Optimization Model Approach to Law Enforcement Police Officers Allocation in Los Angeles

Hannah Nguyen, Dong Dong

DA350 - Advanced Methods for Data Analytics

Dr. Bonifonte

Denison University

Abstract

This project focuses on addressing the pressing issue of allocating limited law enforcement resources to combat crime in the city of Los Angeles, which has experienced a significant increase in crime rates in recent years. We develop an optimization model using the Gurobi solver in Python, using data from reputable resources such as the Los Angeles Police Department and the United States government's open data portal. Our model incorporates crime weight estimation, constraints based on available resources, geographic distribution, and sensitivity analysis to determine optimal thresholds for police officer allocation. The results highlight the potential for optimization models to inform data-driven decision-making processes in public safety management, effectively allocating police resources in Los Angeles.

Overview

Optimization models have emerged as a powerful tool in addressing complex issues across various industries, including transportation, finance, and healthcare. These models have been widely recognized for their ability to maximize or minimize specific objectives while adhering to constraints, leading to more informed and efficient decision-making processes (Dantzig, 2003).

This project is inspired by the pressing challenge faced by law enforcement agencies in allocating limited resources to address the ongoing issue of crime. Los Angeles, a city grappling with an alarming escalation in crime rates, serves as a prime example of the urgency and significance of this challenge. In a recent high-profile debate featuring top candidates for Los Angeles mayor, Rick Caruso, a prominent billionaire businessman, underscored the severity of the public safety crisis in the city. Caruso stated, "Everyone in this city - in every corner of the city, regardless of where you live or your background - is afraid to walk out their doors". Further emphasizing the gravity of the situation, the Los Angeles Police Department reported a sharp increase in violent crime rates, with 206 homicides in 2022, representing a nearly 30% increment from 2020, and 779 shooting victims, marking a 43% rise from 2020 (Spectrum News 1, 2022). These alarming statistics not only reveal the dire state of public safety in Los Angeles but also underscore the urgent need for innovative solutions.

Given the complexities of factors influencing crime rates, it is critical to take a systematic and data-driven approach to better allocate police officers in a way that maximizes their impact on reducing criminal activities. A noteworthy study by Kaplan and Weisburd (2014) examined the impact of optimization in police patrol allocation using a randomized controlled trial, revealing the potential of optimization-based models to decrease violence and foster trust between police and communities. Considering these findings, our purpose is to create an optimization model that takes into account factors such as crime rates, geographical distribution, and available resources for the optimal allocation of police officers across Los Angeles in terms of maximizing crime coverage.

Methods

Data

1. Crime data sources and collections:

1.1. Crime dataset in Los Angeles:

Our crime dataset, Crime Data from 2020 to Present - Catalog, is collected from Data.gov, a reputable and reliable open website from the United States government that provides access to a wealth of datasets from various governmental agencies. This dataset contains crime reports from the city of Los Angeles dating back to 2020, which were transcribed from original crime reports typed on paper. Specifically, the crime data gathered includes critical information such as crime code descriptions and area names, laying the groundwork for our analysis:

- Crime code descriptions: For every reported crime, the police department assigns a corresponding crime description and code, providing information on the various types of crimes that have occurred. For instance, a crime assigned the code 624 is described as "Battery - Simple Assault".
- Area names: This data specifies the location of reported crimes, as defined by the divisions, such as Southwest, Mission, or Central, established by the Los Angeles Police Department. There are 21 distinct areas in total, which correspond to both the crime reporting zones and the police divisions within Los Angeles. We will determine the allocation of police officers across these 21 areas.

1.2. Four main types of crime:

As stated in Wikipedia's criminal law section, there are three primary levels of crime severity: felony, misdemeanor, and infraction, along with a fourth type, the wobbler, which can be prosecuted as either a felony or a misdemeanor depending on specific circumstances. Felonies represent the most serious criminal offenses, often encompassing violent acts or significant damage to people or property, with examples including murder, rape, and armed robbery. Misdemeanors are less severe than felonies, typically involving non-violent actions and carrying lighter penalties such as petty theft or simple assault. Infractions, the least severe criminal offenses, usually involve minor rule or regulation violations, such as traffic infractions, littering, and minor noise disturbances. This information allows us to classify crimes based on severity.

