Using Geographic Information Systems to Analyze the Relationship Between Alcohol Establishments and Violent Crime in the City of Minneapolis

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Abstract

Research suggests that certain populations of people are more inclined to commit violent acts, and that certain neighborhood attributes can also facilitate criminally violent acts. One location where violent crime has been observed to happen more often is in and around areas with a high number of alcohol establishments. Alcohol consumption is thought to impair an individual's judgement and affect their ability to control impulsive and often violent and/or criminal actions. This study used geographic information systems (GIS) to identify statistically significant hot spots for both on sale and off sale alcohol establishments and violent crime within the City of Minneapolis. It also examined the effects of unemployment and poverty on crime rates and how their effects compared to that of alcohol establishments. Using ordinary least square regression, it was determined that the number of alcohol establishments does have a statistically significant correlation to the level of violent crime within a community.

Introduction

Background

Many studies have found a positive correlation between alcohol and crime (Erickson, Carlin, Lenk, Quick, Harwood, and Toomey, 2015). This relationship has regularly been a cause for public concern (White, Gainey, and Triplett, 2015). Policy makers have attempted to address the issue since before Prohibition, through various types of intervention (White *et al.*, 2015). Alcohol consumption is thought to impair an individual's judgement and affect their ability to control impulsive, and often violent, actions (Grönqvist and Niknami, 2014; Gruenewald, Freisthler, Remer, LaScala, and Treno, 2006; White *et al.* 2015).

Research suggests some level of violence associated with alcohol consumption could be related to specific characteristics within the environment that facilitate violence (White *et al.*, 2015; Zhu, Gorman, and Horel, 2004). White *et al.* (2015) suggests bars and clubs may be more accepting, or less restrictive, of certain types of behaviors that could lead to aggression or violence among their patrons. In turn, violent crime seems to happen more often in and around areas with a high density of alcohol outlets (Erickson *et al.*, 2015; Gruenewald *et al.*, 2006; Lipton and Gruenewald, 2002;Zhang, Hatcher, Clarkson, Holt, Bagchi, Kanny, and Brewer, 2015; Zhu *et al.*, 2004). A high density, or clustering, of alcohol

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establishments is thought to increase competition amongst the bars which often leads to discounted alcohol and an increased risk of excessive consumption (White *et al.*, 2015; Zhang *et al*., 2015). One study conducted in New Jersey found that alcohol outlet density alone explained nearly one fifth of the variability in violent crime (Gorman, Speer, Gruenewald, and Labouvie, 2001).

Crime within a community is most often associated with two separate features: the characteristics of the people living in the community and the physical characteristics of the community (Gruenewald *et al.*, 2006). Some of the commonly evaluated variables in relation to violent crime include poverty level, percentage of minority population, percentage of single-female headed households, median household income, and rate of unemployment (Erickson *et al.*, 2015; Gorman *et al.*, 2001; Lipton and Gruenewald, 2002; White *et al.*, 2015; Zhu *et al.*, 2004). Gorman *et al.* (2001) cites a study conducted by Scribner *et al.* (1995) that found 70% of violent crime within Los Angeles County could be explained by demographics such as poverty level, unemployment rate, and proportion of single-female headed households.

Ali and Peek (2009) suggest the attractiveness of illegal activities increases for individuals who are unemployed. Although unemployment is most often associated with property crimes, such as burglary and theft, the chance of violence occurring increases during the commission of these types of crimes (Ali and Peek, 2009). Erickson *et al.* (2015) created an index that measured unemployment, along with other socioeconomic characteristics, of the population living in Minneapolis, MN. A higher value index correlated to a higher socioeconomic status and higher percent white population (Erickson *et al.*, 2015). In addition to unemployment, Erickson *et al.* (2015) evaluated median household income, poverty level, and race. Erickson *et al.* found a negative association between the socioeconomic/racial index and crime levels within a neighborhood.

This study identifies statistically significant hot spots of violent crime, alcohol establishments, poverty, and unemployment based on block groups within the City of Minneapolis. An overlay analysis examines the block groups that are classified as statistically significant hot spots for multiple variables. Additional statistical analysis including ordinary least squares regression analysis was performed to determine correlation between the variables and to try to find a suitable model for predicting violent crime.

Significance of Research

According to the Center for Disease Control and Prevention (CDC) (2018), excessive alcohol consumption cost the United States approximately $249 billion in 2010. The CDC estimates that 10% of those costs were related to law enforcement and criminal justice expenses (CDC, 2018). One method identified by the CDC to decrease this cost is to better regulate the density of alcohol establishments within communities.

A significant positive correlation between density of alcohol establishments and violent crime may encourage changes in legislation and lead to stricter laws regarding alcohol consumption as well as the density and location of alcohol establishments. This could decrease the financial burden on the City of Minneapolis, improve the quality of life for residents, and potentially lead to reduced crime rates in neighborhoods

throughout the city.

Liquor Licenses in Minnesota

The City of Minneapolis Licenses and Consumer Services Division is responsible for managing all of the liquor establishment licensing. This division is responsible for accepting and/or denying liquor license applications as well as performing routine inspections of establishments to ensure safe operating practices (City of Minneapolis Licenses and Consumer Services, 2016). Liquor licenses are awarded on a yearly basis and must be renewed annually. There are various types of liquor licenses that exist in the City of Minneapolis. Different establishments possess different licenses based on the type of alcohol they sell. Multiple licenses refer specifically to the sale of malt liquor containing not less than 0.5% alcohol by volume or more than 3.2% alcohol by weight. Other licenses are specific to event, catering, and temporary licensure needs (City of Minneapolis Licenses and Consumer Services, 2016).

