Traffic Crash Data Analysis

Of Hennepin County

GEO 5561 (Principle of GIS)

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Table of Contents

Introduction

Traffic safety is a crucial concern in urban and suburban areas, where the growing population, increasing road usage, and high vehicle volume often result in traffic crashes. “Spatial–temporal distribution characteristics are important attributes of road traffic accidents” (Ma et al., 2021). There are mainly two methods for spatial distribution characteristics of road traffic accidents: (1) determine the frequency area of traffic accidents by statistical analysis which is based on the accidents location field in the collected accident information (Cheng & Washington, 2005). (2) visually display traffic accidents by using GIS technology and then analyze the spatial distribution characteristics by using the spatial analysis method. Some of the scholars have carried out different spatial analysis of traffic accidents based on GIS technology (Wan et al., 2021).

Hennepin County, Minnesota, as one of the largest and most populated counties in the state, has experienced a substantial number of traffic crashes in recent years. This raises concerns about public safety and emphasizes the need for data-driven approaches to address traffic-related risks. While individual crash data provides a valuable information, the scattered nature of the records poses challenges in identifying spatial and temporal patterns. It is difficult to prioritize high-risk areas or understand trends without detailed geospatial and temporal analyses.

Despite ongoing traffic efforts to reduce traffic crashes through better road design, public awareness, and enforcement, certain areas continue to experience high crash densities. Conversely, some areas see significantly fewer crashes. Understanding these patterns and trends is essential for deploying effective interventions, such as allocating resources to the most affected regions or redesigning high risk road segments. (Guo et al. 2018) used Getis-Ord G* i hot spot analysis to conduct spatial statistics of the results, the accident-prone sections and boundaries were identified. By constructing a large-scale Bayesian network model of traffic accidents, the probability of traffic accidents under different factors was calculated.

However, in this report a different methodology was used to examine both spatial and temporal trends to provide actionable insights. Spatially, the study identified hot spot areas where crash densities are highest and cold spot areas with lower densities. Temporally, it visualizes annual trends in crash occurrence to understand how accidents patterns have changed over the years.

The methodology used in this study combines advanced geospatial tools and visualizations to achieve the following:

1. Define an Area of Interest (AOI) to exclude region with sparse data, ensuring the analysis focuses on significant crash locations.
2. Generate a uniform grid (fishnet) to divide the AOI into cells and analyze crash densities with each grid square.
3. Use spatial joins to aggregate crash point within the grid, creating a robust dataset to identify high-risk areas.
4. Visualize temporal trends using bar plots to identify year-by-year variations in crash occurrences.
5. Create graduated color maps to highlight high-density (hot spots) and low-density (cold spots) areas, enabling clear spatial insights.
6. Create a heat map representing data density by using color gradients to highlight areas with high and low concentration of crashes.

Objective

The primary objective of this study is to analyze traffic crash patterns in Hennepin County from 2021 to June 2024 by identifying spatial hot spots (areas with high accident densities) and cold spots (areas with low accidents densities), while also evaluating temporal trends in crash occurrences. The study aims to provide actionable insights into the spatial distribution and temporal dynamics of traffic accidents, enabling informed decision-making for traffic safety, infrastructure planning, and resource allocation.

Using geospatial tools and visualization, the study seeks to:

1. Identify Priority Area: Highlight locations with the highest concentration of crashes, which can serve as targets for safety interventions, enforcement measures and infrastructure improvements.
2. Exclude Non-Significant Regions: Provide a clear picture of how the number of traffic accidents has changed annually between 2021 and mid-2024.
3. Facilitate Data-Driven Decisions: Assist policymakers, urban planners, and transportation authorities in prioritizing safety measures, planning resources allocation, and designing strategies to minimize traffic accidents.
4. Support Road Safety Goals: Contribute to broader traffic safety goals by identifying specific spatial and temporal patterns that could guide preventive actions and improve public safety.

5. The study combines geospatial analysis with data visualization (bar plots and spatial heat maps) to create a comprehensive overview of traffic accidents patterns, empowering stakeholders with evidence-based insights for enhancing transportation safety and efficiency in Hennepin County.

Data and Methods

The traffic crash data of Hennepin County from the year 2021 to June 2024 was received from Hennepin County GIS via email. Since the data was scattered, I focused on identifying the hot spot area (with the highest number of accidents) and cold spots areas (with fewer accidents). To achieve this, the following steps were undertaken:

1. Area of Interest (AOI): An Area of Interest polygon was created to exclude regions where crash data was sparse. This was achieved using the Minimum Bounding Geometry tool, with the Convex Hull geometry type, to generate a polygon enclosing the scattered crash points while minimizing the inclusion of irrelevant areas.
2. Fishnet Creation: A fishnet grid was created to divide the AOI into equal-sized cells, enabling a systematic spatial analysis of crash density. The Create Fishnet tool was used with the following parameters:

- Cell size: 5000 meters x 5000 meters.
- Extent: The AOI polygon served as the template extend, restricting the grid to the predefined area.
- Geometry Type: The output consisted of square polygon, providing a consistent framework for crash point aggregation. The grid covered the entire AOI with evenly sized cells, facilitating spatial analysis across the study area.
- Clipping the Fishnet: To ensure that the grid did not extend beyond the boundaries of Hennepin County, the fishnet was clipped to the AOI using Clip tool.

