Using GIS Machine Learning Technique to Analysis Road Safety near Parks

Yan Duan
Urban and Regional Planning Department, University at Buffalo-State University of New York, Buffalo, New York, U.S.A.

Keywords: Park Accessibility, Road Safety, Level of Traffic Stress, Machine Learning, Non-Motorized Transportation.

Abstract: Parks are essential components of the city fabric, providing recreation and relaxation places to residents. 0.25-mile is a good walking distance. People within the park's 0.25-mile service area are more likely to use non-motorized transportation to travel to the park. In complex traffic settings, bicycles and pedestrians are frequently at a higher risk of being involved in crashes. Thus, exploring road safety near parks is significant for cyclists and pedestrians. This study aims to analyze and measure spatial relationships between traffic crash clusters and park entrances to explore factors that influence traffic crashes near park entrances. The result suggests that road traffic level of stress and roadway design and park parking locations are both factors to impact the traffic conflicts near park entrances. To guarantee and improve safe non-motorized transportation to parks, park planners and designers should consider alternative park accessibility and connectivity for cyclists and walkers. This research aims to find factors that influence active transportation safety around parks. The result of this paper will contribute to creating a safe walking and bicycle environment around parks.

1 INTRODUCTION

Parks provide a critical opportunity to strengthen the fabric of a community, weaving together the social and cultural landscape with the built and natural environment. Research uncovered evidence of a beneficial relationship between urban parks and emotions, exercise, and attention (Kondo et al 2018). As consequently, the COVID-19 epidemic has raised the demand for active transportation, such as cycling and walking, it provides an affordable, healthy, and pollution-free daily option for transportation. In the post-COVID Era, parks and public green nature places have been gaining attractiveness as a destination for active travel activities. Ensuring accessibility and safety near parks and green spaces is crucial. Also, the demand for active transportation options like walking and cycling has grown within the past ten years (Hasani et al 2019). In urban places, pedestrians and cyclists are frequently at a higher risk of being involved in crashes due to complex traffic situations. Plenty of research reveals that people value safety beyond all else when choosing a means of transportation. Although they love to ride, cyclists feel that their commute is more dangerous and vulnerable than that of automobiles, which is a major impediment to riding and walking (Ferreira et al 2022). In urban settings, walking is a vital kind of active transportation. Due to their vulnerability in complex traffic conditions, people walking, motorcycle riders, and pedal cyclists face a higher chance of collisions in metropolitan areas than the vehicle users.

Road safety is influenced by a multitude of factors, including drivers, environmental conditions, and vehicle specifications (Boggs et al 2020). Curb cuts and junctions can have an impact on how frequently and how badly cars collide with other cars, with people, and with the environment. The type, frequency, and severity of collisions are subsequently impacted by these conflicts (Huang et al 2018). Previous studies have explored park accessibility and walkability through a built environment design perspective, such as bike and pedestrian infrastructure, parking space, transit stops, etc.

This study aims to explore park accessibility from a traffic safety perspective. This paper examines relationships between traffic crash location and park entrance roadway level of traffic stress to explore potential factors related to the crash locations near parks. Traffic levels of stress can be a tool for planning level analysis. The result can guide park designers to think about design guidelines for park safety.

Duan, Y.
Using GIS Machine Learning Technique to Analysis Road Safety near Parks.
DOI: 10.5220/0012888000004547

In *Proceedings of the 1st International Conference on Data Science and Engineering (ICDSE 2024)*, pages 394-399
ISBN: 978-989-758-690-3

2 DATA AND STUDY AREA

2.1 Data Sources

Data used in our study areas are from multiple sources. The table below illustrates the data set and sources.

Table 1 below explains the data and sources used in this research. All data was downloaded as ArcGIS shp. files. The crash data used in this study was from the Georgia Department of Transportation between 2018 and 2022. A total of 152,517 accidents were collected throughout the five-year range. The crash data includes the location of all types of crashes, the roadway alignment, surface conditions, weather conditions, lighting conditions, and level of severity. Road Centerline includes roadway speed limits, road names, and road classification. The county boundary is the exterior boundary of Gwinnett County. County Park includes 53 developed parks in Gwinnett County.