There are also licenses specific to alcohol sale and consumption at taprooms, cocktail rooms, micro distilleries, and breweries (City of Minneapolis Licenses and Consumer Services, 2016). All of the licenses fall under one of two categories: on sale or off sale. On sale licenses permit the sale of alcoholic beverages for consumption on the premise of a licensed facility (City of Minneapolis Licenses and Consumer Services, 2016). Off sale licenses permit the sale of alcoholic beverages, in their original packaging, specifically for consumption off premises (City of Minneapolis Licenses and Consumer Services, 2016).

Study Area

The study area observed for this research included 378 block groups within the City of Minneapolis. A shapefile containing Hennepin County block groups was downloaded from the United States Census Bureau. The Minneapolis block groups were extracted using a City of Minneapolis boundary shapefile obtained online through the City of Minneapolis Open Data Portal. There are two block groups located in the southeastern section of the city that are split by the city boundary. These block groups were included in the study area as they contained data that was within the city boundary. These two block groups are identified in Figure 1.

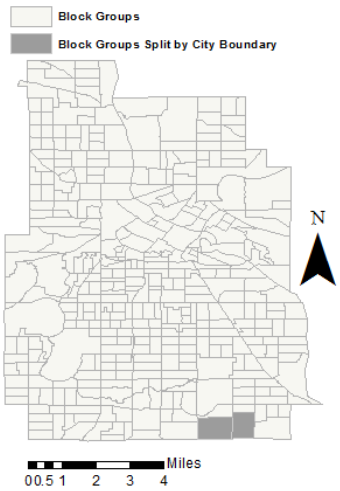

Figure 1. City of Minneapolis divided by block groups.

Minneapolis is the largest city by population in the state of Minnesota with an estimated 2016 population of 419,952 (Metropolitan Council, 2018). The largest percent of the population in Minneapolis falls between the ages of 20-34 with 16.45% of males and 15.88% of females (Metropolitan Council, 2018). Minneapolis covers approximately 57.4 square miles with nearly 10% of the area considered parks, recreation, and preserves. The median household income

between the years 2012 and 2016 was $52,600 (Metropolitan Council, 2018).

Methods

Alcohol Establishment Data

Data pertaining to alcohol establishments for the year 2016 was obtained through a public data request to the City of Minneapolis. Due to a change in the city's licensing system that took place in mid-November 2016, these data did not include any establishments that were newly opened between mid-November to the end of December 2016.

The data were divided into two separate spreadsheets, on sale and off sale, using Microsoft Excel. There were multiple duplicates within the data. It was determined that these duplicates were caused by establishments switching ownership within the year, establishments applying for temporary or event licenses, and by varying licensing needs of the establishment. All duplicates were eliminated to prevent any single establishment from being represented more than once.

After removing duplicates there were a total of 699 on sale establishments and 147 off sale establishments. A third spreadsheet was created by combining the on and off sale establishments. Since multiple establishments require both on and off sale liquor licenses to accommodate their specific sale needs, additional duplicates arose and had to be removed. One example of this type of an establishment are the breweries in Minneapolis. Every brewery needs to have at least one on sale license for distributing alcohol in their taproom and an additional off sale license to sell alcohol to customers for off-site consumption. After removing duplicates there were a total of 813 establishments. All three spreadsheets were uploaded into ArcMap as tables.

Geocoding

The alcohol establishment data did not contain any location information and needed to be geocoded. Address point data for all of Hennepin County were obtained from the Hennepin County GIS Open Data website. The address points specifically for the City of Minneapolis were extracted within Microsoft Excel and then displayed in ArcMap 10.4 as XY data. An address locator was created within ArcMap using the Minneapolis address points. This address locator was then used to individually geocode all three alcohol establishment tables. The minimum match score was set to 85. There was an average match rate of approximately 86% for each table.

All the unmatched or tied addresses were extracted and manually searched using Google Maps. The latitude and longitude of these data were added to the original Minneapolis address points spreadsheet from which a new address locator was created. The alcohol establishment data were than geocoded again and each resulting layer returned a 100% match rate.

Violent Crime Data

Crime data was collected from the online City of Minneapolis Open Data Portal for the year 2016. The Minneapolis Police Department works directly with the city to make their crime data publically available through this website. If more than one crime was committed during a single incident, only the most serious offense was recorded. This is common practice by many police departments to avoid inaccurately inflated statistics.

These data included the latitude and longitude of the city block and/or nearest intersection where the crime occurred. There was a total of 20,155 crimes documented for the year 2016. Approximately 5.8% or 3,469 were violent crimes. The violent crime data were extracted using Microsoft Excel and then imported and displayed in ArcMap 10.4 as XY data. There were 13 incidents that did not include any location data. These incidents were excluded from the study as their geographic location was not clear.

Violent crime was defined based on the Federal Bureau of Investigations (FBI) Uniform Crime Reporting (UCR) Program which identifies violent crime as murder and non-negligent manslaughter, forcible rape, robbery, and aggravated assault. For the purposes of this study robbery included aggravated robbery, robbery of a person, and robbery of a business. Assault included first, second, and third degree domestic assault; assault with a dangerous weapon; assault of police or emergency personnel; assault with significant bodily harm; and assault with great bodily harm.

Poverty and Unemployment Data

The data for poverty and unemployment levels were obtained through the United States Census Bureau American Fact Finder website. These data were based on the 2012-2016 American Community Survey 5-year estimate and were divided by block groups. Poverty data were determined by the number of households whose income for the last 12 months fell below the poverty level. Unemployment data were based on number of unemployed individuals in the labor force. Data for both poverty and unemployment were the estimated amounts for the year 2016.

Results

Optimized Hot Spot Analysis

Statistically significant hot and cold spots were identified using the Optimized Hot Spot Analysis tool in ArcMap10.4. This tool uses the Gi_Bin statistic while automatically correcting for multiple testing and spatial dependence issues. The data for each variable were aggregated based on the Minneapolis block group polygon layer. An output feature class containing a confidence level bin was created for each variable. Figure 2 displays the output for all six hot spot analysis outputs.