3. Spatial Join: A spatial joint was performed to aggregate crash points into the fishnet grid cells. This operation:
    - Input: Crash point data set (Join Features) and fishnet grid (Target features).
    - Join Operation: JOIN_ONE_TO_ONE.
    - Statistic: The tool calculated to count of crash points within each grid cell, populating a new attribute in the fishnet layer. This step quantified 5000-meter x 5000-meter grid cell, enabling further analysis and visualization.
4. Visualization: The grid was symbolized based on the crash counts using Graduated Colors.
    - Symbology: A color ramp (light to red gradient) was applied to represent crash density visually

- Hot Spots: High crash density cells were symbolized with bright red color.
- Cold Spots: Low crash density cells were symbolized with lighter color.

5. Heat map: The heat map serves as a complementary tool to grid-based spatial analysis, offering smooth and continuous visualization of crash patterns. It provides a representation of data density by using color gradients to highlight areas with high and low concentrations of crashes.
6. Bar plot visualization of accidents: A bar plot was created using ArcGIS Pro 3.0 to visualize the number of accidents for each year from 2021 to June 2024. This visualization provided an overview of how accident trends have changed over time. In this plot:

- The x-axis represents the total number of accidents.
- The y-axis represents the years

Results

The analysis of traffic crash data in Hennepin County from 2021 to June 2024 yielded into both spatial and temporal patterns of crashes densities. The results were presented through a series of maps, including heat maps and grid-based crash density visualizations for each year, enabling a clear understanding of high-density crash areas (hot spots) and low density crash areas (cold spots). Below is a detailed interpretation of the results:

1. Temporal Trends

The spatial analysis across 2021 to 2024 reveals consistent pattern of crash densities, with certain areas showing persistent high crash rates over the years.

a) 2021

- The heat map highlights a significant concentration of traffic crashes in the urban areas of Minneapolis and surrounding areas.
- The grid based maps shows the highest crash density, 227 -513 crashes per square in the southeast quadrant of Hennepin County, with a gradient of decreasing crash count as on moves towards the outskirts.
- 2022
- The heat map indicates a similar pattern of 2021 with dense crash occurrence in central Hennepin County, especially near Minneapolis.
- The grid map shows crash counts ranging from 230 to 460 in high-density area, reinforcing the continued clustering of incidents in urbanized zones.

b) 2023

- Both the heat map and grip-based show a slight shift and expansion of crash clusters towards the west of Minneapolis. However, the central and southeastern portion of Hennepin County remain dominant crash hot spots
- Grid-based analysis shows crash densities reaching up to 454 crashes per square in certain areas.

c) 2024

- Preliminary data for 2024 (up to June) reflects a continuation of trends observed in previous years. The heat map shoes densities remain concentrated near Minneapolis, while the grid-based map identifies high-density area with crash counts ranging from 97 to 235.

2. Spatial Patterns

The spatial distribution of crash densities shows clear clustering around major road networks and urban centers:

- Urban Area: Across all years, the regions around Minneapolis consistently exhibit the highest crash densities, correlating with high traffic volume and urban infrastructure.
- Peripheral Areas: Cold spots are evident in the outskirts and rural parts of Hennepin County, where crash densities remain spare, as shown in both the heat maps and grid-bases analyses.

3. Heat Map Interpretation

The heat maps provided a continuous visualization of crash densities. The light yellow area consistently aligns with central Hennepin County, highlighting urban regions with dense traffic activity. Dark yellow indicates less frequent crashes particularly in rural or less populated regions.

The heat maps for 2021 to 2024 illustrate a stable pattern of crashes, with no significant expansion or contraction of dense areas, suggesting persistent traffic- related risks in specific zones.

4. Grid-Based crash density

The grid-baes maps offers a more granular view of crash distribution, quantifying the number of crashes within each 5000 m x 5000 square. This allow for a comparative analysis of crash densities across different years:

- The highest crash density values are consistently observed near Minneapolis, reaching up top 513 crashes per square in 2021 and decreasing slightly in subsequent years.
- A slight westward shift in crash concentrations was observed between 2023 and 2024 indicating potential changes in traffic patterns or infrastructure usage.

5. The bar charts

The bar charts present a comparative analysis of traffic crash occurrences on weekdays versus weekends for the years 2021 to 2024. Each chart highlights a consistent trend, with a higher number of crashes recorded during weekdays compared to weekends across all years. In 2021, the total number of weekday crashes reached 4,209, significantly surpassing the 1,294 crashes reported on weekends. Similarly, in 2022, weekday crashes increased slightly to 4,239, while weekend crashes showed a smaller rise to 1,417. This trend reflects the heightened traffic activity and risk associated with weekdays, likely due to work commutes and higher vehicular volumes. In 2023, the number of weekday crashes slightly declined to 4,019, while weekend crashes also dropped to 1,390. Despite the slight decrease, the pattern of more crashes on weekdays remained consistent. By 2024 (up to June), the total number of weekday crashes recorded was 1,981, with weekend crashes at 614. This substantial drop compared to previous years is likely due to incomplete annual data but still maintains the trend of higher weekday crash frequency. Overall, the charts demonstrate that weekdays consistently experience a higher number of crashes than weekends, highlighting the need for targeted interventions during peak weekday travel times. The trends also suggest variations in traffic dynamics over the years, with a general decline in crash numbers observed in the most recent data.

