Parking Site Selection: A Case Study

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Abstract

Parking lot selection is a necessary resource for people who are driving to a restaurant, mall, or businesses center. The main objective in parking lot selection is finding the most suitable parking lots meeting the desired conditions defined by various criteria. A geographic information system (GIS) provides a valuable platform for spatial decision support, including the ability to capture, store, query, analyze, display, and derive geographic information. GIS is also compatible with other decision support methods such as multi-criteria decision-making. A synergistic effect is generated by combining these methods with the GIS technology, enhancing the efficiency and quality of spatial analysis for parking lot selection. This paper explores a process for parking lot selection around the Macy's department store located in downtown Minneapolis, Minnesota.

Introduction

Transportation is a rapidly growing field that plays an important role in people's daily life. This is especially true for the Downtown West neighborhood in Minneapolis, Minnesota, where many shopping stores, office buildings, and servicing locations are located. Macy's, established in 1858, is a U.S. department store, with a location in the Downtown West neighborhood. More than one hundred parking lots are in the neighborhood near Macy's.

Rapid growth of cities and use of vehicles has increased problems in urban transportation systems; therefore, appropriate parking lot selection is more important than before (Diallo, Bourdeau, Morency, and Saunier, 2015). Suitable site selection for public parking spaces not only increases parking efficiency, but it also decreases road congestion and thus increases available street width and traffic fluency (Ghaziasgari, 2005; Karimi, 2006).

Some have studied the parking lot selection question, and their research offers parking lot companies an effective way to supervise and manage their parking lots. For example, Lee, Kim, and Yang (2002); Liu, Lu, Zhou, and Li (2006) proposed a parking guidance information and management system based on Internet, cellular phone, and GIS technologies, which would provide effective parking information distribution, integration with traffic information systems, and spatial data analysis capabilities.

Parking site selection is important for people who want to go shopping. In order to optimize parking lot selection and minimize the traffic queues, the integration of a multi-criteria decision method and GIS spatial analysis is proposed to offer customers parking consideration options.

This paper used GIS spatial overlay methods to analyze the parking lot selection in the Downtown West neighborhood in Minneapolis with a case

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study application applied to Macy's department store. Such methods made it possible to evaluate parking site priorities, reconcile conflicting priorities, and finally display appropriate parking lots.

Methods

Study Region

The Downtown West neighborhood of Minneapolis is the study region for this study. Its boundaries are as follows: 12th Street to the southwest, 3rd Avenue North, Washington Avenue North, and Hennepin Avenue to the northwest, the Mississippi River to the northeast, and Portland Avenue and 5th Avenue South to the southeast as shown in Figure 1.

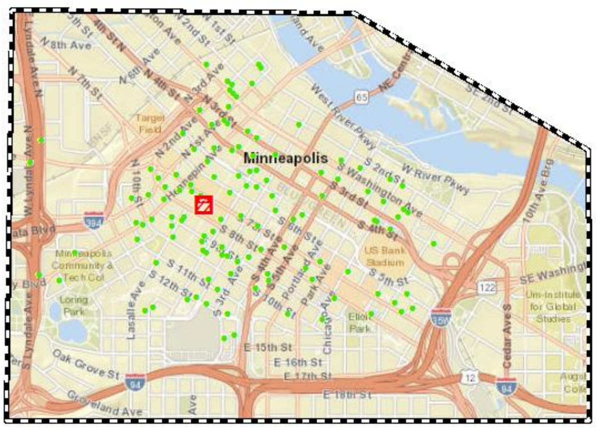

Figure 1. Study area in downtown West Minneapolis. The red point represents Macy's location; green points represent parking lots.

Data Needed for the Study

Many factors affect customers' parking lot selection. Quick access to Macy's is the main factor for analysis; people are not content spending a long time in traffic, so traffic congestion also needs to be taken into consideration for parking lot selection (Farzanmanesh, Ghaziasgari, and Abdullah, 2010). Civil engineering and traffic experts have indicated that distance from major roads and distance from the destination are important criteria (Ghaziasgari, 2005). Thus, the distance from the parking lot to Macy's was considered a critical factor most people would consider before choosing a parking lot. The third criterion for parking lot selection was the financial cost of parking. In this study, road congestion, distance to Macy's, and cost of parking were the three criteria analyzed.

