Facilities Layout and Location Analysis based on Police Department Position in Dekalb, IL

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Abstract. The officers of Dekalb Police Department were aware of the high crime rate and they’re considering whether set up a new office or relocate the existing department to shorten the distance, also, ensure to reach the crime scene in super speedy. To select a more reasonable location, an essential assumption is that the current office will no longer associated with. Besides the existed office, geo-policing is not a necessary factor neither. Therefore, the police officers will work from the new location that we inferred and answer the incoming calls there. First thing first is to model it as a single facility location problem, and then, calculate by the Minisum model with rectangular distances as well as the Minimax model with tchebychev distances.

1. Introduction

There are a variety of aspects to be considered when deciding where to live. Such as education resources, city services, medical treatment conditions, religion, etc. However, the top priority should be security. Virtually all people want to live at safety community and be harmony with surroundings. This is also the reason we refer to crime rate in daily life. It also happens to when people looking for high quality university. The college town of Dekalb, Illinois would be a convinced example. The violent crime rate of Dekalb was 4.63, whereas the state rate was 4.29, and the national median was 4. Obviously, among the three, the violent crime rate of Dekalb is the highest. Meanwhile, the property crime was much higher than no matter the state rate nor national rate; A report by the analysts at NeighborhoodScout (2019), shows that Dekalb having a 34.03 rate, the state having a 20.11, and the national median being 24. If the crime index of Dekalb is 10, it means that it’s only safer than any 10% of other cities in US.

The officers of Dekalb Police Department were aware of the high crime rate and they’re considering whether set up a new office or relocate the existing department to shorten the distance, also, ensure to reach the crime scene in super speedy. To select a more reasonable location, an essential assumption is that the current office will no longer associated with. Besides the existed office, geo-policing is not a necessary factor neither. Therefore, the police officers will work from the new location that we inferred and answer the incoming calls there. First thing first is to model it as a single facility location problem, and then, calculate by the Minisum model with rectangular distances as well as the Minimax model with tchebychev distances.

2. Data

In order to gather data for this project, crime reports were used that were printed on the Daily Chronicle’s website representing true crimes that have happened in the neighborhoods of Dekalb, IL. These arrest reports can be seen in Table 1. The table was created using the information provided from the reports. The data represents six attributes about the individuals: name, age, location of arrest, city,
date, and charges. All of the attributes involved in this data set are not pertinent to how the problem will be solved. The attribute that will be the focus will be the location of arrest. Of these twenty reports, there are 19 unique arrest locations. The way to represent unique locations will be to assign weights to each location, the weights will represent how many arrests have happened at a location of arrest. For this data set, the points will either be assigned a weight of one translating to a unique location, or a 2 which would be a location with two arrests. The 1100 block of West Lincoln Highway will be the only arresting location with a weight of 2.

Table 1. Crime report data. (City of Dekalb, 2019a; 2019b)