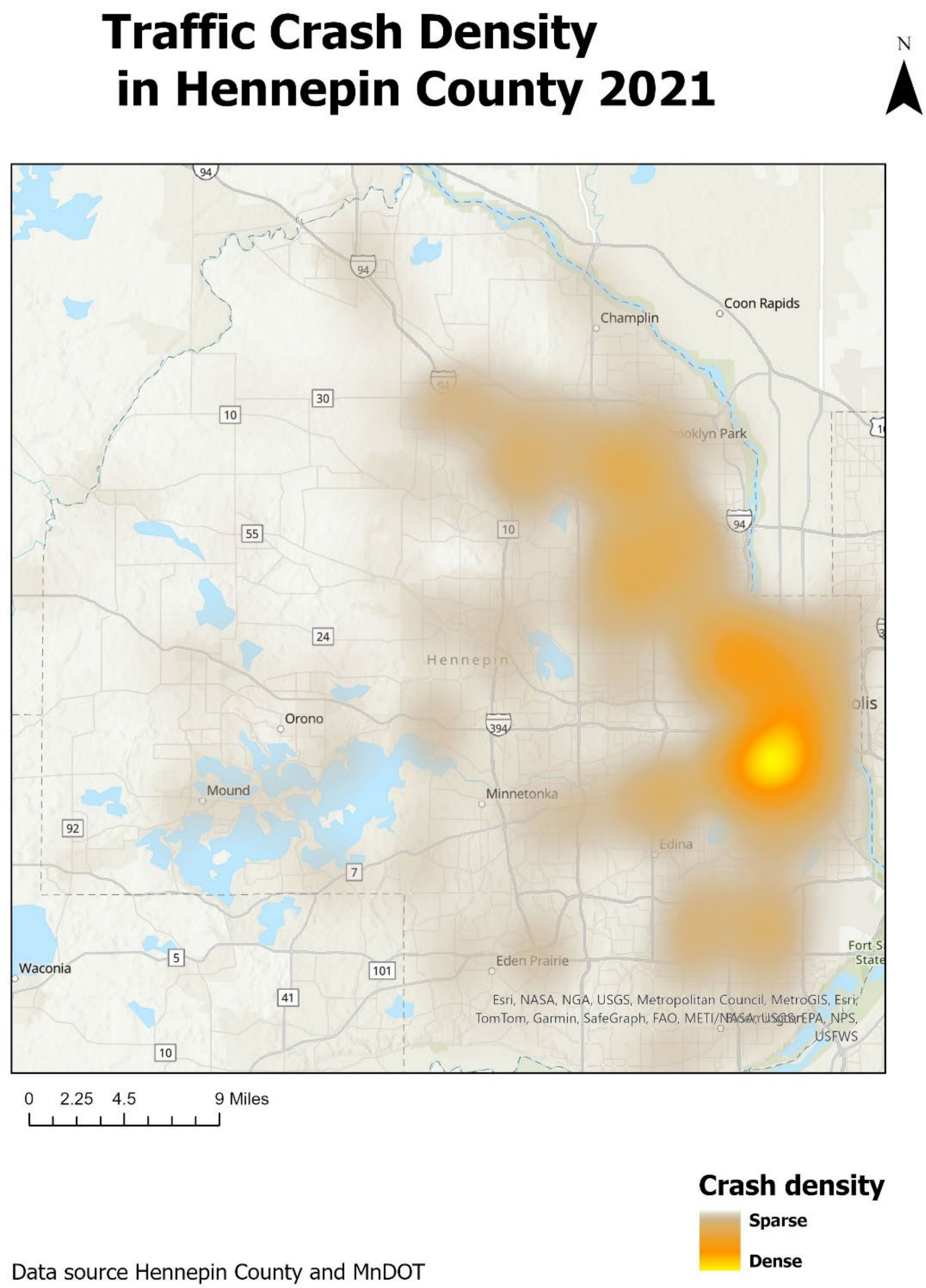

Figure 1-Traffic Crash Density in Hennepin County, 2021. The heat map shows crash density in Hennepin County for 2021, with high-density areas (hot spots) near Minneapolis and low-density areas (cold spots) in rural regions. Data Source: Hennepin County and MnDOT.