Overlay Analysis

An overlay analysis was performed on the hot spots to detect block groups where multiple variables had hot spots with a 99% confidence level. Alcohol establishment data was the combined on and off sale outlets. There were 26 block groups that were considered hot spots for all four variables. These block groups are all grouped together in the center of the city. This area of Minneapolis is considered downtown Minneapolis. It includes the Gateway District, Downtown East, Downtown West, Loring Park, and part of the North Loop. The location of this area is west of 35W, northeast of where 94 and 35W intersect and South of W Broadway Ave. The same 26 block groups were identified as overlapping when comparing crime and alcohol establishments, alcohol and poverty, and alcohol and unemployment. There were 106 block groups overlapping hot spots between crime and poverty and 89 block groups overlapping hot spots between crime and unemployment. Figure 3 shows block group overlapping hot spots.

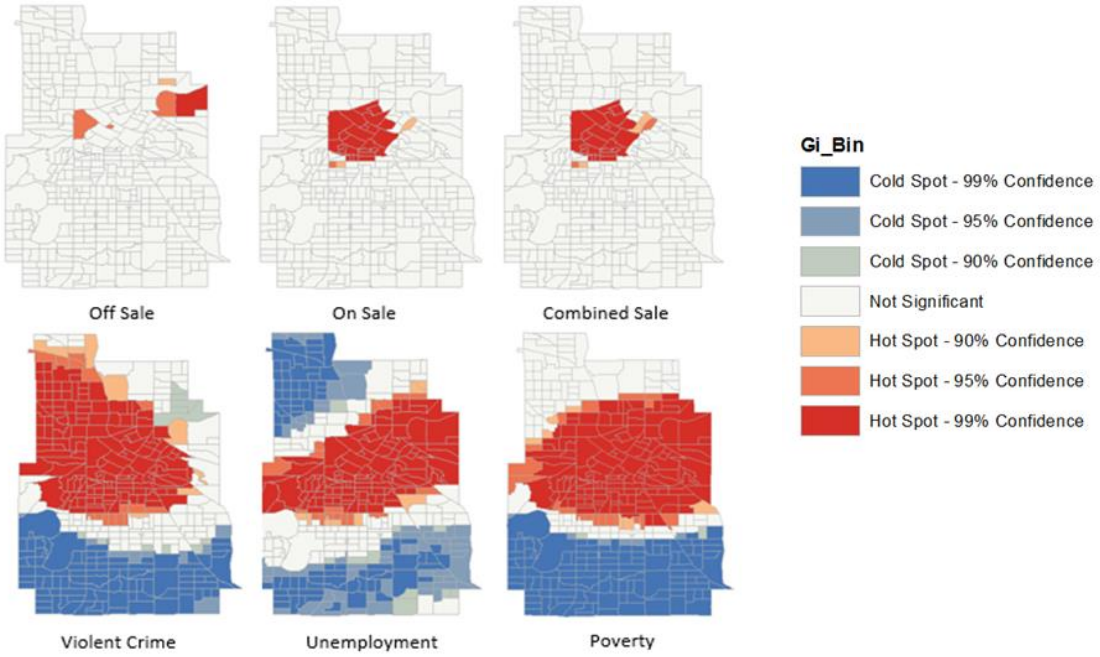

Figure 2. Maps of optimized hot spot analysis output for all six variables.

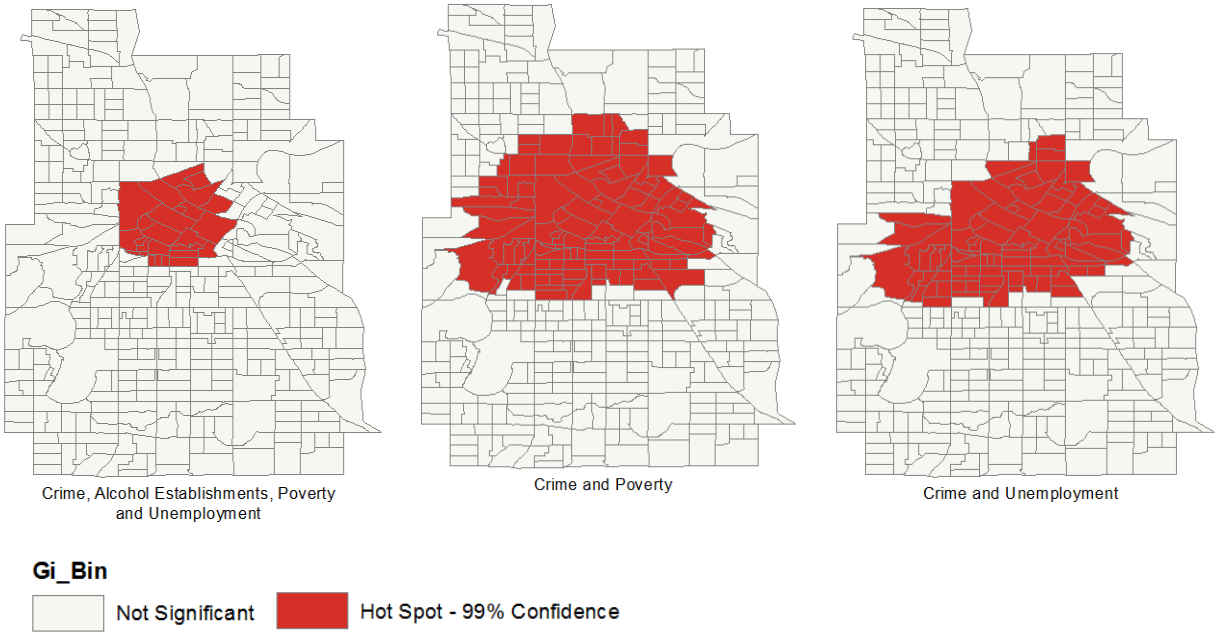

Figure 3. Maps of overlapping hot spots based on block groups.