Table 1: Research Data Source.

Data	Source
Road centerline	Atlanta Regional Commission Open Data https://opendata.atlantaregional.com/
Traffic Accident	Georgia Department of Transportation https://gdot.aashtowaresafety.net/crash-data#/
County boundary	Gwinnett County GIS Data Resource https://gcgis-gwinnettcountyga.hub.arcgis.com/
County Park	Gwinnett County Online GIS Data https://gcgis-gwinnettcountyga.hub.arcgis.com/

2.2 Study Area

The geographic scope of this research is within the Gwinnett County Boundary. Fig. 1 shows the Gwinnett County boundary, municipalities within the County boundary, County Parks, major roads, and non-residential land use.

3 METHODOLOGY

3.1 Data Process

This section presents the methodological component of this study. A total of three methods are used in this research. (1) GIS-mapping of the crash location by using the hotspot cluster method. (2) Coding roadway traffic level of stress based on the decision tree method in GIS. (3) GIS-mapping road network for visualizing park's 0.25 mi walking area.

3.1.1 GIS-Mapping Crash Hot Spot Analysis (Getis-Ord G_i^*) (Spatial Statistics)

The Hot Spot Analysis is a tool for calculation of the Getis-Ord G_i^* statistic (pronounced G-i-star). The resulting p-values and z-scores can show the spatial clustering of characteristics with high or low values. The Getis-Ord local statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (1)$$

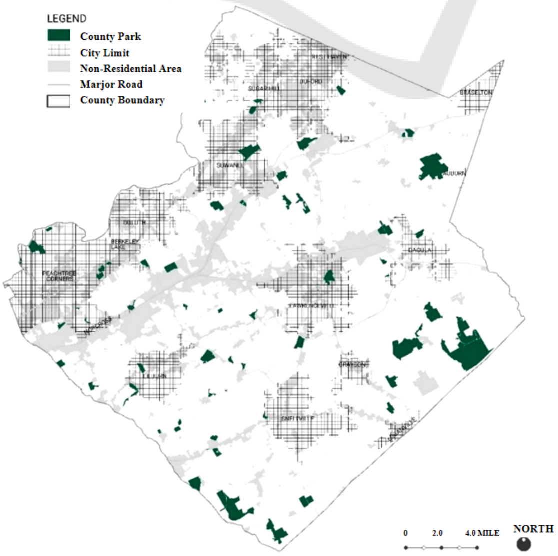

Figure 1: Study Area-Gwinnett County (Picture credit: Original).

Where x_j is the attribute value for feather j, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features, and $\bar{X}$ and S can be calculated through the following formulas (2) and (3):

$$\bar{\boldsymbol{X}} = \frac{\sum_{j=1}^{n} x_j}{n} \tag{2}$$

$$\boldsymbol{S} = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2} \tag{3}$$

The G_i^* statistic is a z-socre so no further calculations are required.

3.1.2 Level of Traffic Stress Method

An indicator named the Level of Traffic Stress (LTS) differentiates a road network's features according to how challenging it can be for walkers and bikers (Huertas et al 2020).

When testing the perceived level of travel comfort, Level of Traffic Stress is a useful measure for people walking or bicycling along a given roadway. Supporting efforts to develop safe and connected networks of transportation facilities, LTS analysis can identify streets that work well and areas in need of improvement. Moving beyond minimum design criteria, LTS helps planners, engineers, and advocates understand the interrelated factors that either encourage or discourage walking and bicycling.

Bicycle Level of Traffic Stress (BLTS) can be used as a measurement for performance and safe with respect to bicyclist. Pedestrian Level of Traffic Stress (PLTS) is used to people who are neither riding on a bicycle nor in a car. LTS is applicable regardless of the presence or absence of a bike lane or sidewalk, and it may be evaluated for both proposed and current conditions.

The LTS's simplicity, which is based on a clear decision tree approach in most of its implementations, is one of its greatest advantages. However, because there are so many segment-level variables required for the categorization, LTS can be difficult to use and comprehend (Harvey et al 2019). This research only coded LTS for roadways near park entrances that have a high traffic crash density cluster.