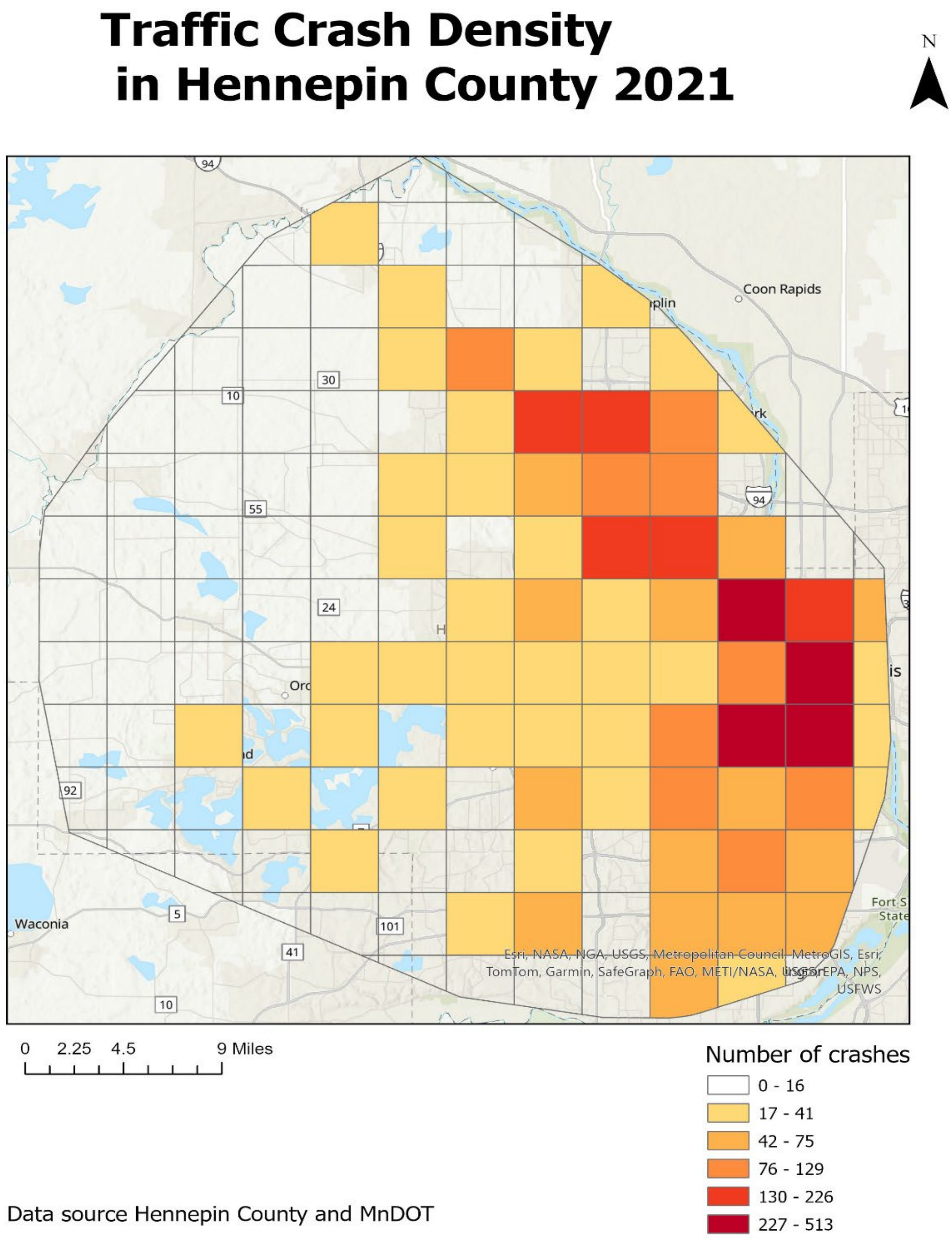

Figure 2-Traffic Crash Density in Hennepin County, 2021. This grid-based map displays crash densities across Hennepin County in 2021. High-density areas (227–513 crashes) are concentrated near Minneapolis, while low-density areas (0–16 crashes) are found in the outskirts. Data Source: Hennepin County and MnDOT.