Statistical Analysis

A spatial join was performed linking the crime, combined alcohol establishments, poverty, and unemployment data to the Minneapolis block group layer. When joining the crime data, it was determined that four crimes fell directly on the border of two block groups. These crimes were counted twice, once in each block group

that they shared a border with.

Ordinary least square (OLS) regression was run for four possible combinations of variables: crime and alcohol establishments; crime, alcohol establishments, and poverty; crime, alcohol establishments, and unemployment; and all four variables together. This analysis was used to determine the best fit model to explain the correlation between variables. Spatial Autocorrelation (Global Moran's I) analysis was performed to determine if the residuals of the best fit model were clustered. Scatterplot graphs were also created to visualize the relationship between variables.

OLS Crime and Alcohol

The OLS test for crime and combined alcohol establishments returned a statistically significant correlation based on a p-value of 0.000. The adjusted R^2 value was 0.419. The coefficient was 1.882. These results indicate that the number of alcohol establishments within a block group can explain approximately 42% of the variation in violent crime. Figure 4 shows the residuals from this OLS test.

The color scale depicts the standard deviation. Areas of red and orange indicate that the actual values were higher than the model predicted. Areas in blue and grey indicate the values being lower than what the model predicted. The spatial autocorrelation tool was run on these residuals and found a z-score was 19.468 and the Moran's Index was 0.427.

The Moran's Index is a test that measures for spatial autocorrelation. It determines whether a spatial pattern is clustered, dispersed or random. A Moran's index of zero is completely random, 1 indicates clustering, and -1 indicates dispersion. The results for this model indicate that the residuals are clustered. The z-score evaluates the statistical significance of the pattern. In this model, the z-score indicates that there is a less than 1% chance that the clustering is random. This suggests that there are additional variables, not included in the model, that are statistically significant.

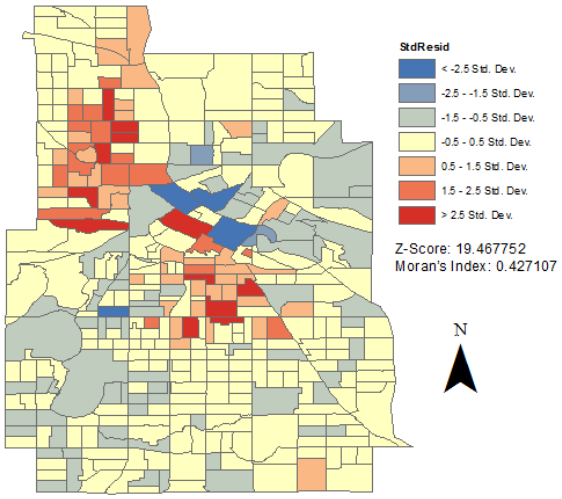

Figure 4. Map of residuals from the OLS test including alcohol establishments and violent crime.

OLS Crime, Alcohol Establishments, and Poverty

Poverty was added to the test above to determine how it would alter the results. The OLS test for crime, alcohol establishments, and poverty returned a statistically significant correlation with a p-value of 0.000 for both alcohol establishments and poverty. The adjusted R^2 value was 0.477. The coefficient for poverty was 0.043 and the coefficient for alcohol establishments was 1.747. Spatial autocorrelation found that the residuals were still clustered with a z-score of 17.258 and a Moran's Index score of 0.377. Figure 5 shows the residuals from this OLS test.

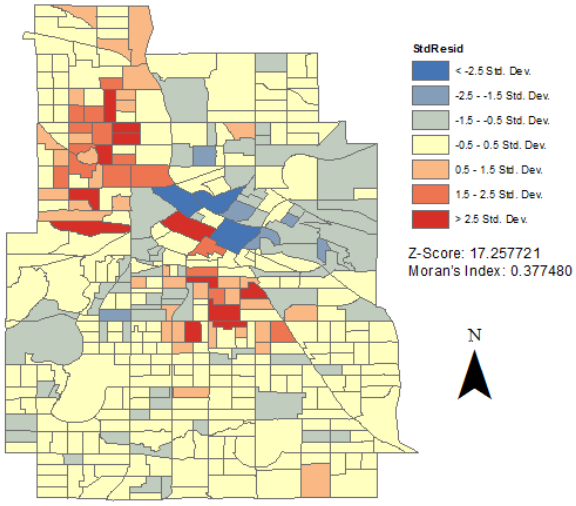

Figure 5. Map of residuals from the OLS test including alcohol establishments, violent crime, and poverty.

OLS Crime, Alcohol Establishments, and Unemployment

OLS was run a third time with the variables crime, alcohol establishments, and unemployment. The results returned a statistically significant correlation based on a p-value of 0.000 for alcohol establishments and 0.004 for unemployment. The adjusted R^2 value was 0.430. The coefficient for alcohol establishments was 1.991. The coefficient for unemployment was -0.006. A negative coefficient for unemployment was returned which indicates that as unemployment levels increase, violent crime rates decrease. The residuals for this model were again determined to be clustered with a z-score of 18.755 and a Moran's Index score of 0.412. Figure 6 portrays the residuals of this test.

OLS Crime, Alcohol Establishments, Poverty, and Unemployment

An OLS analysis was performed including all four variables. The results show a statistically significant correlation based on a p-value of 0.000 for all three variables. The adjusted R^2 value of 0.514. This was the highest R^2 value found during this study. Residuals for this test were determined to be clustered with a z-score of 14.172 and a Moran's Index score of 0.310.

