 shows the top 4 incident types by 2016-2017 percent change. Each year, Tennessee state and local governments report crime statistics to the UCR program and the National Incident Based Reporting System (NIBRS). NIBRS defines an incident as one or more crime(s) committed by the same individual or group of individuals acting in concert at the same time and place [1].

With crime rates on the rise, it is important for police to respond to incidents quickly. In 1978, the Kansas City Police Department investigated the necessity of response time in criminal incidents. The department looked to find correlation of response time to a number of positive outcomes affecting citizen satisfaction [2]. Law enforcement quality is increasingly measured by citizen perceptions. In a separate Canadian study, researchers found that citizen perception of quality service was reflected by shorter response times [3].

Unfortunately, there is a large variation in the amount of time between a witness seeing a crime and reporting it [2]. Approximately 75 percent of crimes are reported after they have concluded; rendering rapid police response time useless [4]. However, as citizens become more satisfied with the effectiveness of their law enforcement, they become more likely to report a crime more quickly. If the time between crime discovery and crime reporting is decreased, police may be able increase the probability of arrest [5]. Therefore, rapid police response times in the 25 percent of crimes that can benefit from it can lead to a decrease in reporting delay, and thus better overall outcomes.

Numerous papers have studied the use of machine learning in the field of criminology. These studies can generally be categorized as either investigations into crime suppression or studies of criminal activity response [6-9]. One difficulty in analyzing crime is how quickly crime patterns can shift. Data mining and machine learning allows us to find hidden patterns and to adapt quickly to the evolving crime landscape. For example, Agarwal measured law enforcement's ability to respond to criminal activity using K-means clustering [10].

Most of these studies attempted to address the specific root cause or bias leading to criminal activity or unfair policing practices. While valuable in the field of criminology, the results discovered and the solutions they proposed in this manner require societal changes which are usually extremely slow. In this paper, instead of attempting to define any causes or reasons which may lead an individual to criminal activity, we explore approaches that can have a more immediate effect on crime by focusing on procedures instead of causes. In particular, we re-evaluate the current precinct jurisdictions and demonstrate that the distance from the precinct headquarters to a crime incident can be effectively shortened by realigning precinct jurisdictions. Reduced distance from the incidents results directly in rapid police response time, which is an increasingly important internal quality metric.

## II. Data Collection and Preprocessing

### A. Data Collection

The dataset used in this project was obtained via data.nashville.gov. The data represents incidents in Metro Nashville Davidson County in 2018. The data consists of 86,000 observations [11].

### B. Data Preparation

To adequately prepare the data for analysis, we followed a four-step process: (1) Remove any records with invalid or blank Latitude and/or Longitude; (2) Assign each incident with its current precinct location based on the Incident Zone; (3) Remove incidents in an 'Open' status; and (4) Extract one record per incident of crime.

In step (1), records with missing geographic coordinates were removed. One record contained coordinates of (0,0) was removed as well.

In step (2), each incident was mapped to its assigned precinct using the "Zone." A zone to precinct map was obtained from Metro Nashville Police Department website.

In step (3), incidents that were labeled as 'Open' were removed from the dataset. In order to protect privacy, 'Open' incidents are those missing specific location information, including the Incident Zone. Therefore, their current precinct could not be assigned. Without the current precinct information, these records cannot be used for later comparison and must be removed.

In step (4), duplicate records were removed. Duplicates are caused when one crime results in multiple crime types (i.e. Assault and Burglary). Since this analysis focuses primarily on geography, "Incident Occurred," "Incident Status", "Latitude," and "Longitude" were used to get distinct incidents.

After data preprocessing was complete, we were left with 36,966 incidents in 2018 for analysis. At the time of this research, Metro Nashville's official UCR crime rates for 2018 had not been published. The number of incidents we resulted in after our preprocessing seems to be reasonable, considering 33,848 incidents were reported in 2017 [1]. From this 2018 data, we found crime is up 9.21 percent from the 2017 official reported count.

## III. Current State Analysis

Metro Nashville Davidson County currently consists of 8 precincts. Fig. 1 below shows the current state of the precincts and their jurisdiction. While we know that most likely there will be a police patrol car closer to you than your assigned precinct location, in our analysis we treated the precinct as a worst case scenario, i.e., this would be the farthest an officer would have to travel to you in the event of an emergency. As the distance from the incidents correlates the police response time, here we minimize the distance from an incident of crime to its assigned precinct as a way to minimize response time.