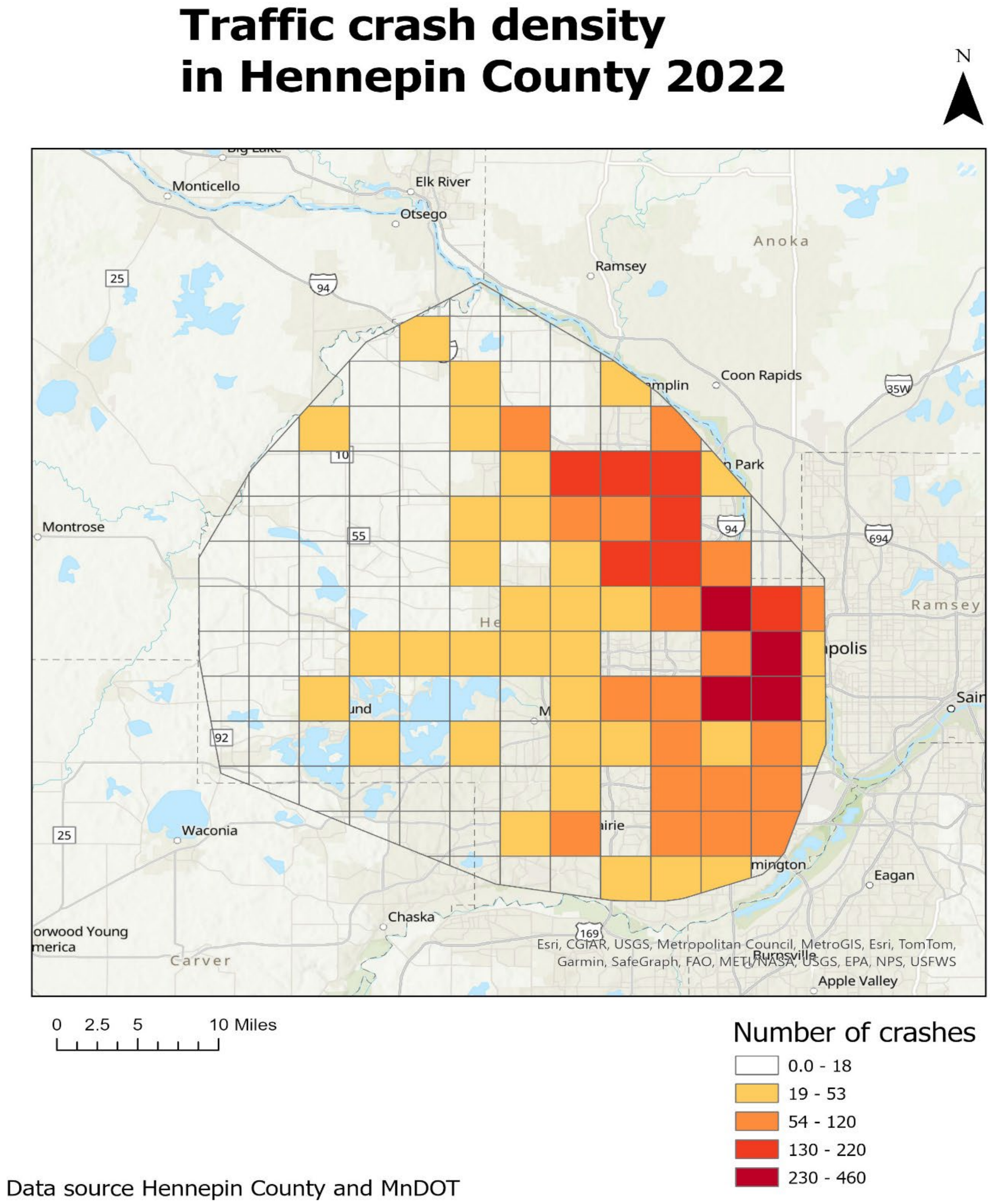

Figure 3-Traffic Crash Density in Hennepin County, 2022. The grid-based map illustrates traffic crash densities in Hennepin County for 2022. High-density areas (230–460 crashes) are concentrated near Minneapolis, while rural areas show significantly lower densities (0–18 crashes). Data Source: Hennepin County and MnDOT.

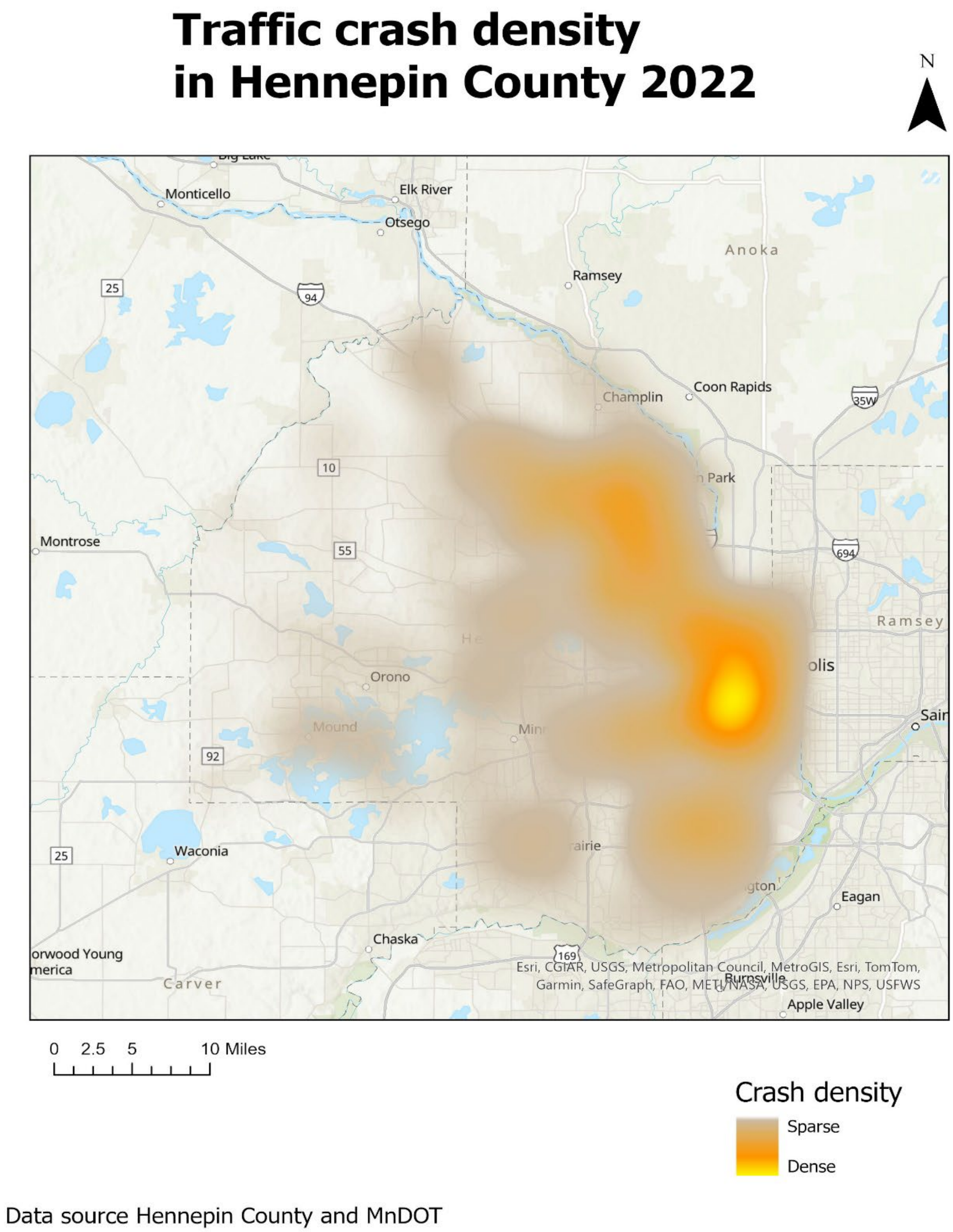

Figure 4-Traffic Crash Density in Hennepin County, 2022. The heat map highlights the spatial distribution of traffic crashes in Hennepin County for 2022. Dense crash areas (hot spots) are concentrated near Minneapolis, while sparse areas are located in the outskirts. Data Source: Hennepin County and MnDOT.