2. Police data sources and collections:

2.1. Los Angeles Police Department data:

We estimate the number of police officers needed in each Los Angeles neighborhood using data from the Los Angeles Police Department's website, https://www.lapdonline.org/ (LAPD Online), ensuring the information is accessible and derived from an official source. LAPD Online provides valuable information, including the Office of Operations divided into 21 divisions as stated above, and the population size for each area.

2.2. Ratio of police officers to citizens:

With population data for each area obtained from the LAPD website, we proceed to identify a suitable ratio of police officers to residents. The ICMA Center for Public Safety Management, a respected organization that serves local governments across the nation, suggests an average rate of 1.8 to 2.6 officers per 1,000 inhabitants. We will use this information to reasonably estimate the required number of police officers for each area.

2.3. Available resources of police officers in Los Angeles:

According to Wikipedia, regarding the Los Angeles Police Department, there are approximately 9,000 police officers in Los Angeles. We use this figure to estimate the number of officers available for allocation purposes.

3. Data preprocessing and cleaning:

Step 1: Classify each crime code description into the four types of crimes by consulting information from Wikipedia's criminal law resources. We then add a new column in the crime dataset called 'crime type' to associate each reported crime with its corresponding crime category.

Step 2: Estimate crime weight. We define crime weight as a numerical value assigned to each crime type, reflecting its relative severity and the potential demand for police officer resources in comparison to other crime types. This weight aims to allocate officers based on not only the number but also the estimated resources needed for a more optimized approach. Since infractions are the least severe offenses, which may only require one or two officers to address issues like noise disturbances, we assign them a weight of 1. Misdemeanors, being more serious, are assigned a weight of 2. Felonies, the most severe criminal offenses, which can involve a significant number of detectives, investigators, and other resources to handle cases, are assigned a much higher weight - 5. Wobblers, which can be charged as either a misdemeanor or a felony depending on the circumstances, are given an intermediate weight of 3 to reflect their variable nature. Acknowledging that these crime weights are estimated values rather than actual statistics, we will explore using different crime weights in our model to ensure a comprehensive analysis.

Step 3: Count the number of crimes of each type in each area by utilizing Pandas dataframe.groupby() function on area name and crime type column.

Step 4: Calculate the weight crime scores. We define weight crime score as the total number of each crime type in each area, multiplied by the assigned crime weight:

- Weight of each crime: Felony: 5; Wobbler: 3; Misdemeanor: 2; Infraction: 1

- The number of each crime in each area: X_i where X represents the area and i represents the crime type.
- Weight Crime Score in each area: $(X_f \times 5) + (X_w \times 3) + (X_m \times 2) + (X_i \times 1)$ where X represents the area, f, w, m, and i represents felony, wobbler, misdemeanor, and infraction crime type respectively.

Model Development Process

To develop our optimization model for assigning police officers to each police division based on the crime rate, we used the Gurobi optimization solver in Python. Here is how our model is built:

1. Data: We denote

- The minimum number of officers per 1000 residents is 1.8
- The maximum number of police officers available in LAPD is 9000
- D represents the list of 21 police divisions
- $p_i\ for\ i \in D$ represents the population of residents in the police divisions i
- $W_i\ for\ i \in D$ represents the weight crime score in the police division i

2. Decision variables: Our decision variable is the number of police officers assigned to each police division. We chose to model x_i as an integer variable because we cannot assign fractional police officers to a division.

$$x_i\ for\ i \in D:\ D\ represents\ the\ list\ of\ 21\ police\ divisions$$

3. Objective Values: Maximize the coverage of the crime rate by police officers assigned to each division. To achieve this, we formulated an objective function that is the sum of the crime rate prevented by police officers in each division. The crime rate was calculated by dividing the total weighted crime scores by the population of the division. The objective function can be expressed as

$$MAXIMIZE \sum_{i=1}^{D} x_i \times \frac{W_i}{P_i}$$

4. Constraints:

- The total number of police officers in each area can not exceed the total number of police officers available in the LAPD.

$$\sum_{i=1}^{D} x_i \leq 9000$$

- The number of police officers in each division must be higher than the minimum police rate in that division.