| Report | Name             | Age | Block Address       | City       | Long Date                  | Charge 1                                      | Charge 2                                      | Charge 3                                      | Charge 4                                      |
|--------|------------------|-----|---------------------|------------|---------------------------|------------------------------------------------|------------------------------------------------|------------------------------------------------|------------------------------------------------|
| 1      | Stephanie D. Brown | 34  | 1500 Elmood Avenue  | Dekalb     | Monday, March 25, 2019    | warrant for failure to appear in court          |                                               |                                               |                                               |
| 2      | Adale Cross      | 25  | 1100 West Lincoln Highway | Dekalb     | Tuesday, March 26, 2019  | robbery                                       |                                               |                                               |                                               |
| 3      | Cornelius L. Haynes | 47  | 200 Augusta Avenue  | Dekalb     | Tuesday, March 26, 2019  | warrant for failure to appear in court          | obstructing identification                    |                                               |                                               |
| 4      | Juan C. Sanchez  | 36  | 1100 Varsity Boulevard | Dekalb     | Monday, March 25, 2019   | warrant for failure to appear in court          | domestic battery                              |                                               |                                               |
| 5      | Kearn S. Scott  | 25  | 800 Edgebrook Drive | Dekalb     | Tuesday, March 26, 2019  | warrant for failure to appear in court          | resisting a police officer                    |                                               |                                               |
| 6      | Marquita M. Seals | 24  | 2300 East Eves Circle | Dekalb     | Monday, March 25, 2019   | warrant for failure to appear in court          |                                               |                                               |                                               |
| 7      | Lindsey A. White | 27  | 300 College Avenue  | Dekalb     | Monday, March 25, 2019   | battery                                       | resisting a police officer                    |                                               |                                               |
| 8      | Aaron Yepiz      | 34  | 1000 West Lincoln Highway | Dekalb     | Tuesday, March 26, 2019  | warrant for failure to appear in court          |                                               |                                               |                                               |
| 9      | Jayann A. Young | 25  | 600 Glidden Avenue  | Dekalb     | Monday, March 25, 2019   | warrant for failure to appear in court          |                                               |                                               |                                               |
| 10     | Jasmine N. West  | 25  | 900 Spess Court     | Dekalb     | Thursday, March 28, 2019 | battery                                       | disorderly conduct                            |                                               |                                               |
| 11     | Katherine A. Korner | 31  | 900 North 14th Street | Dekalb     | Friday, January 4, 2019  | assault                                       | criminally trespassing on a residence          |                                               |                                               |
| 12     | Montrell T. Taylor | 18  | 800 Ridge Drive    | Dekalb     | Saturday, January 5, 2019| battery                                       |                                               |                                               |                                               |
| 13     | Monica L. Smith  | 30  | 800 Russell Road   | Dekalb     | Friday, January 4, 2019  | battery                                       | battery causing bodily harm                    | possession of marijuana                       |                                               |
| 14     | Madison H. Ricke | 19  | 1300 East Dreser Road | Dekalb     | Saturday, January 5, 2019| retail theft                                  | violation of liquor control act                |                                               |                                               |
| 15     | Steven Michael Pokorny | 24  | 300 Cloverleaf Court | Dekalb     | Friday, January 4, 2019  | domestic battery                              |                                               |                                               |                                               |
| 16     | Britney A. Rigs | 25  | 800 Greenbrier Road | Dekalb     | Friday, January 4, 2019  | warrant for failure to appear in court          |                                               |                                               |                                               |
| 17     | Terril L. Myers | 45  | 600 Ellwood Avenue  | Dekalb     | Saturday, January 5, 2019| warrant for failure to appear in court          |                                               |                                               |                                               |
| 18     | Montrell T. Taylor | 18  | 800 Ridge Drive  | Dekalb     | Saturday, January 5, 2019| warrant for failure to appear in court          |                                               |                                               |                                               |
| 19     | Brendan G. Elliot | 32  | 1100 Rushmore Drive | Dekalb     | Saturday, January 5, 2019| warrant for failure to appear in court          | unlawful possession of a controlled substance  |                                               |                                               |
| 20     | Michael C. Johnson | 49  | 1100 West Lincoln Highway | Dekalb     | Saturday, January 5, 2019| warrant for failure to appear in court          |                                               |                                               |                                               |

The locations need to be translated into usable data points to model this problem. The first step to translate the locations of arrest into data points that can be used is to input all locations into Google Maps. This provided an insight about the spread of the data. The next step was to take the addresses and turn them into a set of latitudinal and longitudinal data points, these are represented in table 2. This was done using a geocoding website, gps-coordinates.net. The origin, was provided by the Dekalb Police Department and will be considered as the intersection of Garden Rd and Lucinda Ave. Then to overlay the points on an aerial map, ArcMap was used. ArcMap is an imagery software developed by the Prairie Research Institute of University of Illinois Urbana-Champaign, the overlay can be seen in Figure 1 (2015). In order to get the points onto the map, the XY Event layer was used to overlay the points on the aerial map, which is a tool in ArcMap. An example of the XY Event Layer is shown in Figure 2. This has transitioned the location of arrests into latitudinal and longitudinal points overlaid on an aerial map.

Finally, the locations of arrests can be translated from geographic coordinate system into a project coordinate system. Geographic coordinate system is based off the curved surface, whereas the
projected coordinate system will be based off of a flat surface. Using a combination of the Project Tool and Calculate Geometry Tool in ArcMap the data points will be calculated using the projected coordinate system. When it is originally projected, it is provided with an absolute coordinate, since we are localizing to Dekalb, with the origin at (0,0) for Garden Rd and Lucina Ave, the absolute coordinate has to be augmented to a relative coordinate. The equations used for this are shown in equation (1) and equation (2). The complete data set can be seen in:

Table 4, this depicts all locations of arrests with their respective weights, along with the relative coordinates in relation to the origin.