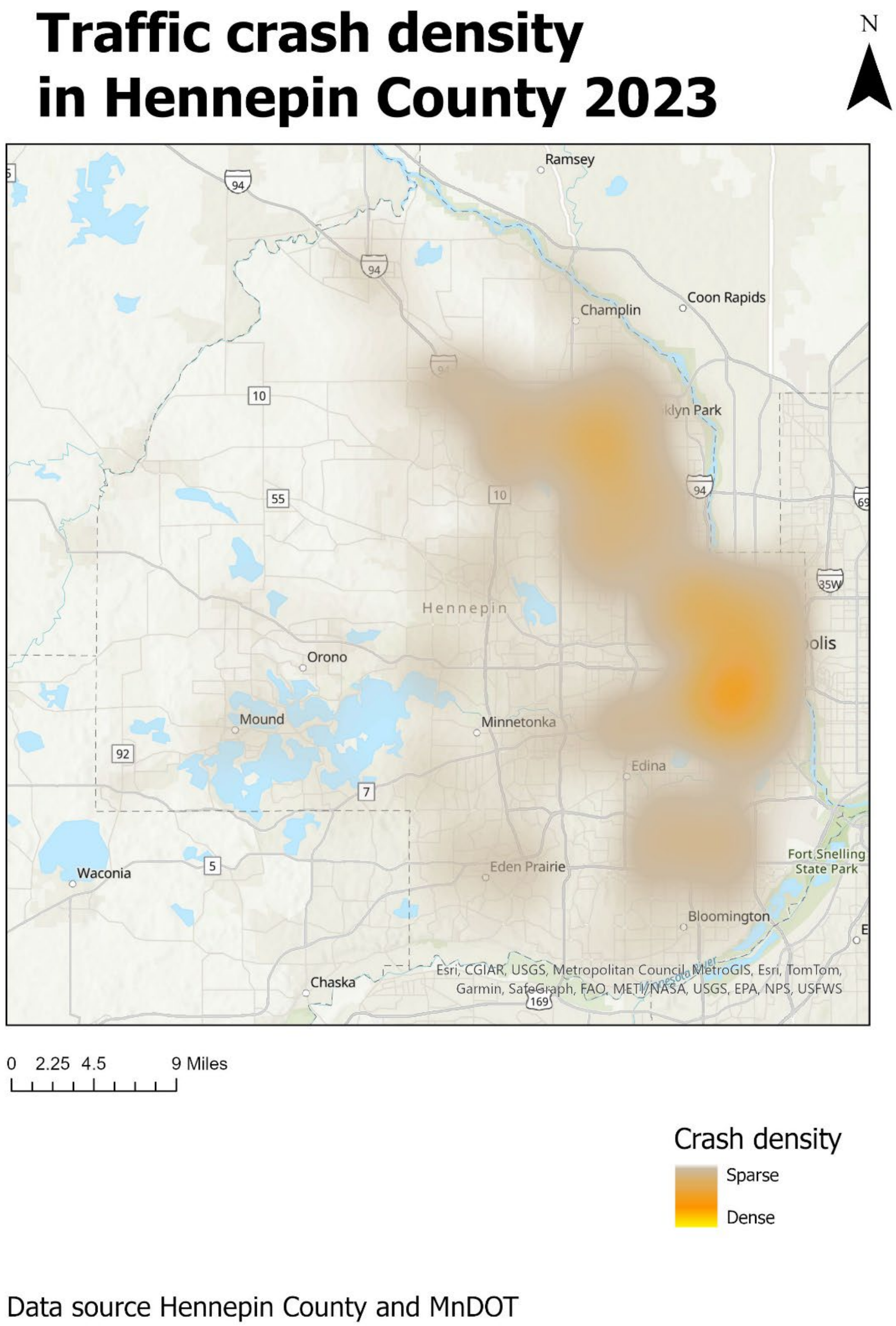

Figure 5-Traffic Crash Density in Hennepin County, 2023. The heat map shows the distribution of traffic crashes in Hennepin County for 2023, with dense crash areas (hot spots) near Minneapolis and sparse crash areas in rural regions. Data Source: Hennepin County and MnDOT.