Table 2 below shows a matrix that determines Bicycle Level of Traffic Stress and Pedestrian Level of Traffic Stress for mixed traffic (no designated bike lane, whether it has a shoulder or not). This table shows a total of 4 levels of traffic stress, ranging from 1 to 4. There are 3 variables used for determining the level of traffic stress: Traffic through lanes, annual average daily traffic (AADT), and traffic speed (mph). The degree of traffic stress is positively correlated with all three variables. It suggests higher AADT, greater velocity limits, and more lanes along roads will all end up in higher levels of traffic stress.

3.2 Analysis of Roadway Network Systems

Anyone may utilize network analysis to find service areas surrounding a specific location on a network. A network service area is a shed. A shed that contains all accessible streets—that is, roadways that are within a given impedance—is referred to as a network service area. For instance, the 0.25-mile service area for a park entrance includes all the streets that can be reached within 0.25 miles (0.5 minutes walking) from that park entrance. By doing this analysis, it can seen that the 0.25-mile distance that people are most likely to walk to parks. The average distance that an American will walk before deciding to drive is 400 meters, or 0.25 miles or five minutes on foot. In US park accessibility studies, a quarter mile (0.4 km) was chosen as a typical threshold distance (Cutts et al 2009). In GIS, the study uses a network analysis tool to create a 0.25-mile walking area for each park. People who live or work within the 0.25-mile walking area are more likely to use walking or bicycling to access the park. These people have a higher risk of being exposed to traffic crashes.

Table 2: Bicycle Level of Traffic Stress and Pedestrian Level of Traffic Stress Criteria.

Lanes	AADT	≤ 20 mph	25 mph	30mph	35mph	40mph	45mph	50+ mph
1 thru lane per direction (or 1 lane one-way street)	0-750	1	1	3	4	4	4	4
	751-1500	1	2	3	4	4	4	4
	1501-3000	2	2	3	4	4	4	4
	3000+	2	3	3	4	4	4	4
2 thru lanes per direction	0-7000	3	3	3	4	4	4	4
	>7000	3	3	4	4	4	4	4
3+ thru lanes per direction	Any ADT	4	4	4	4	4	4	4

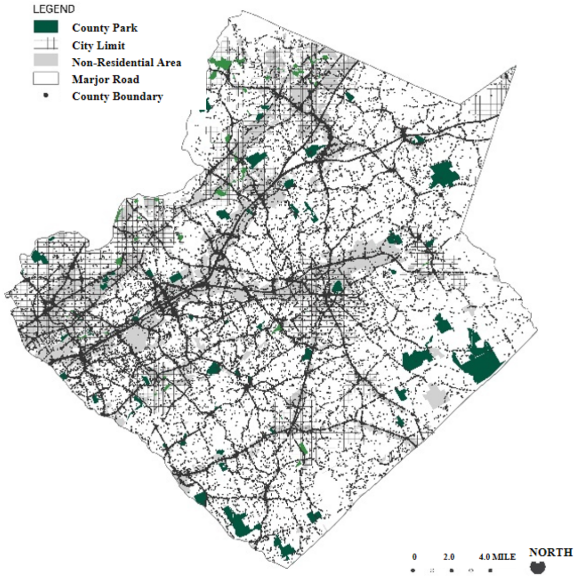

Figure 2: 2018-2022 Traffic Crash Point Map (Picture credit: Original).

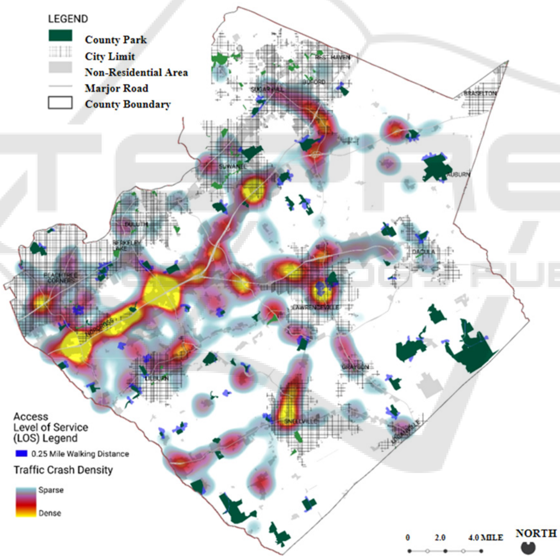

Figure 3: 2018-2022 Traffic Crash Density Heat Map (Picture credit: Original).