From Monday to Saturday, Macy's opens at 10:00 AM and closes at 8:00 PM, open ten hours each day. On Sunday, the hours change to 12:00 PM to 6:00 PM. In this study, the ten-hour time period for Monday through Saturday was considered.

One hundred and eleven parking lots were chosen for this analysis, all located in the Downtown West neighborhood around Macy's. Each parking lot has their own parking policy and cost varies depending on the time of day and duration of stay. The average parking rate for one hour at each parking lot was used for analysis.

Addresses for Macy's store location and parking lots were used with road network data to obtain accurate point locations representing each analysis target. Bestparking.com offered addresses of the one hundred eleven parking lots for this analysis. The Minnesota Department of Transportation provided the road network data for the Downtown West neighborhood of Minneapolis. Parking lot addresses were also used to determine the straight-line distance from their location to Macy's.

ArcGIS Online includes a valuable set of ready-to-use content. The Live Traffic Map is one of the ArcGIS Online resources that can be used for visualization and query. The Live Traffic Map covers large parts of the world and is updated every 5 minutes with the latest available data. In the map, traffic speeds are separated into four levels: green, yellow, orange, and red. Each color represents a different percentage of free-flow speeds. The ArcGIS map service provides views of the past and current traffic congestion. One month (September 20, 2016 to October 20, 2016) of traffic information in Downtown Minneapolis from 10:00 AM to 8:00 PM each day was observed. The average traffic congestion of each road segment in the study area in that time period was used for this study.

Process Overview

The process for determining the suitable parking lot selection was divided into three steps. First, data for each criterion was classified and ranked into different suitability categories. The numbers 1, 2, 3, 4, and 5 represented the level of suitability, with 1 as the best option and suitability decreasing as the number increased. Second, analytic hierarchy process (AHP) was considered for weighting parking lot criteria. AHP is used to decompose the decision into a hierarchy of sub-problems. Decision- makers systematically evaluate criteria by comparing them to each other two at a time (Saaty and Peniwati, 2008). Last, Esri's ArcMap was used for analysis.

Classifying and Ranking the Criteria

Distance to Macy's

The ArcGIS Measure tool was used to calculate the straight-line distance from Macy's to each parking lot. The minimum distance found was 90.57 meters and the maximum distance was 2213.27 meters. For equitable distribution, distances were divided into five equal intervals and classified into five suitability categories. The category interval (r) was acquired using equation (1), where *n* represented the number of categories and *r* represented the interval between the five categories.

$$\mathrm{r} = \frac{max\ distance - min\ distance}{n} \quad (1)$$

Equation (2) calculated the maximum distance (*f*) for each suitability score. Table 1 displays the maximum distance for each of the five suitability categories.

$$f = max\ distance - r \quad (2)$$

Table 1. Maximum distance for each of the five suitability categories. Suitability category 1 includes values starting with the minimum value of 90.57 meters between a parking lot and Macy's to a maximum distance of 515.10.

Distance Categories	Distance (meters)
1	515.10
2	939.64
3	1364.18
4	1788.73
5	2213.27

Second, the ArcGIS Multiple Ring Buffer tool was used to delineate and classify the five distance categories using the values in Table 1 (Figure 2).