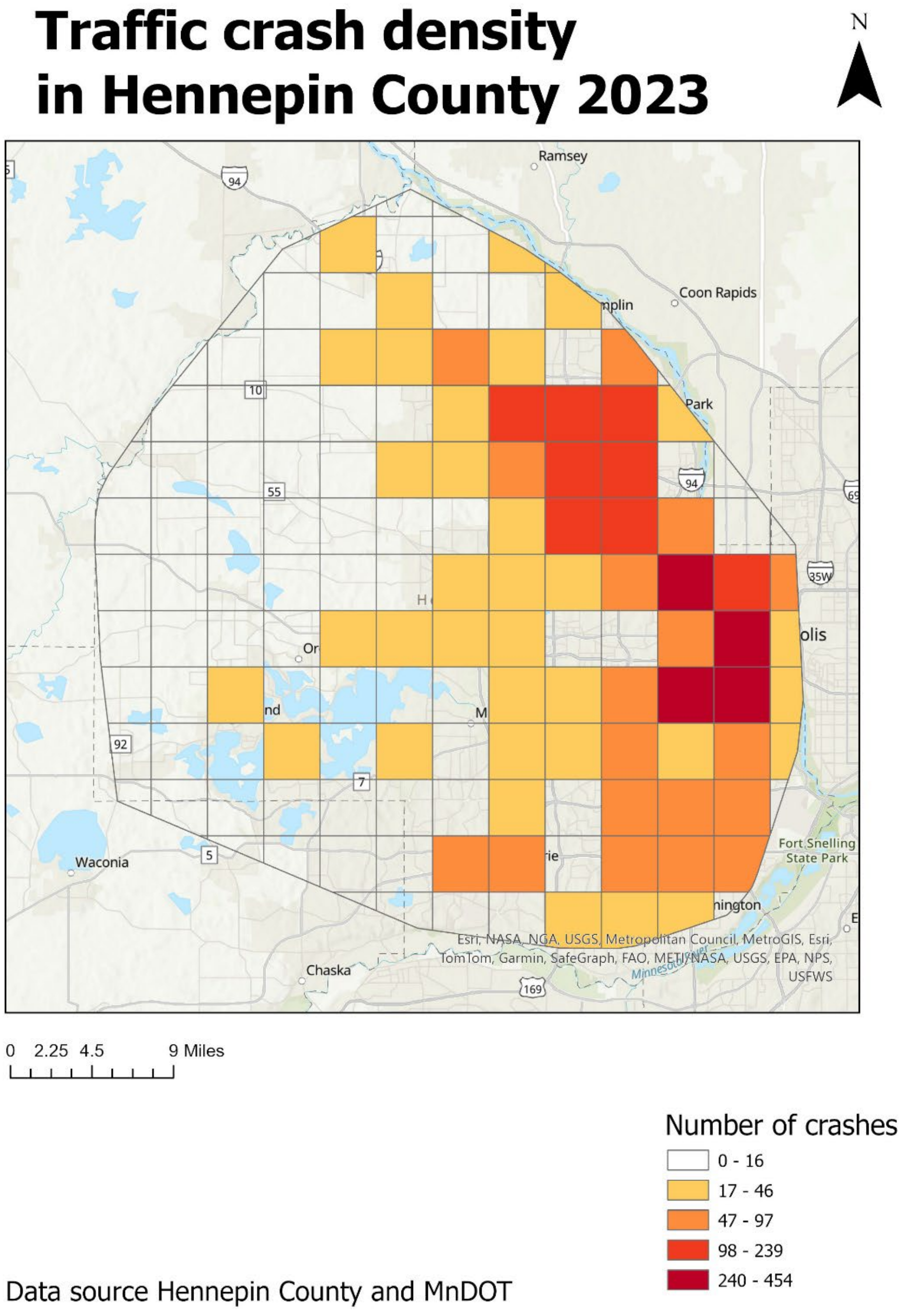

Figure 6-Traffic Crash Density in Hennepin County, 2023. This grid-based map depicts traffic crash densities in Hennepin County for 2023. High-density areas (240–454 crashes) are concentrated in and around Minneapolis, while lower-density areas (0–16 crashes) are located in the outskirts. Data Source: Hennepin County and MnDOT.

Traffic Crash Density in Hennepin County 2024

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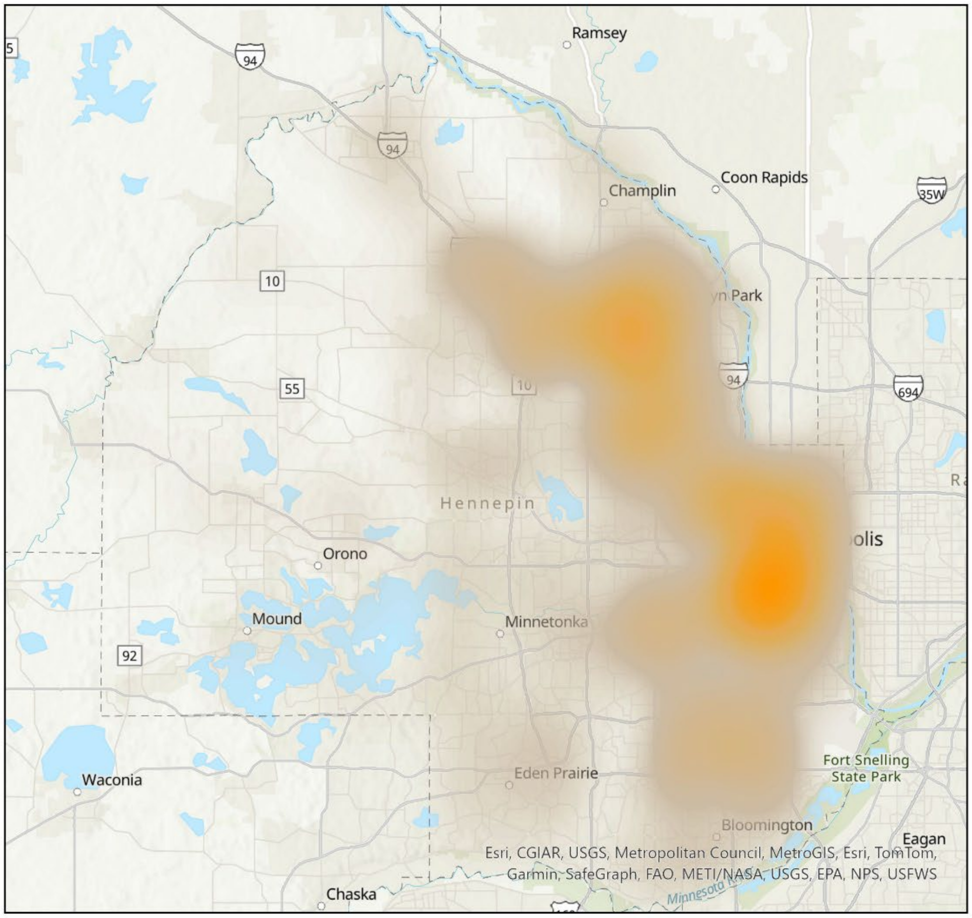