Table 3: Parks have traffic crash clusters near their entrance.

Park Name	Area (AC)	Park Classification	Street Name	Bike Lane
Bay Creek Park	154.6	Community Park	Ozora Rd	No
Best Friend Park	43.1	Community Park	Jimmy Carter Blvd	No
Club Drive Park	25.5	Special Neighborhood Park	Club Dr	No
Duncan Creek Park	114.3	Community Park	Braselton Hwy	Yes
Freeman's Mill Park	11.9	Special Neighborhood Park	Alcovy Rd	No
Jones Bridge Park	30.0	Community Park	Jones Bridge Rd	No
Lilburn Activity Building	2.1	Activity Buildings	Hillcrest Rd	No
Lucky Shoals Park	70.0	Community Park	Britt Rd	Yes
Mountain Park Park	43.4	Community Park	Five Forks Trickum Rd	No
Peachtree Ridge Park	153.8	Community Park	Suwanee Creek Rd	No

Pinckneyville Community Center	14.4	Community Recreation Centers	Peachtree Industrial Blvd	Yes
Shorty Howell Park	66.5	Community Park	Pleasant Hill Rd	Yes
Simpsonwood Park	222.4	Open Space Park	Jones Bridge Cir	No
South Gwinnett Park	22.9	Community Park	McGee Rd	No
Yellow River Post Office	5.1	Cultural Resource Park	Five Forks Trickum Rd	No

4 RESULT

4.1 County-Wide Level Mapping Result Analysis

Fig. 2 shows county-wide crash locations. Fig. 3 is a crash heatmap; it shows crash clusters. When some of the crash cluster areas are within a park's 0.25-mile walking shed, they bring safety risk to active transportation.

4.2 Park Level Mapping Result Analysis

This research finally selected 15 parks where traffic crash clusters fall exactly on its main entrance. Then, this paper selected the roadways that are next to park entrances. The level of traffic stress results shows most of the selected roadways are in traffic levels of stress 4. This brings risk to pedestrians and cyclists who travel to the 15 parks. In terms of the rest of the county parks, there are traffic crash clusters within the 0.25-mile walking area of all county parks. Except for those 15 parks that have higher traffic risk, all county parks have potential traffic risk for cyclists and walkers. Fig. 4 shows one example of the map result.

Figure 4: Bay Creek Park Entrance and Traffic Cluster Spot (Picture credit: Original).

Table 3 shows detailed information on the fifteen (15) parks that have high traffic risk for cyclists and pedestrians. Most of them are community parks, those park sizes are 25 acres or more. Community Park typically is designed to serve an area within a ½ mile to over a 3-mile radius. Most of them do not have separate infrastructure for active transportation.

In summary, based on the spatial analysis above, there is a strong traffic crash impact near the park entrance. And there is a correlation between the road level of traffic stress and the density of crashes. A higher and larger traffic crash density is on a higher roadway level of traffic stress.

For deeper investigation, 226 traffic crashes that occurred at the park entrance between 2018 and 2022 were gathered. Table 4 shows the crash detailed information on the traffic crash near parks' entrances. It shows most of the crashes happened in clear weather, daylight, and dry weather conditions. Most of the injuries are not severe. The result may indicate that under good weather conditions during the daytime, people may be less careful when driving. There is no data showing fatal crashes near park entrances. There are, however, high levels of traffic stress, such as high travel speed, multiple travel lanes, and large traffic volumes that cause incidents when turning into park entrance. To improve park accessibility and safety for walkers and cyclers, there should be more regulations around park entrances, such as speed control, active and motorized transportation entrance separation, control signals, etc (Jerrett et al 2016 & Francis et al 2012).