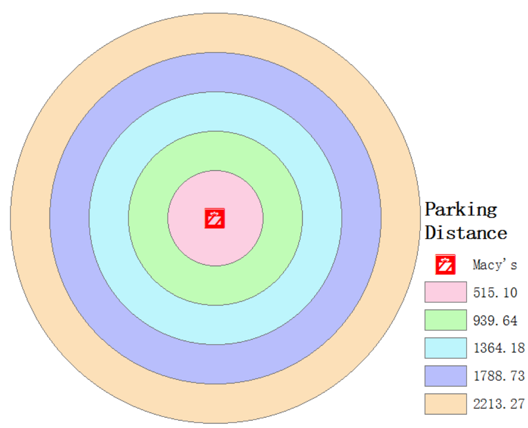

Figure 2. With Macy's at the center, each color represents a different parking suitability distance (meters) as shown in the legend. For example, the pink color represents a distance within 515.10 m of Macy's. Light orange color represents parking lots within 1788.73 to 2213.27 m of Macy's.

Parking Cost

After collecting and analyzing the parking lot rates data, the ArcGIS natural breaks method was applied to classify the rates into five suitability categories. The natural breaks method is a data clustering method designed to determine the best arrangement of values into different classes and was created by George F. Jenks (1967). This method was used for minimizing each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other groups. Most of the parking lot rates were nine dollars or less for one hour; however, several parking lot rates were between fourteen and twenty-one dollars (Figure 3). The natural breaks method was well suited for the rates data because of the data's high variance and the classification's accurate representation of the trends in the data (McMaster, 1997).

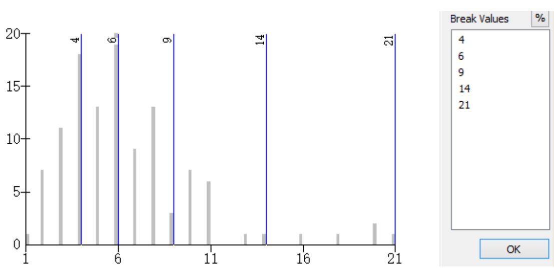

Figure 3. Parking rate suitability categories (divisions shown in blue). Category 1 represented parking rates from zero dollars to four dollars; 2 represented four dollars to six dollars; 3 represented six dollars to nine dollars; 4 represented parking rates from nine dollars to fourteen dollars; and, 5 represented parking rates from fourteen to twenty-one dollars.

The ArcGIS Field Calculator was used with the parking rate suitability categories (Figure 3) to calculate and classify rate data into five levels (Figure 4). The rate categories are symbolized in Figure 5.

Road Congestion

Road congestion was observed from 10:00 AM to 8:00 PM each day for one month from September 20, 2016 to October 20, 2016.

```
Reclass(!charge!)
def Reclass(ParkingRate):
  if (ParkingRate<=4):
    return 1
  elif(ParkingRate>4 and ParkingRate<=6):
    return 2
  elif(ParkingRate>6 and ParkingRate<=9):
    return 3
  elif(ParkingRate>9 and ParkingRate<=14):
    return 4
  elif (ParkingRate>14):
    return 5
```

Figure 4. Python function used to classify the parking rates.

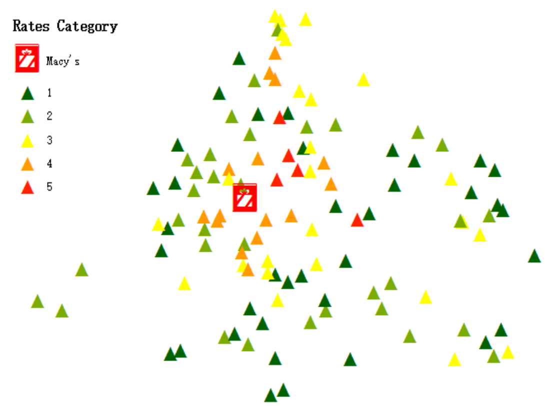

Figure 5. Rate categories symbolized by color. Green triangles represent the lowest price and red triangles represent the most expensive price.

The road congestion values were divided into four classes according to the symbology used on the traffic map, and these four classes were assigned numbers to represent their level of suitability. Green, representing fast speeds of approximately 85-100% of free flow speeds, was assigned the value 1. Yellow, representing moderate speeds of approximately 65-85% of free flow speeds, was assigned value 2. Value 3 was assigned to orange segments, representing slow speeds of 45-65% of free flow speeds. Red, which represented stop-and-go traffic of 0-45% of free flow speeds, was assigned the value 4. The road congestion values were based on the average congestion observed for each segment during the time period described above.