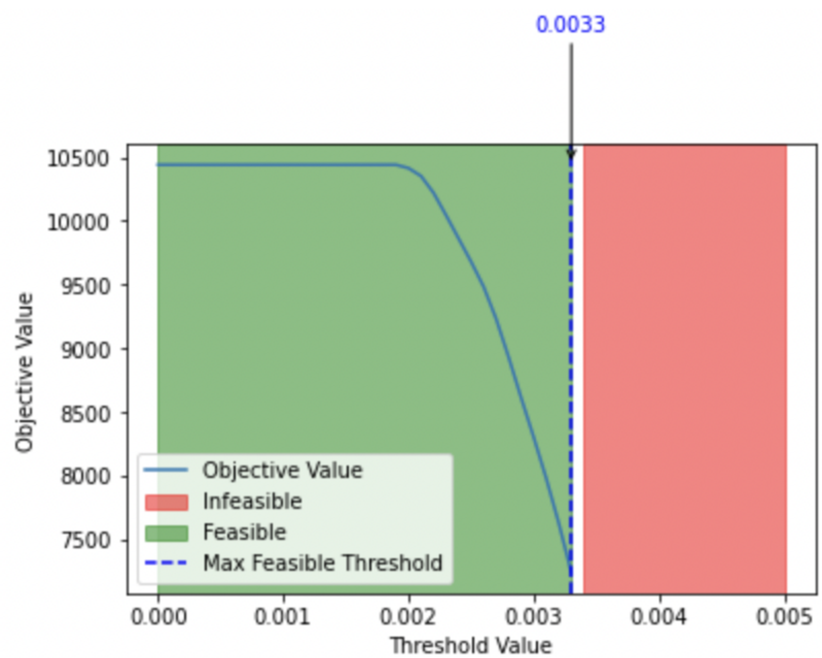
$$x_i \geq 1.8 \times \frac{P_i}{1000} \; for \; i \in D$$

- The number of police officers in each area must cover a certain number of weighted crime scores in that area. We add this constraint to avoid over-policing in a single area and distribute more equally.

$$x_i \geq threshold \times W_i \; for \; i \in D$$

To select the threshold for the total weighted crime score covered by police officers, we perform a sensitivity analysis. We start by graphing the objective value, the total crime rate covered by police officers in LA, versus the threshold value by running the model with different values of threshold. We then examine the graph to determine the threshold value that results in the maximum coverage of weighted crime score per police officer while still satisfying the other constraints.

Figure 1: *Threshold Sensitive Analysis for Main Model*



The graph shows that as the threshold value ranges from 0.002 to 0.0033, the objective value begins to decrease (refer to figure 1). This trade-off in the optimization model is reasonable because as we impose more strict constraints, we obtain a less optimal objective value. In this case, we aim to allocate police officers to the LAPD such that each area has a sufficient number of officers to cover a specific number of weighted crime scores. However, this results in a reduction of the total crime rate covered across all Los Angeles divisions.

To address this trade-off, our model selects a threshold value of 0.0033 that maximizes the coverage of weighted crime scores per police officer in each area while still satisfying other constraints. Here is how our new constraints are expressed in mathematical expression:

$$x_i \geq 0.0033 \times W_i \; for \; i \in D$$

Results

Here is a table illustrating how the model distributes the police officers to different divisions of LAPD. The proportion column is the number of police officers rates per 1000 residents in that area. This column tells us how many police officers are assigned to each division relative to the population size of that area. For example, in the "Central" division, there are 14.1 police officers per 1000 residents. The weight column is the number of weight crime scores covered in that area per police officer. This column tells us how effective the police officers are in covering the crime rate in each area. For example, in the "Van Nuys" division, each police officer covers 0.00412 weighted crime scores (refer to table 1).