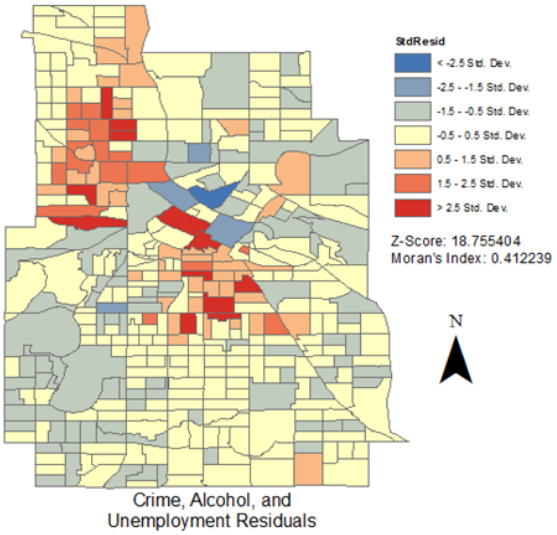

Figure 6. Map of residuals from the OLS test including alcohol establishments, violent crime, and unemployment.

The coefficient values for this model are as follows: alcohol establishments was 1.911, poverty was 0.053, and unemployment was -0.012. This model found a positive correlation for alcohol establishments and poverty but a negative correlation for unemployment. Figure 7 shows the residuals for this model. Table 1 depicts all of the R^2, p-values, z-scores, and coefficients of the OLS models described. The p-values and coefficients are reported for each explanatory variable.

Scatterplot Graphs

Scatterplot graphs were created to visualize the correlation between the variables on an individual basis. Violent crimes and alcohol establishments portray

the strongest correlation with an R^2 value of 0.421. The R^2 values for each set of variables are listed in Table 2. The scatter plots can be found in Appendix A.

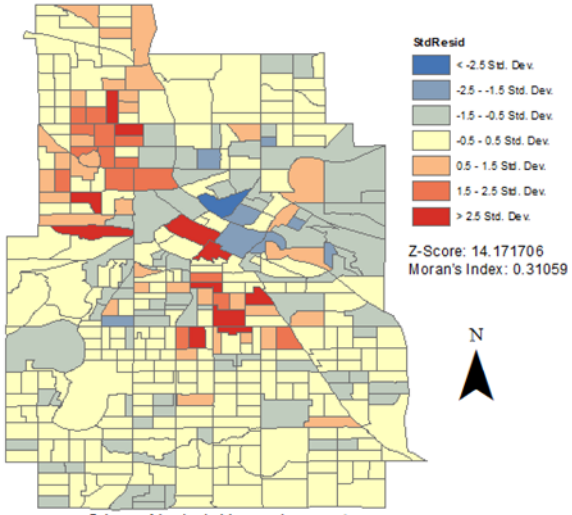

Figure 7. Map of residuals from the OLS test including alcohol establishments, violent crime, poverty, and unemployment.

Discussion

The optimized hot spot analysis consistently identified hot spots directly in the center of the city. This area of Minneapolis is highly populated and would be considered more urban than the outer portions of the city.

It also contains some of the major tourist attractions in Minneapolis including, US Bank Stadium, Target Field, and the Minneapolis Convention Center. Two of the city's largest public transportation lines, the Blue Line and the Red Line, also run directly through this section of the Minneapolis.

No hot spots for any variables were found in the southern section of the city. There were in fact statistically significant cold spots of poverty, unemployment, and violent crime in southern Minneapolis. Hot spots for alcohol establishments differed greatly between on sale and off sale data. There were much fewer off sale establishments, which could have contributed to the lack of statistically significant findings. The OLS analysis repeatedly found a statistically significant, positive correlation between violent crime rates and alcohol establishments. Results suggest that alcohol establishments alone predict approximately 42% of the variation in violent crime in the City of Minneapolis. The coefficient for alcohol establishments with this model was 1.882, which indicates that as the number alcohol establishments increases by one it can be predicted that the number of violent crimes would increase by approximately 1.88, assuming all other variables remain unchanged.

Table 1. Table summarizing the results of the OLS models.

Model	**R^2 Value**	**P-Value**	**Coefficient(s)**
Violent Crime and Alcohol Establishments	0.419	Alcohol: 0.000	Alcohol: 1.882
Violent Crime, Alcohol Establishments, and Poverty	0.477	Alcohol: 0.000	Alcohol: 1.747
		Poverty: 0.000	Poverty: 0.043
Violent Crime, Alcohol Establishments, and Unemployment	0.43	Alcohol: 0.000	Alcohol: 1.991
		Unemployment: 0.004	Unemployment: -0.006
Violent Crime, Alcohol Establishments, Poverty and Unemployment	0.514	Alcohol: 0.000	Alcohol: 1.911
		Poverty: 0.000	Poverty: 0.053
		Unemployment: 0.000	Unemployment: 0.012

Adding poverty to the model accounted for an additional 6% of the variation in violent crime rates. Poverty, when paired with alcohol establishments, increased the strength of the correlation, resulting in an R^2 value of 0.477 and explaining nearly 48% of variation of violent crime rates in Minneapolis. Another important finding to note is that there was a positive relationship between violent crime and poverty. This means that as poverty increases violent crime rates should increase as well.

The R^2 value also increased when unemployment was added to alcohol establishments. The R^2 value for this model was 0.430. Unemployment only accounted for an additional 1% of the variation in crime rates. The coefficient for unemployment was negative which indicates that as unemployment rates go up it can be predicted that violent crime rates will go down. This was not a particularly strong correlation.

Table 2. The R^2 values derived from scatterplot analysis comparing variables individually.