Parking Lot Selection Criteria Weighting

After assigning scores to individual criteria values, AHP was evaluated for weighting parking lot selection criteria. Weights can be calculated individually or based on an evaluator's judgment. Based on personal assessment and lack of literature justifying weighting some criteria more than others, the three factors were assumed to hold the same significance, so no weights were applied to the three criteria (Table 2).

Table 2. Final suitability classes for each criterion. The number 1, 2, 3, 4, 5 represented the level of suitability. The lower the number, the better the suitability.

	Distance	Rates	Road Congestion
Good to Bad Suitability	1	1	1
	2	2	2
	3	3	3
	4	4	4
	5	5	

Using ArcMap to Analyze and Display Data

In order to overlay the criteria values with parking lots, the ArcGIS Buffer tool was used to buffer the roads to a distance of 43 meters. This distance was sufficient to overlay the parking lot points. Traffic congestion suitability values are displayed in Figure 6.

The ArcGIS Intersect tool merged the classified distance to Macy's and traffic congestion data (Figure 2 and Figure 6) by adding their intersecting values (Figure 7). After combining the result with the third criteria, parking lot price, the result indicated the parking lot suitability for each lot (Figure 8).

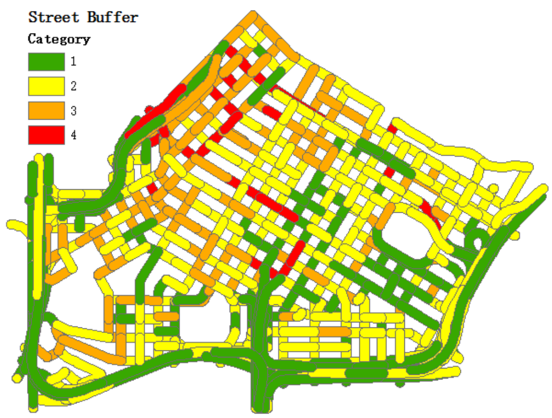

Figure 6. Traffic congestion suitability values. Green represents fast speed, yellow is moderate speed, and orange indicates that the speeds are slow. Red represents stop-and-go traffic.

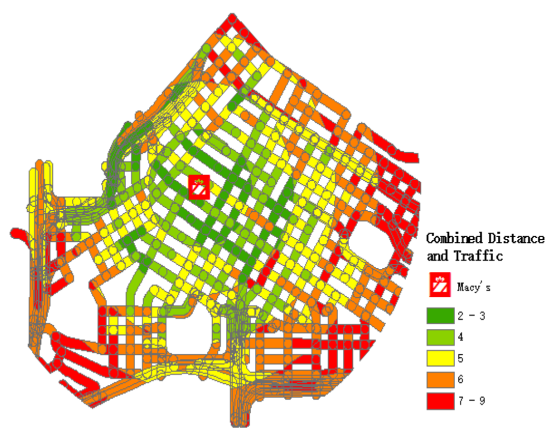

Figure 7. Combined distance to store and road congestion categories. The color indicates good (green) to bad (red) suitability.

Modifying the Distance Measurement Method

To investigate how the results would change, the method used to measure the distance between the parking lot and store was then modified from a straight-line distance to a travel distance following the street network.

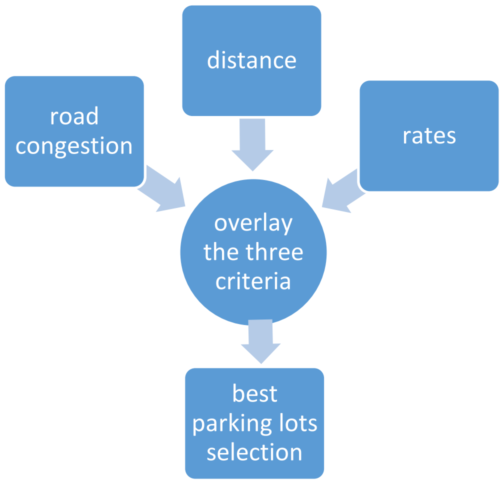

Figure 8. Suitability Model.