Table 1: *Police Allocations Result from Optimization Model*

Area Name	Police	Proportion	Weight
Van Nuys	585.0	1.8	0.00566
Central	565.0	14.1	0.00338
Hollywood	540.0	1.8	0.00412
77th Street	533.0	3.0	0.00330
Pacific	463.0	2.3	0.00330
Wilshire	452.0	1.8	0.00394
Northeast	450.0	1.8	0.00427
Southwest	443.0	2.7	0.00330
Southeast	423.0	2.8	0.00330
West LA	411.0	1.8	0.00365
Newton	411.0	2.2	0.00331
N Hollywood	409.0	1.9	0.00330
Mission	407.0	1.8	0.00423
Olympic	400.0	2.9	0.00331
Devonshire	395.0	1.8	0.00403
Rampart	372.0	2.3	0.00331
Topanga	370.0	1.8	0.00378
Hollenbeck	360.0	1.8	0.00393
West Valley	355.0	1.8	0.00343
Harbor	328.0	1.9	0.00330
Foothill	328.0	1.8	0.00397

By analyzing the table, we can see how the model optimally allocates police officers to different divisions based on the given constraints and objective function. The model assigns more police officers to areas with higher crime rates and ensures that each division has enough police officers to cover the minimum police rate required. For example, in high-population areas such as ‘Van Nuys’ division or ‘Hollywood’ division, there are more police officers assigned to these areas with 585 and 540 police officers respectively. In areas with higher crime rates such as ‘Central’ division or ‘77th Street’, there are also more police assigned to these areas with 565 and 533 police officers respectively. However, the proportion of ‘Central’ division is significantly high with up to 14.8 police officers per 1000 residents. Overall, the result of the model provides insights into how to optimally allocate police resources to effectively combat crime in Los Angeles while considering the available resources and constraints.

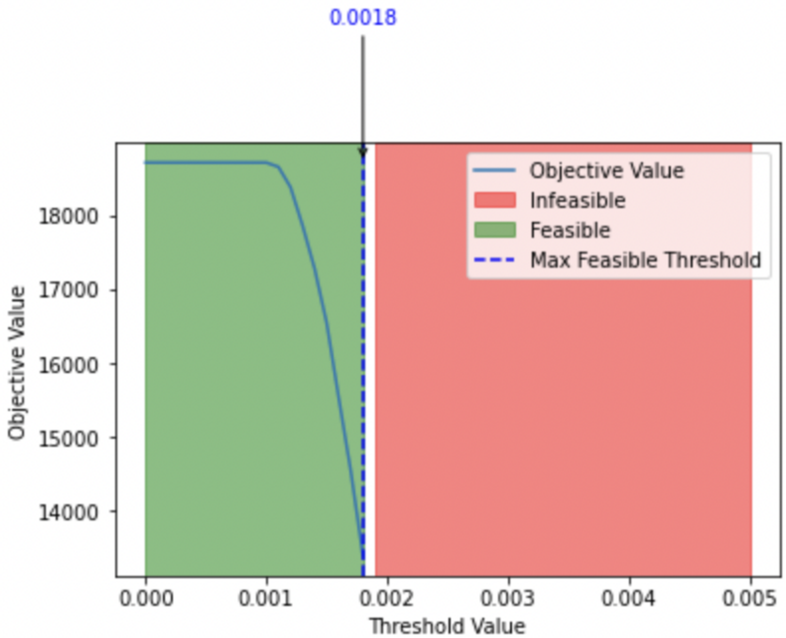
Model Exploration and Improvement

Based on the feedback provided from the presentation, we decide to explore more about the model and make some improvements so that we can choose different models for many crime situations and improve for more practical use.