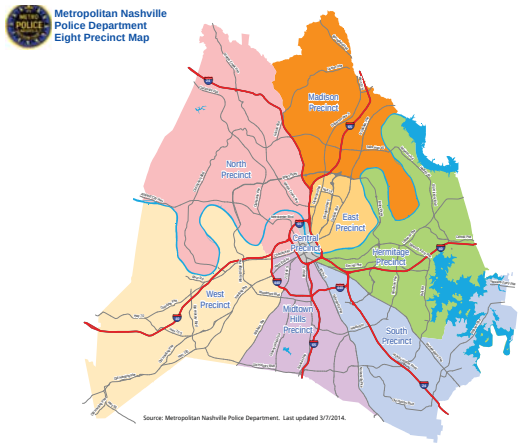


Fig 1. Metro Nashville Police Precinct Map [12]

To establish a baseline for comparison, we used the R (version 3.4.4) package *geosphere* to calculate the distance between each crime incident and its current precinct location. The output of the function *distm* was in meters and was converted to miles.

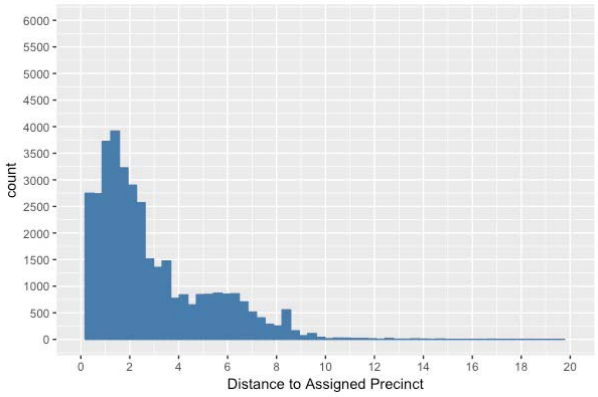


Fig 2. Distance from incident to assigned precinct, in miles (current state)

Fig 2 shows the distance (in miles) from incident to assigned precinct. It shows although many crimes occurred within three miles from precinct headquarters, which have not changed since 2014, quite a few occurred at the distance of 4-7 miles from precinct headquarters.

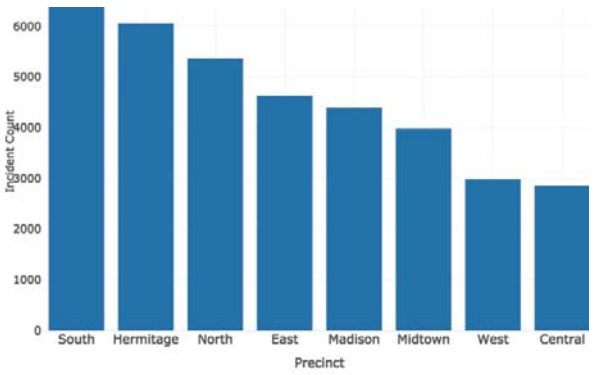


Fig 3. Count of incidents per precinct (current state)

The count of incidents per precinct is provided in Fig. 3. Unsurprisingly, the precinct with the least area of coverage (Central Precinct) has the lowest incident count. This graph does not take into account the number of citizens living in each precinct, as this information was not available to us at the time of this research.

## IV. Precinct Enhancement

### A. *K-Means Clustering*

As quite a few crimes occurred at the distance of 4-7 miles from precinct headquarters, as indicated in Fig. 2, we wonder whether the current precinct locations were reasonably placed based on the distance from an incident to its assigned precinct.

To answer this question, we use K-means clustering to perform clustering analysis. K-means segregates a large segment of data into k number of clusters by minimizing the sum of squared distances inside each cluster [13]. As an unsupervised machine learning method, it is more widely used than other clustering algorithms such as spectral clustering and hierarchical clustering due to its simplicity and efficiency. One noted disadvantage to using K-means is the requirement of selecting the number of clusters up front. For our application, however, this becomes trivial since we

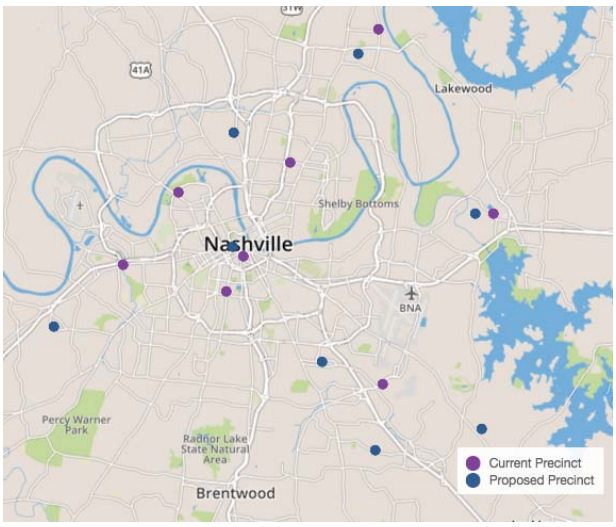


Fig 4. Map of K-means proposed precincts versus current precints

have already known the number of clusters: each current precinct will act as a cluster.