Variables	**R^2 Value**
Violent Crimes and Alcohol Establishments	0.421
Violent Crime and Poverty	0.130
Violent Crime and Unemployment	0.010
Alcohol Establishments and Unemployment	0.102
Alcohol Establishments and Poverty	0.035
Unemployment and Poverty	0.113

Based on the findings of this study, the best fit model for predicting crime included alcohol establishments, poverty and unemployment as variables. This model resulted in a R^2 value of 0.514. These results indicate the combination of alcohol establishments, poverty level, and rate of unemployment can explain 51% of the variation in violent crime rates in Minneapolis. There was a positive coefficient for both alcohol establishments and poverty and a negative coefficient for unemployment. Spatial autocorrelation analysis for this model revealed a z-score of 14.172 and a Moran's Index score of 0.310. Although this was the highest scoring model, based on the result of the Moran's Index, there are additional explanatory variables not included in this study that are significantly correlated to violent crime rates.

Potential Sources of Error

All the data went through many stages of preparation before being analyzed in ArcMap. Although precautions were taken to reduce error there is a chance that data was inadvertently altered or deleted during this time. During the geocoding process portions of the data were manually searched using a third-party search engine to obtain a latitude and longitude. There is a chance that errors were made when transferring the location data back into ArcMap.

The City of Minneapolis was going through a licensing program transition during the time frame that the alcohol establishment data was collected for. There is a chance that amid the transition data was lost or altered. Additional data may have been deleted or altered while being manually reviewed to remove duplicates.

The only crime data available were the crimes that were reported to the police in a formal manner. There was no way to account for unreported crime during this study. The Bureau of Justice Statistics estimates that more than half, nearly 3.4 million, violent crimes go unreported in the United States every year (Langton, Berzofsky, Krebs, and Smiley-McDonald,

2015). It is important to recognize that there were likely many violent crimes that occurred but were not represented through the scope of this study.

Future Research

Due to the lack of time and budget for this study, the scope was particularly small. Future researchers could incorporate additional variables and use exploratory regression to find a more suitable model for predicting crime. It would also be interesting to see how recent changes to liquor laws in Minnesota allowing the sale of liquor on Sundays may effect crime.

Conclusion

The purpose of this study was to evaluate the relationship between the presence of alcohol establishments and the rates of violent crime in the City of Minneapolis. It was determined that there is a statistically significant, positive relationship between violent crime and alcohol establishments. Additional socioeconomic variables were integrated during regression analysis to determine a best-fit model for predicting crime.

This study was not able to find a completely reliable model. The highest-ranking model accounted for approximately 51% of the variation in violent crime but the residuals were clustered. Additional research would need to be conducted in order to determine what other variables are associated with the rate of violent crime in Minneapolis.

All of the hot spots of violent crime were located in highly populated areas. This study did not control for population density when establishing hot spots. It is likely that the increased population alone played a role in the increased level of violent crime in these areas. It is difficult to differentiate between the effect of the population and the alcohol establishments. This could be something that future researchers explore.