Exploration Model 1

To explore the impact of crime weight estimation on our model, we decided to try a different weight for each type of crime. Initially, we estimated the weights for felony, wobbler, misdemeanor, and fraction crimes to be 5, 3, 2, and 1, respectively. However, we wanted to put more emphasis on felony and wobbler crimes and decided to adjust their weights to 10 and 6, respectively. This change in weight estimation might have a significant impact on the crime rate and the weighted crime score, and we wanted to see how it would affect the allocation of police officers to different divisions. As a result, we would need to update the constraints in the model, specifically the sensitive analysis to select the new value of the threshold.

Figure 2: *Threshold Sensitve Analysis for Exploration Model 1*



As expected in the model, when we put more weight into felony and wobbler crime, the crime weight in each area increases and as a result, the feasible threshold area also decreases to 0.0018 (refer to figure 2). Therefore, we will change one of our constraints to

$$x_i \geq 0.0018 \times W_i \, for \, i \in D$$

Exploration Model 2

Our project aims to explore sensitivity analysis to select a different threshold value for the constraint in our model. Initially, we chose the maximum feasible threshold value of 0.0033 based on our initial estimated crime weights to maximize the coverage of weighted crime scores per police officer and ensure each division achieves a minimum level of crime coverage. This approach allows for the effective allocation of police resources as criminal activities can change across different areas.

To examine how different threshold values affect our model, we selected a new reasonable threshold value of 0.0028, which falls within the range of 0.002 to 0.003 where the objective value begins to decline. Accordingly, we modified our constraints to

$$x_i \geq 0.0028 \times W_i \text{ for } i \in D$$

To avoid over-policing in areas with small populations and promote more equitable allocation of police resources, we introduced an additional constraint that limits the police officer rate per 1000 residents to no more than 15 police officers per 1000 residents. Mathematically, this is expressed as: $x_i \leq 15 \times \frac{P_i}{1000} \text{ for } i \in D$.

Comparison the results of different models

Table 2: *Results Comparison among Initial Model, Exploration Model 1, and Exploration Model 2*

Area Name	Initial Model	Model Exploration 1	Model Exploration 2
Van Nuys	585.0	585.0	585.0
Central	565.0	628.0	600.0
Hollywood	540.0	540.0	540.0
77th Street	533.0	532.0	913.0
Pacific	463.0	454.0	393.0
Wilshire	452.0	452.0	452.0
Northeast	450.0	450.0	450.0
Southwest	443.0	430.0	376.0
Southeast	423.0	420.0	359.0
West LA	411.0	411.0	411.0
Newton	411.0	409.0	348.0
N Hollywood	409.0	402.0	396.0
Mission	407.0	407.0	407.0
Olympic	400.0	388.0	339.0
Devonshire	395.0	395.0	395.0
Rampart	372.0	362.0	315.0
Topanga	370.0	370.0	370.0
Hollenbeck	360.0	360.0	360.0
West Valley	355.0	355.0	355.0
Harbor	328.0	322.0	308.0
Foothill	328.0	328.0	328.0

In the first exploration model, the results indicate that changing the weight of the crime does not have a significant impact on the allocation of police officers. The top four areas with the highest number of police officers remain the same, namely 'Central,' 'Van Nuys,' 'Hollywood,' and '77th Street.' However, there is a slight change in the allocation of police officers when the weight is increased, with the 'Central' division having the highest number of police officers assigned, with 628 police officers. This is likely due to the fact that the 'Central' area experiences more felony and wobbler cases, which increases the overall crime rate in this area. The model's results provide valuable insight into how police resources can be more effectively allocated in areas with high crime rates, particularly those with a high incidence of felony and wobbler crimes (refer to table 2).