Generate Service Areas was used to determine travel distance from each parking lot to Macy's and the distances were classified into five categories. Generate Service Areas is an ArcGIS Online service for creating a service area geoprocessing service on the web. The network service area is a region that encompasses all streets that can be accessed within a given distance or travel time from one or more facilities. For example, the 515.10 meter service area for a facility would include all the streets that can be reached within 515.10 meters of that facility.

Although the method to calculate the distance between the parking lot and store changed, the distance intervals for the five suitabilty categories remained the same. Travel distances from parking lots to Macy's are depicted in Figure 9. The three criteria were again combined, by adding their intersecting values, to obtain the resulting parking lot suitability map.

Results

Figure 10 and 11 display the most suitable parking lots in green, with the level of

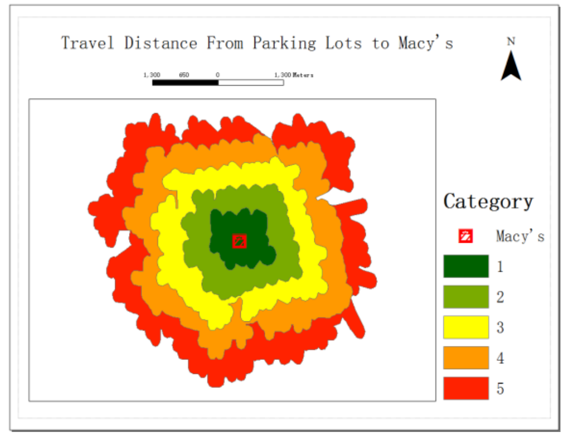

Figure 9. Travel distance to Macy's. The dark green color represents the travel distance following the street network within 515.10 meters of Macy's. The red color represents the parking lots 1788.73 to 2213.27 meters from Macy's.

suitability decreasing to the least suitable in red; the difference is in how the distance between each parking lot and Macy's was calculated. Figure 10 was generated using the straight-line distance calculation and Figure 11 was generated using the travel distance calculation.

Comparing the results using the two distance methods (Figures 10 and 11), parking lot suitability was determined to have changed somewhat. Thirteen parking lots had the same suitability using both distance methods, most of the parking lots had minor differences in suitability, and eleven parking lots changed 4 or 5 levels of suitability between the two distance calculation methods. Some parking lots of low suitability in Figure 10 were found to have high suitability in Figure 11. Figure 12 shows the final suitability for the 111 parking lots using both distance calculation methods.

Discussion

In this research, a questionnaire regarding individual parking preferences was considered, but ultimately not pursued because it was difficult to reach the proper survey participants. Another factor in this