![Table 4](image)

Table 4. Set of latitudinal and longitudinal points. (gps-coordinates.net, 2019) And Existing points. (Locations of Arrests)

![Figure 1](image)

Figure 1. Overlay of latitudinal and longitudinal points on aerial map.

Relative Coord \( X = (\text{Absolute Coord} \ A) - (\text{Original Coord} \ X) \) \hspace{1cm} (1)

Relative Coord \( Y = (\text{Absolute Coord} \ Y) - (\text{Original Coord} \ Y) \) \hspace{1cm} (2)
3. Minisum Model with Rectangular Distances

This problem involving a new building for the police department is being modeled as a single facility Minisum problem using rectangular distances. Rectangular distances make sense to be used because there are restrictions on how travel must occur. The restrictions are to follow the road networks. It can be acknowledged that travel distances should be minimized for reasons involving cost for responding to calls and response time. Calls can be considered as existing points that police officers must respond to with:

Table 4. Translated data set.

| Location | Latitude | Longitude | Absolute coordinate x | Absolute coordinate y | Relative x (m) | Relative y (m) | Weight |
|----------|----------|-----------|-----------------------|-----------------------|----------------|----------------|--------|
| 1        | 41.940575 | -88.7304088 | 266.767598 | 585.57909 | 3.6 | -0.5 | 1 |
| 2        | 41.930674 | -88.77806 | 263.115473 | 584.97371 | 0.0 | -1.6 | 2 |
| 3        | 41.934173 | -88.756596 | 265.063459 | 584.876176 | 1.9 | -1.2 | 1 |
| 4        | 41.943447 | -88.774123 | 263.449298 | 585.914377 | 0.3 | -0.1 | 1 |
| 5        | 41.946904 | -88.765921 | 264.131364 | 586.294881 | 1.0 | 0.2 | 1 |
| 6        | 41.952937 | -88.781794 | 262.818716 | 586.97173 | -0.3 | 0.9 | 1 |
| 7        | 41.933371 | -88.756041 | 264.943171 | 584.78771 | 1.8 | -1.3 | 1 |
| 8        | 41.93106 | -88.768733 | 263.889245 | 584.531431 | 0.8 | -1.5 | 1 |
| 9        | 41.925616 | -88.763147 | 264.349524 | 583.929274 | 1.2 | -2.1 | 1 |
| 10       | 41.94782 | -88.776163 | 263.280902 | 586.063472 | 0.2 | 0.0 | 1 |
| 11       | 41.936567 | -88.735585 | 266.641369 | 585.134504 | 3.5 | -0.9 | 1 |
| 12       | 41.948437 | -88.765919 | 264.132389 | 586.46515 | 1.0 | 0.4 | 1 |
| 13       | 41.941932 | -88.7681 | 263.947885 | 585.743556 | 0.8 | -0.3 | 1 |
| 14       | 41.943566 | -88.733003 | 266.859122 | 585.910879 | 3.7 | -0.2 | 1 |
| 15       | 41.92422 | -88.787089 | 262.365262 | 584.251144 | -0.8 | -1.8 | 1 |
| 16       | 41.94408 | -88.765931 | 264.128952 | 585.981224 | 1.0 | -0.1 | 1 |
| 17       | 41.925622 | -88.761759 | 264.464655 | 583.929364 | 1.3 | -2.1 | 1 |
| 18       | 41.948437 | -88.765919 | 264.132389 | 586.46515 | 1.0 | 0.4 | 1 |
| 19       | 41.947902 | -88.771429 | 263.675219 | 586.408048 | 0.6 | 0.3 | 1 |

Original 41.936384 -88.777993 263.124319 586.063472 0 0

Their services, these points can be seen in . Thus, locating a new building where it could best provide these services from. The modeling of the problem will be defined as shown in equations (3), (4), (5), and (3): Let f(x, y) be the location of the new police station. The objective function is:

Minimize f(x, y)

\[ f(x, y) = \sum_{i=1}^{m} w_i (|x - a_i| + |y - b_i|) \]  