Acknowledgements

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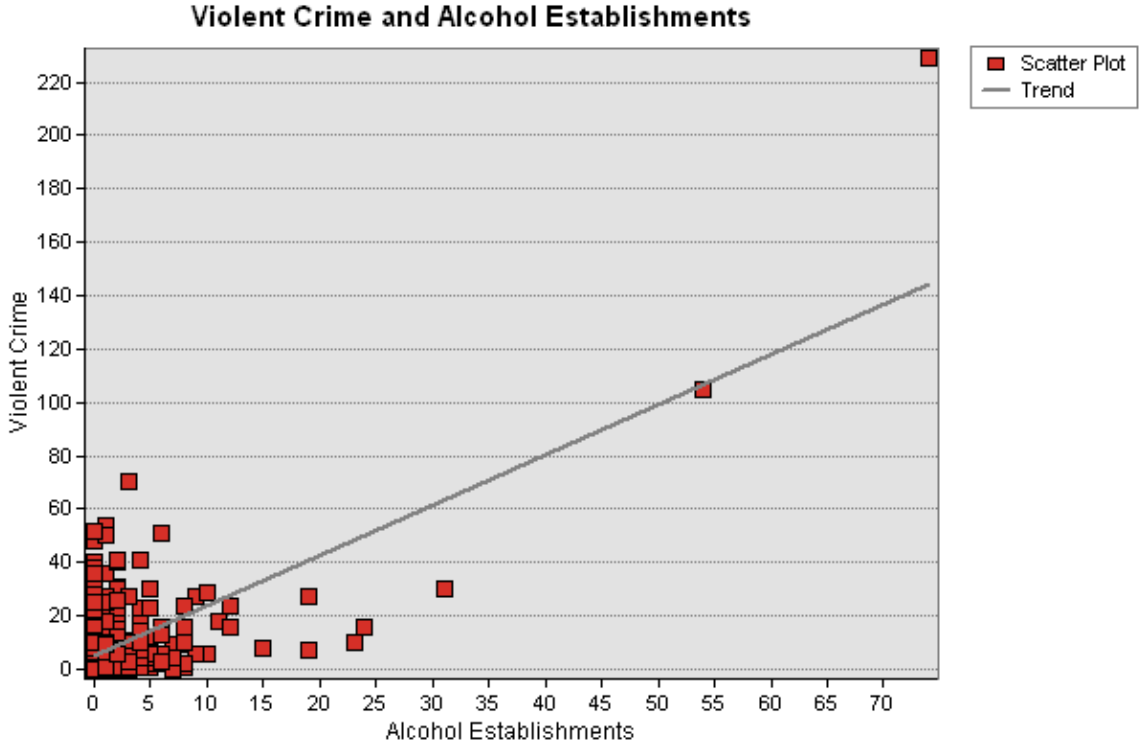
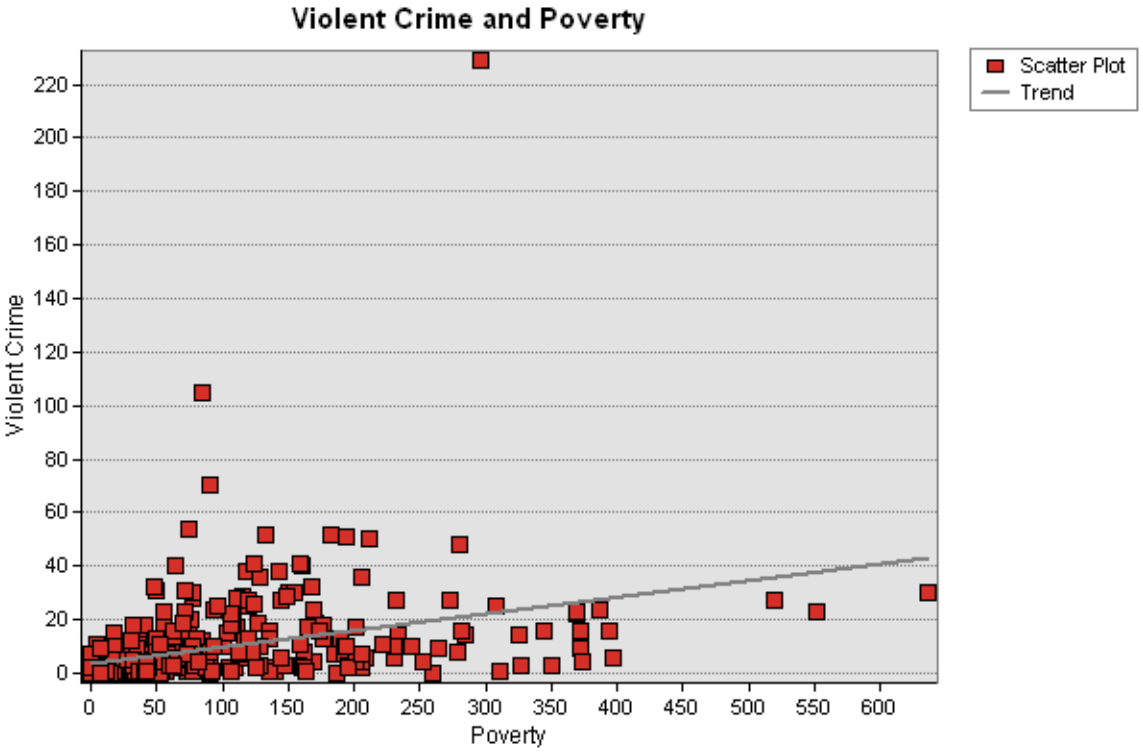
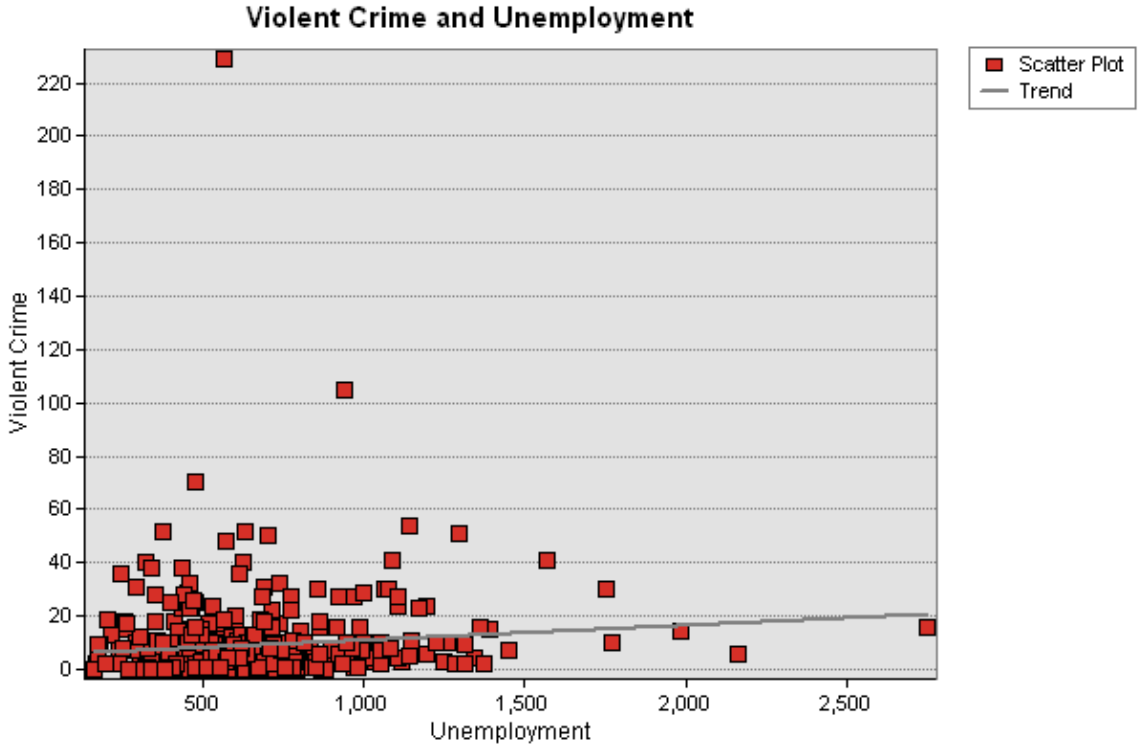
Appendix A. Scatterplot graphs depicting the correlation between explanatory variables and violent crime.