In the second model, the results show that the number of police officers assigned to the 77th Street division is the highest with 913 police officers, which is around 300 police officers higher than the Central and Van Nuys divisions. This is due to the fact that the 77th Street area has the second-highest crime rate area, and after distributing police officers to every area to satisfy the constraints, the model allocates the remaining officers to the 77th Street area. However, it is important to note that the allocation of a significantly high number of police officers to a single area may not always be practical or feasible due to the dynamic nature of the crime. Therefore, it is essential to consider the value of the threshold when conducting exploratory analysis, and the maximum officer rate in the new constraints to modify the model to become more practically applicable (refer to table 2).

Discussion

In this project, we aimed to create an optimization model for the allocation of police officers across Los Angeles to maximize crime coverage, considering factors such as crime rates, geographical population, and available resources. Our results demonstrated that the model could effectively allocate police officers to different divisions with more emphasis on high crime rate areas while still remaining a minimum police officers rate per 1000 residents. By adjusting crime weights and performing sensitivity analyses on the threshold value, we explored various scenarios and provided valuable insights into different situations for police to allocate resources.

However, there are some limitations to our study. First, the crime weights assigned to different types of crimes are estimated and not based on actual statistical data. As such, the accuracy of the model may be affected by these estimations. Additionally, our model may not account for other factors that could impact the effectiveness of police resource allocation, such as the dynamic nature of the crime or socioeconomic. Furthermore, our model assumes that the number of police officers available remains constant and does not take into account possible changes in police force size or budget constraints.

Future research could address these limitations by incorporating more accurate crime weights, accounting for additional factors that influence crime rates and police effectiveness, and exploring dynamic models that can adapt to changes in available resources. Moreover, researchers could also consider applying this model to other cities or regions with varying crime rates, resource constraints, and other challenges. This would provide a more comprehensive understanding of the model's applicability and effectiveness in diverse contexts.

In conclusion, our project demonstrates the potential of optimization models in addressing complex issues such as crime and police resource allocation. By exploring various scenarios and adjusting model parameters, we can provide valuable insights and recommendations for law enforcement agencies seeking to maximize their impact on crime reduction. While there are limitations and areas for improvement, our study serves as a foundation for future research in this field and contributes to the development of innovative solutions for public safety.

References

Home of the Los Angeles Police Department. *LAPD Online*. Retrieved May 5, 2023, from https://www.lapdonline.org/

Kaplan, J., & Weisburd, D. (2014). Reducing violence and building trust through police optimization: a randomized control trial. *Policing: A Journal of Policy and Practice*, *8*(2), 163-173.

McCabe, J. (2023). An analysis of police department staffing: How many officers do you really need? *ICMA Center for Public Safety Management*.

Rector, K. (2022). How bad is crime in L.A.? Here are the numbers behind the mayoral race rhetoric. *Los Angeles Times*. Retrieved from https://www.latimes.com/california/story/2022-03-22/how-bad-is-crime-in-l-a-here-are-the-numbers-behind-the-mayoral-race-rhetoric.

Segundo, E. (n.d.). LAPD chief addresses rise in crime, violence. *Spectrum News 1*. Retrieved from https://spectrumnews1.com/ca/la-west/inside-the-issues/2022/07/27/lapd-chief-addresses-the-rise-in-crime-and-violence-in-l-a--county-.

Wikimedia Foundation. *Criminal law*. Wikipedia. Retrieved May 5, 2023, from https://en.wikipedia.org/wiki/Criminal_law#:~:text=Criminal%20law%20includes%20the%20punishment,than%20on%20punishment%20or%20rehabilitation.

Wikimedia Foundation. *Los Angeles Police Department*. Wikipedia. Retrieved May 5, 2023, from https://https://en.wikipedia.org/wiki/Los_Angeles_Police_Department.

U.S. Government's Open Data. *Crime data from 2020 to present*. Catalog. Retrieved May 5, 2023, from https://catalog.data.gov/dataset/crime-data-from-2020-to-present