4) \[ f_1(x) = \sum_{i=1}^{m} |x - a_i| \]

5) \[ f_2(y) = \sum_{i=1}^{m} |y - b_i| \]

6) \[ f(x, y) = f_1(x) + f_2(y) \]

First, for the x-direction, using equations (7) and (8), the x-slopes can be calculated. The x-slopes are shown in Table 5. The x-slope changes from nonpositive to nonnegative at x = 1. The optimal x coordinate is x* = 1.
\( f_1(x) = |x - 3.6| + 2|x - 0| + |x - 1.9| + |x - 0.3| + |x - 1| + |x - 0.2| + |x - 0.8| + |x - 3.7| + |x + 0.8| + |x - 1| + |x - 1.3| + |x - 1| + |x - 0.6| \\
\) (7)

\( f_1(x) = |x + 0.8| + |x + 0.3| + 2|x - 0| + |x - 0.2| + |x - 0.3| + |x - 0.6| + 2|x - 0.8| + 4|x - 1| + |x - 1.2| + |x - 1.3| + |x - 1.8| + |x - 1.9| + |x - 3.5| + |x - 3.6| + |x - 3.7| \\
\) (8)

Then for the y-direction, using equations (9) and (10), the y-slopes can be calculated. The y-slopes are shown in Table 6. There are multiple solutions for the optimal y-coordinate of the new police station: \( y^* \in [-0.5, -0.3] \). The optimal locations for the new police station are along the line connecting (1, -0.5) and (1, -0.3) because the slope here is 0. For the absolute coordinate are (264.124319, 585.563472) and (264.124319, 585.763472). The actual address of this location is between 607 Normal Rd and 801 Normal Rd. Along the street are private houses and Islamic Center of Dekalb. The map of the optimal address is shown in Figure 2.

**Table 5. x-Slopes.**

| x ≤ -0.8 slopes: -20 | 0.3 < x ≤ 0.6 slope: -8 | 1.3 < x ≤ 1.8 slope: 10 |
|-----------------------|--------------------------|--------------------------|
| -0.8 < x ≤ -0.3 slope: -18 | 0.6 < x ≤ 0.8 slope: -6 | 1.9 < x ≤ 3.5 slope: 14 |
| -0.3 < x ≤ 0 slope: -16 | 0.8 < x ≤ 1 slope: -2 | 3.5 < x ≤ 3.6 slope: 16 |
| 0 < x ≤ 0.2 slope: -12 | 1 < x ≤ 1.2 slope: 6 | 3.6 < x ≤ 3.7 slope: 18 |
| 0.2 < x ≤ 0.3 slope: -15 | 1.2 < x ≤ 1.3 slope: 8 | 3.7 < x ≤ 20 |

\( f_2(y) = |y + 0.5| + 2|y + 1.6| + |y + 1.2| + |y + 0.1| + |y - 0.2| + |y - 0.9| + \)

\( |y + 1.3| + |y + 1.5| + |y + 2.1| + |y - 0.1| + |y + 0.9| + |y - 0.4| + |y - 0.3| + |y + 0.3| + |y + 0.2| + |y + 1.8| + |y + 0.1| + |y + 2.1| + |y - 0.4| + |y - 0.3| \\
\) (9)

\( (y) = 2|y + 2.1| + |y + 1.8| + 2|y + 1.6| + |y + 1.5| + |y + 1.3| + |y + 1.2| + |y + 0.9| + |y + 0.5| + |y + 0.3| + |y + 0.2| + 2|y + 0.1| + |y - 0.1| + |y - 0.2| + |y - 0.3| + 2|y - 0.4| + |y - 0.9| \\
\) (10)

**Table 6. y-Slopes.**

| y ≤ -2.1 slopes: -20 | -1.2 < y ≤ -0.9 slope: -4 | 0 < y ≤ 0.2 slope: 10 |
|-----------------------|--------------------------|--------------------------|
| -2.1 < y ≤ -1.8 slope: -16 | -0.9 < y ≤ -0.5 slope: -2 | 0.2 < y ≤ 0.3 slope: 12 |
| -1.8 < y ≤ -1.6 slope: -14 | -0.5 < y ≤ -0.3 slope: 0 | 0.2 < y ≤ 0.3 slope: 12 |
| -1.6 < y ≤ -1.5 slope: -10 | -0.3 < y ≤ -0.2 slope: 2 | 0.3 < y ≤ 0.4 slope: 14 |
| -1.5 < y ≤ -1.3 slope: -8 | -0.2 < y ≤ -0.1 slope: 4 | 0.4 < y ≤ 0.9 slope: 18 |
| -1.3 < y ≤ -1.2 slope: -6 | -0.1 < y ≤ 0 slope: 8 | 0.9 < y slope: 20 |
4. Minimax Model with Tchebychev Distances