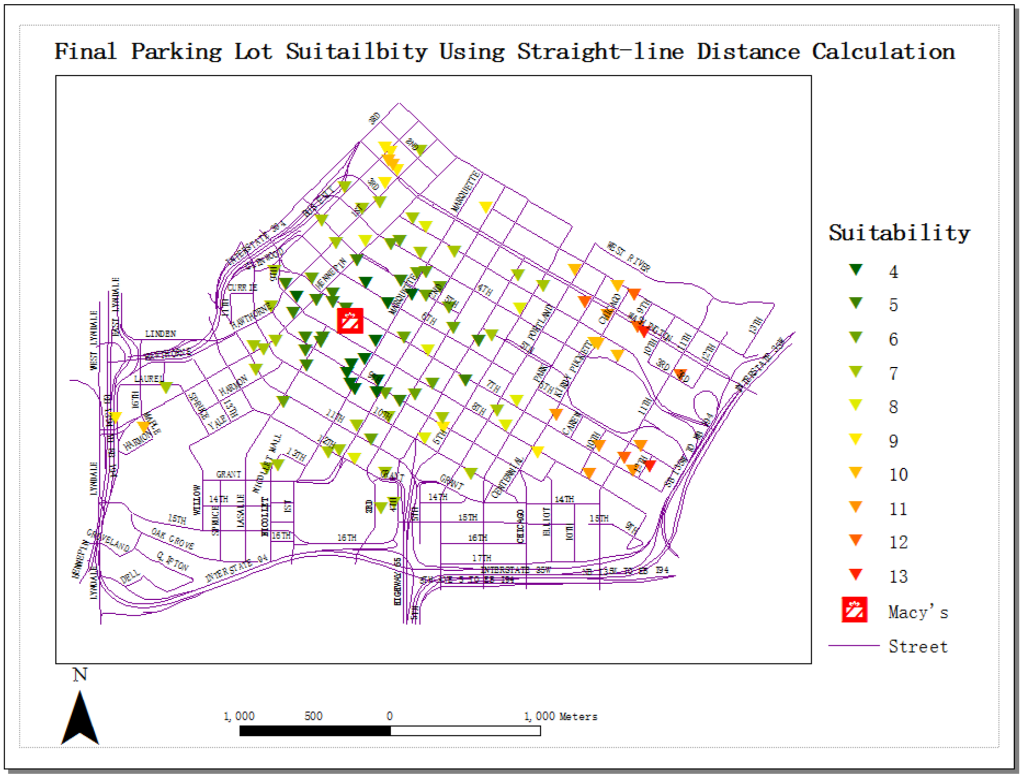

Figure 10. Result of combining the three criteria using the straight-line distance calculation for the distance to store criterion.

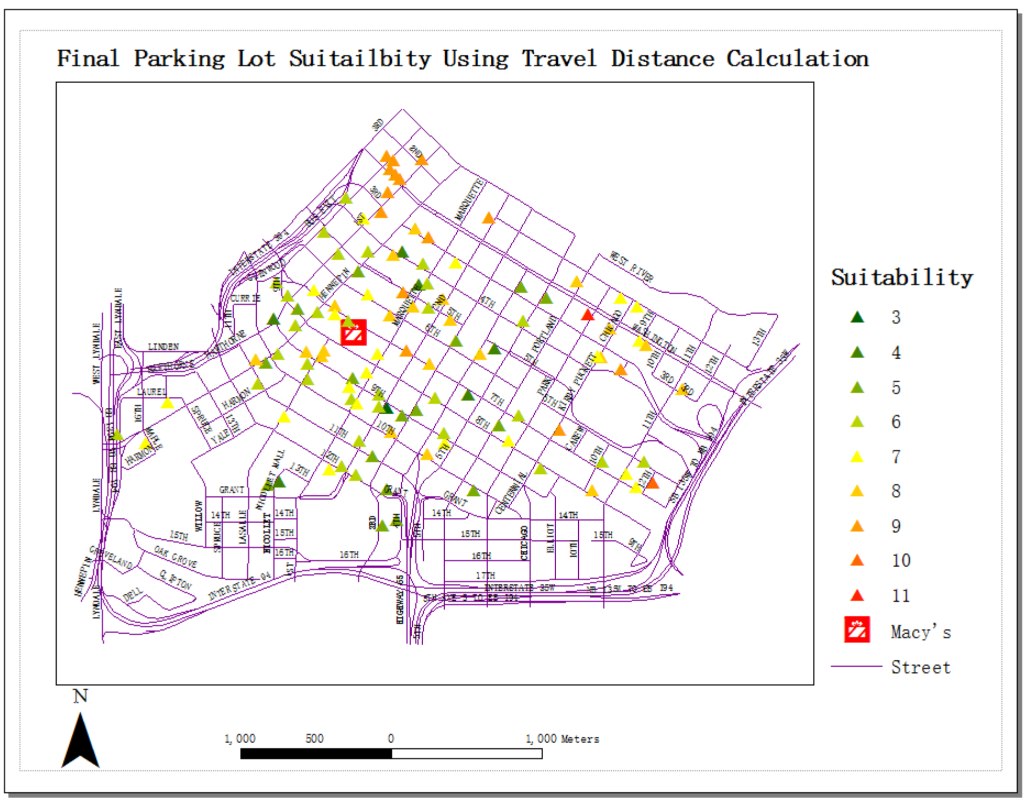

Figure 11. Result of combining the three criteria using the travel distance calculation for the distance to store criterion.