Using k = 8 to match the current police precinct count, we ran K-means on the incident data to see where the optimal locations of 8 precincts would be (Euclidian distance is used as distance measurement). The result of K-means is plotted in Fig. 4. From Fig. 4, we can see while many locations shifted drastically, the Central Precinct, Madison Precinct, and Hermitage Precinct are fairly close to the new locations found by K-means.

Then, we calculated the distance from incident to the precinct headquarters assigned by K-means and provided the result in Fig 5, which shows very few crimes now occurred within 5-7 miles from the K-means proposed headquarters.

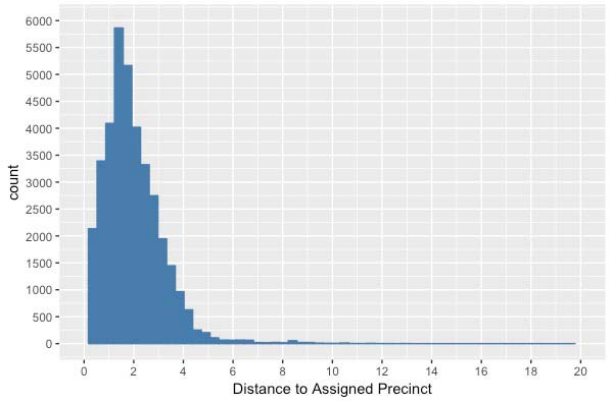


Fig. 5. Distance from incident to assigned precinct, in miles (K-means reassigned precincts and boundaries)

### B. *Redefining precinct jursidiction*

Due to the impractical nature of relocating precinct buildings, we next explored the possibility of redefining the precinct jurisdiction boundaries. This would leave the precinct headquarters where they are, but redefine the area they serve. We reassigned each incident to its new precinct by calculating the distance from said incident to each existing precinct location and choosing the precinct headquarters that was closest. The redefined precinct jurisdictions was plotted in Fig. 6.

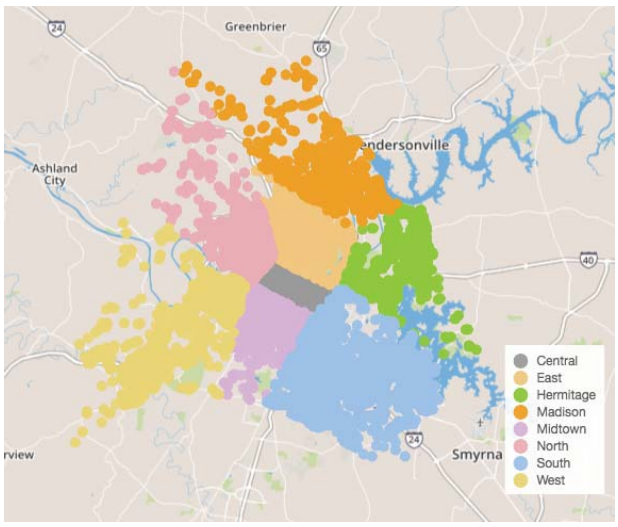


Fig. 6. Map of redefined precinct jurisdictions

Fig. 6 shows by redefining the boundaries, the central district became larger and the East district grew to split in between the North and Madison districts. The South precinct grew larger and shifted the Midtown precinct to the west.