It must be made clear as to the definition of Tchebychev distances. Think of the connection between two points as the hypotenuse of a triangle. If the largest distance along the triangle, either side A or side B, is the Tchebychev distance. Now, taking the original data points set and converting into Tchebychev distances, a new set of data points arise. This is shown in Table 7. The map of these sets is shown in Appendix A.

Table 7. Minimax tchebychev parameters.

| xi  | yi  | u_i | v_i | w_i | h_i |
|-----|-----|-----|-----|-----|-----|
| 0   | 0   | 0   | 0   | 0   | 0   |
| 1   | 3.6 | -0.5| 3.2 | -4.1| 1   |
| 2   | 0.0 | -1.6| -1.6| -1.6| 2   |
| 3   | 1.9 | -1.2| 0.8 | -3.1| 1   |
| 4   | 0.3 | -0.1| 0.2 | -0.5| 1   |
| 5   | 1.0 | 0.2 | 1.2 | -0.8| 1   |
| 6   | -0.3| 0.9 | 0.6 | 1.2 | 1   |
| 7   | 1.8 | -1.3| 0.5 | -3.1| 1   |
| 8   | 0.8 | -1.5| -0.8| -2.3| 1   |
| 9   | 1.2 | -2.1| -0.9| -3.4| 1   |
| 10  | 0.2 | 0.0 | 0.2 | -0.2| 1   |
| 11  | 3.5 | -0.9| 2.6 | -4.4| 1   |
| 12  | 1.0 | 0.4 | 1.4 | -0.6| 1   |
| 13  | 0.8 | -0.3| 0.5 | -1.1| 1   |
| 14  | 3.7 | -0.2| 3.6 | -3.9| 1   |
| 15  | -0.8| -1.8| -2.6| -1.1| 1   |
| 16  | 1.0 | -0.1| 0.9 | -1.1| 1   |
| 17  | 1.3 | -2.1| -0.8| -3.5| 1   |
| 18  | 1.0 | 0.4 | 1.4 | -0.6| 1   |
| 19  | 0.6 | 0.3 | 0.9 | -0.2| 1   |

Solving for u: Calculate the gamma values using equation (10). Use \( u_i \) for each \( \alpha_i \). The Gamma values for \( u_i \) can be seen in Appendix B. Then, calculate the gamma values using the following equation (11). Use \( v_i \) for each \( \alpha_i \). The Gamma values for \( v_i \) can be seen in Appendix C. Solving for \( u^* \) and \( v^* \) is shown in Appendix D and Appendix E, respectively. The optimal location for the new police station is (0.85, -0.75). The absolute coordinate that relates is (263.974319, 585.313472). The physical address of this location is 518 Russell Rd, DeKalb, IL which is shown in Figure 3.

\[
Y = \frac{w_j x_j (\alpha_i - \alpha_j) + w_j h_j + w_j h_j}{w_j + w_j} \tag{11}
\]
5. Conclusion

After solving for the new location of the building for the Dekalb Police Department, it was found that both models came up with very similar optimal locations. The Minisum model provided several answers along a stretch of private houses located at 607-801Normal Rd. Once selected, the police department would have to purchase one of the private houses. The Islamic Center of Dekalb could then be ignored as an option as this would be a protected location. In other words, this answer provides a better probability for a private address to be purchased. Whereas the Minimax model provides just one solution, which is a private address located at 518 Russell Rd, but the owner will be the key point, that will lead the trends to highly costs instead of being a likely valid location any longer. However, since the solutions are relatively located in a small radius, it is possible for the decider to consider all locations as a possible future location for the Dekalb Police Department. It would be recommended that Dekalb Police Department consider both the Minisum and the Minimax solutions giving more choices for the new building.

6. Acknowledgments

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References
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