Violent Crime and Unemployment
Scatter Plot
Trend
Violent Crime
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200
180
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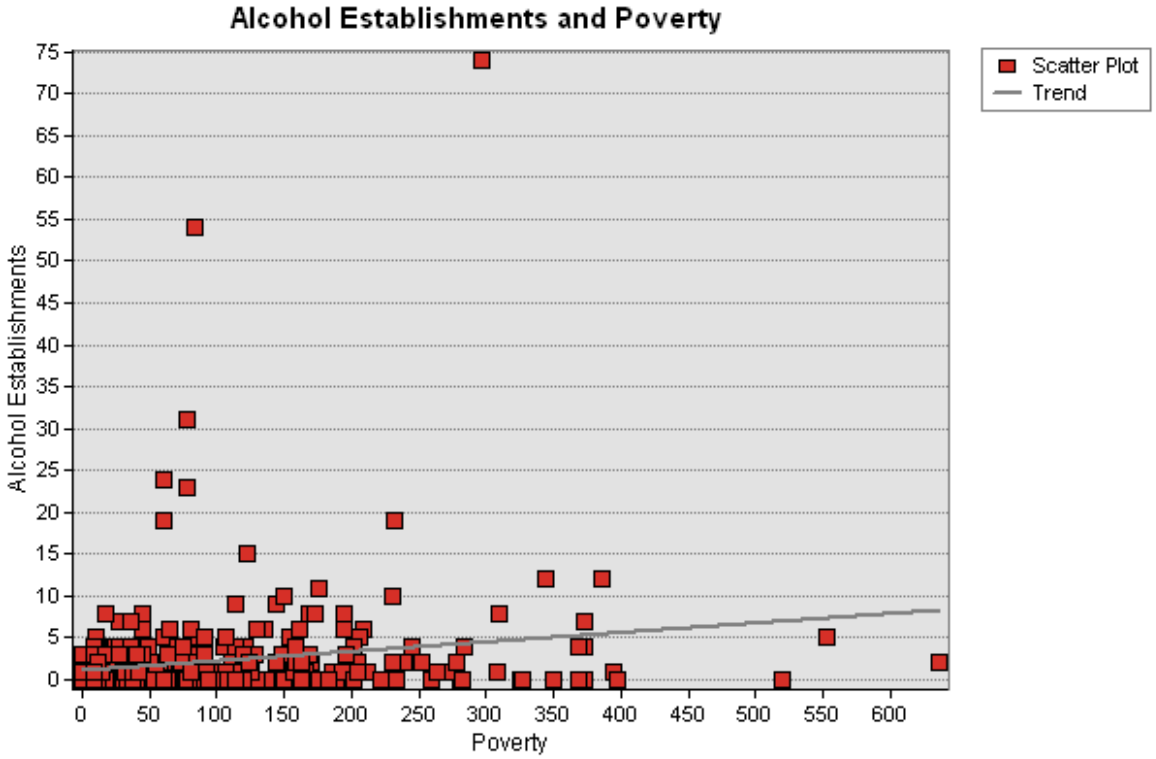
Unemployment


Alcohol Establishments and Poverty
Scatter Plot
Trend
Alcohol Establishments
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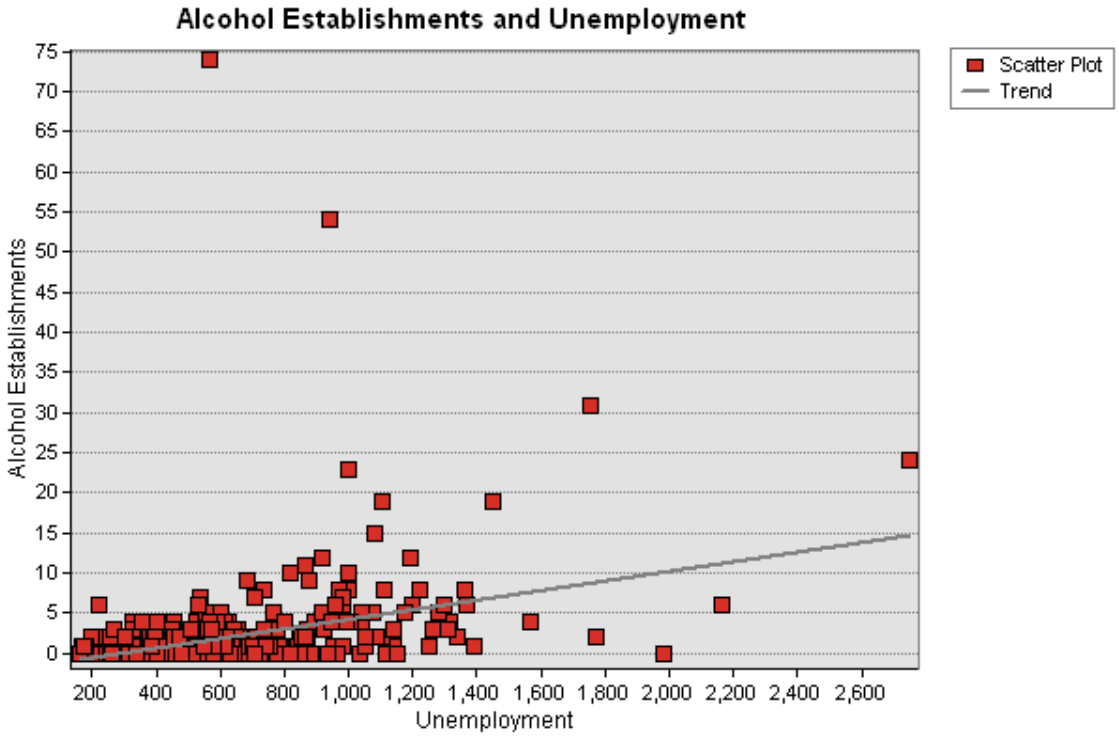
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500
550
600
Poverty


Alcohol Establishments and Unemployment
Alcohol Establishments
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
Unemployment
Scatter Plot
Trend