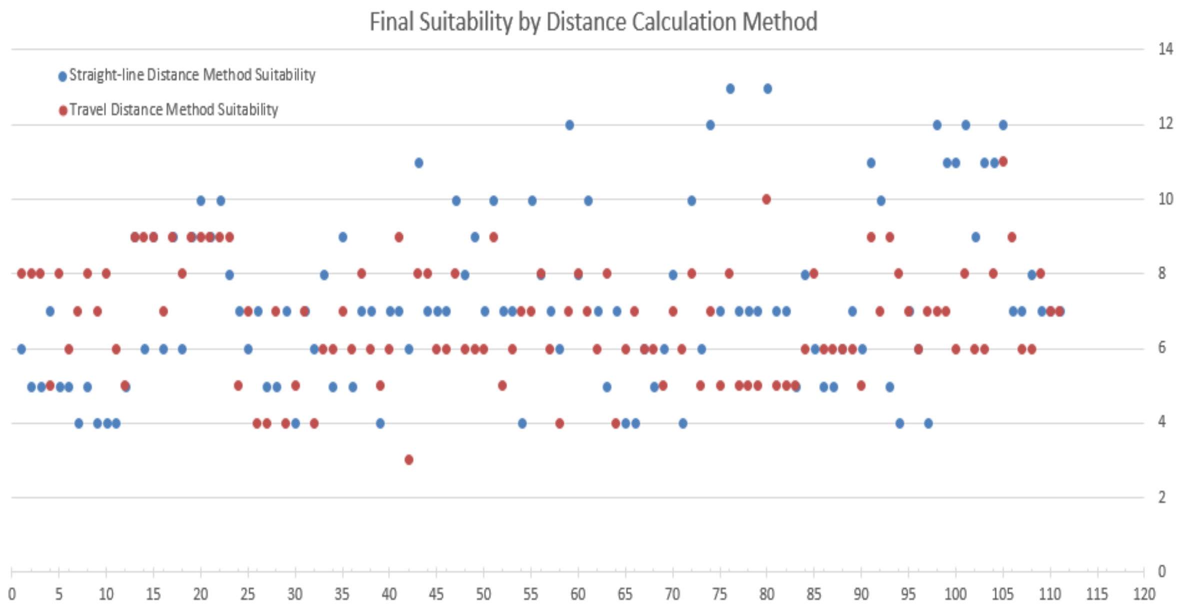

Figure 12. Point chart of suitability. The X-axis represents the one hundred and eleven parking lots, while the Y-axis represents the suitability categories of the three criteria together. The blue dots show the suitability result using the straight-line distance calculation method and the red dots show the resulting suitability using the travel distance calculation method.

research was the weighting method; the three factors were assumed to have the same weight. However, if the weights were changed in the study, then the results would be different.

Residents of all large cities face the same challenge of determining an appropriate parking lot selection method, with the high-volume demand for parking and lack of a map comparing parking lot choices. Parking lot selection is often performed by people in daily life using only one criterion. This research provides a method for parking lot selection based on three criteria. Comparing the two distance calculation methods, each has a different advantage. The straight-line distance method provides an easy and feasible approach, while the travel distance following the street network likely provides a more accurate representation of the distance a person would need to travel from the parking lot to the store.

Conclusions

Road congestion, distance to Macy's, and parking lot price were the three parameters chosen to determine the appropriate parking lot selection in the Downtown West neighborhood of Minneapolis. Assuming the significance of these three factors were equal, they were each allocated the same weight. GIS spatial overlay analysis determined final parking lot suitability. GIS can analyze many parameters simultaneously and allow customers to visualize the most suitable parking lots.

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