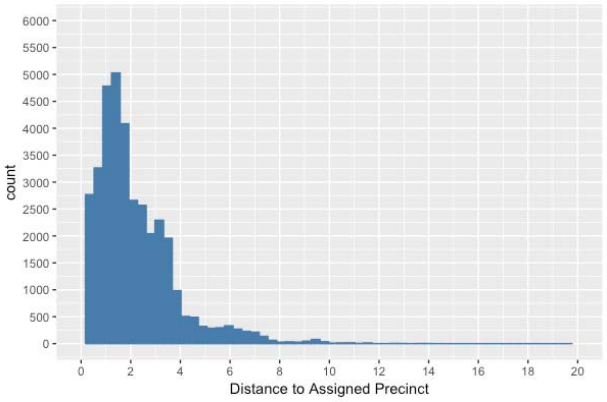


Fig. 7. Distance from incident to assigned precinct, in miles (redefined jurisdictions)

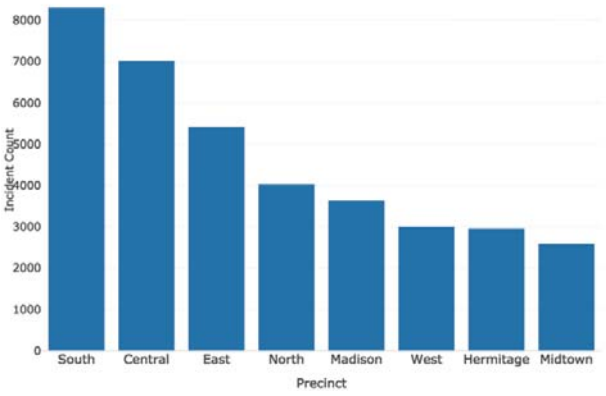


Fig. 8. Count of incidents per precinct (redefined jurisdictions)

Fig. 7 shows the distance from the incidents in the newly defined precinct jurisdictions to the precinct headquarters. We can see clear improvement over Fig. 2. Rredefining the jurisdictions, however, can potentially imbalance the incident count across the precincts, as suggested in Fig. 8.

### *C. Statistical analysis*

Fig. 9 and Table 2 below show the distribution of the distance from incident to precinct for the aforementioned three jurisdiction types.

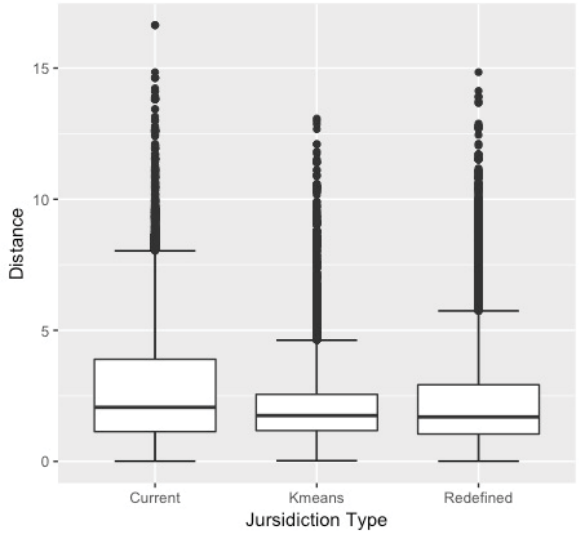


Fig 9. Boxplots of the distance (from incident to assigned precicnt) distribution for the 3 Jurisdiction types.

| Type | Median (miles) | Mean (miles) | Standard Deviation |
|---|---|---|---|
| Current | 2.063 | 2.780 | 2.249 |
| K-means | 1.748 | 1.968 | 1.190 |
| Redefined | 1.696 | 2.125 | 1.613 |

Table 2. Overview statistics of the 3 jurisdiction types

Using the Wilcoxon Signed Ranked Test for Paired Distributions, the comparison of the current state versus the redefined jurisdictions resulted in a p-value of less than $2\times10^{-6}$. The comparison of the current state versus K-means clusters also resulted in a p-value of less than $2\times10^{-6}$. Therefore, the saving in distance through K-means and the redefined boundaries is statistically significant.

## V. Discussion

This study seeks to improve law enforcement's capability to respond to crimes. Although crimes may occur for any number of reasons, we did not weight one crime as more important than another in our study. We did not consider important issues, such as criminal suppression, modification of criminal activity, and law enforcement's interaction with the public, either, which, however, are potential topics of future development.

For our k-means clustering algorithm, the Euclidian distance measurement may not be ideal. Further improvement may be achieved by using Manhattan distance and taking traffic data into consideration. In addition, a graph-theory based approach may be better suited to incorporate streets and viable driving paths into this work.

Based on our analysis, we recommend adjusting precinct jurisdictions to counter sharp jump in crime rates in Nashville metropolitan area in order to have rapid police response time. This method lowers not only mean response distance, but also standard deviation of distance.

For future development, normalizing jurisdictions by minimizing geographical distance may alleviate or uncover improper policing practices or biases in response time. Moreover, shifting away from a geographic model of determining precinct jurisdictions may also have additional advantages.

## Acknowledgment

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