Table 4: Detailed Information of 226 Traffic Crashes that Near Park Entrance.

Surface	Number
Dry	116
Wet	39
Water	3
Ice/Forst	1
Slush	1
Weather	**Number**
Clear	138
Cloudy	53
Rain	33

Snow	1
Sleet	1
Injury	**Number**
No Injury	130
Possible Injury / Complaint	80
Suspected Minor/Visible Injury	13
Unknown	3
Light	**Number**
Daylight	154
Dark-Lighted	31
Dark-Not-Lighted	21
Dawn	5
Dusk	5

5 CONCLUSION

This research uses GIS machine learning techniques to explore traffic crashes and park accessibility and safety for active transportation. Heatmap, street network analysis, and roadway level of traffic stress are three mythologies used for spatial analysis. This study explores the connection between crash risk and the quantity of traffic stress on the roads. A total of 53 developed county parks were used as research targets and a total number of 152,517 traffic crashes collected from 2018 to 2022 were used in this analysis. The traffic heatmap shows a total of 15 park entrances having traffic crash clusters. Roadways that are next to those park entrances were analyzed in GIS for traffic level of stress. The result shows that 12 roadways are in traffic stress level of 4, which is categorized as the highest level of traffic stress. 2 roadways are in traffic stress level 3, which is categorized as the second highest level. Simpson Wood Park is an open space park where pedestrians and bicycles rarely go, with few facilities and amenities in the park, so people don't consider that park entrance roadway level. In planning park entrances, a level of roadway traffic stress should be considered to lessen the risk of crashes. Park entrance should avoid being opened at roadways that are in traffic stress level 4 or 3. Roadways that are in high functional classification, with large number of through lanes or having high speed limits will negatively impact active transportation safety near their park entrances, especially for parks that have many facilities and amenities. A good number of facilities and amenities will attract many visitors, and this can increase traffic volume. Thus, to guarantee park travel safety, within a park 0.25-mile walking distance, regulations such as park zone speed control, non-motorized and motorized entrance separation, and traffic volume control should be considered when designing a park. To guarantee that active travelers receive the proper degree of care and access, laws strategy, and planning efforts could be implemented to address safe approaches to parks.

An additional aspect of the physical environment that may promote a sense of community is public areas, such parks, and plazas, which allow for chance of interactions between neighbors. while offering opportunities for people to access recreation and nature. Walking and cycling to public places are not only for improving residents' physical and mental health, but also saves energy to improve environmental sustainability.

REFERENCES

M. Kondo, J. McKeon, C. Branas, International journal of environmental research and public health, 15(3), 445 (2018).

M. Hasani, A. Jahangiri, IN. Sener, S. Munira, JM. Owens, B. Appleyard, S. Ryan, SM. Turner, M. Ghanipoor, Journal of advanced transportation, (2019).

M.C. Ferreira, P.D. Costa, D. Abrantes, J. Hora, S. Felicio, M. Coimbra, TG. Dias, Transportation research part F: traffic psychology and behaviour, 91:136-163 (2022).

A.M. Boggs, B. Wali, A.J. Khattak, Accident Analysis & Prevention, 135:105354 (2020).

Y. Huang, X. Wang, D. Patton, Journal of transport geography, 69:221-233 (2018).

J.A. Huertas, A. Palacio, M. Botero, GA. Carvajal, T. van Laake, D. Higuera-Mendieta, SA. Cabrales, LA. Guzman, OL. Sarmiento, AL. Medaglia, Transportation Research Part D: Transport and Environment, 85:102420 (2020).

C. Harvey, K. Fang, DA. Rodriguez, Mineta Transportation Institute Publications (2019).

B.B. Cutts, K.J. Darby, C.G. Boone, A. Brewis, Social science & medicine, 69(9):1314-1322 (2009).

M. Jerrett, J.G. Su, K.E. MacLeod, C. Hanning, D. Houston, J. Wolch, Environmental research 151:742-755 (2016).

J. Francis, B. Giles-Corti, L.Wood, M. Knuiman, Journal of environmental psychology 32(4): 401-409 (2012).