0 2.25 4.5 9 Miles

Crash density

Sparse

Dense

Data source Hennepin County and MnDOT

Figure 7-Traffic Crash Density in Hennepin County, 2024. The heat map displays the spatial distribution of traffic crashes in Hennepin County for 2024 (up to June). Dense crash areas (hot spots) are concentrated around Minneapolis, while sparse areas are evident in rural regions. Data Source: Hennepin County and MnDOT.

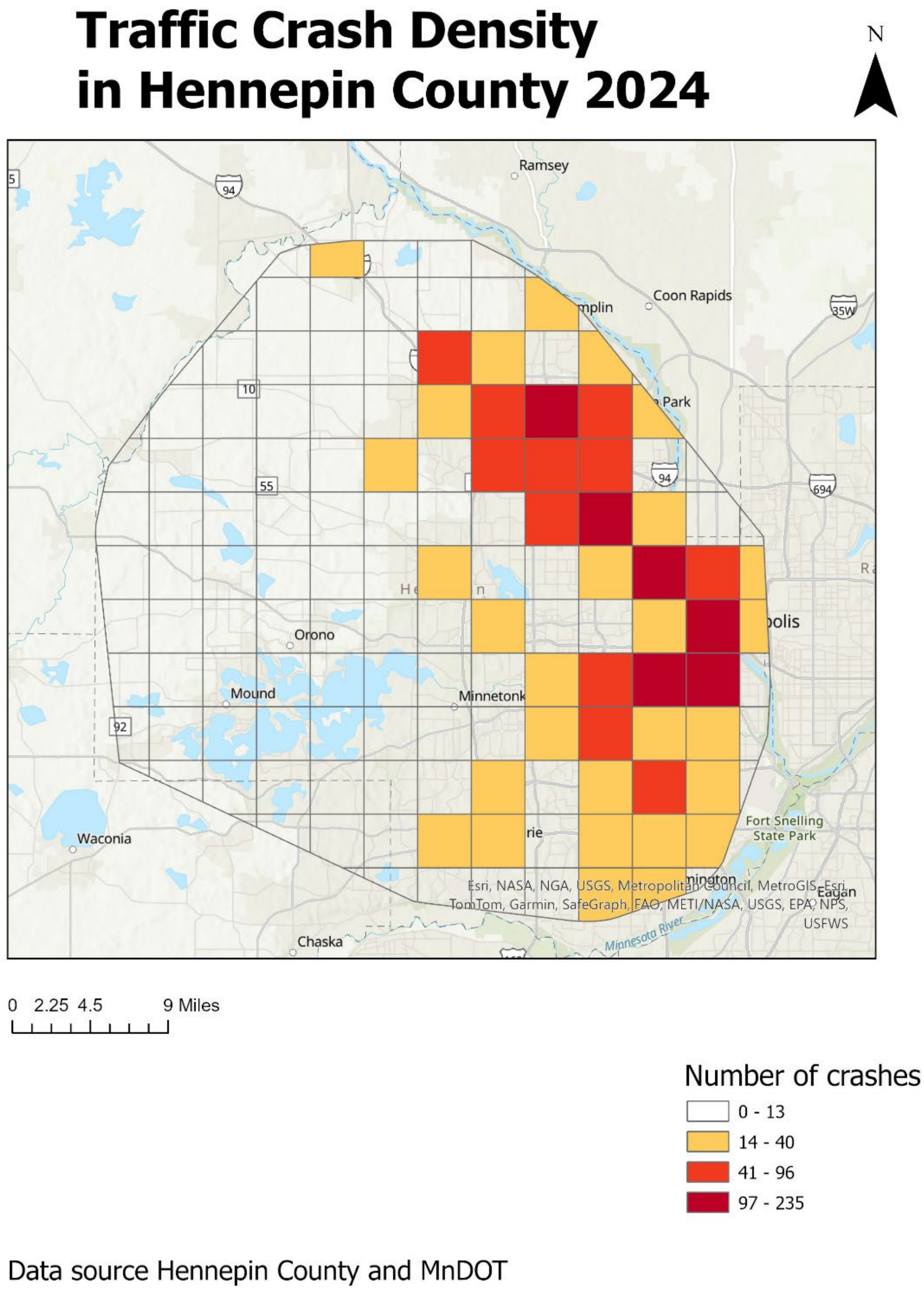

Figure 8-Traffic Crash Density in Hennepin County, 2024. This grid-based map illustrates traffic crash densities in Hennepin County for 2024 (up to June). High-density areas (97–235 crashes) are concentrated near Minneapolis, while lower-density areas (0–13 crashes) are predominantly in rural regions. Data Source: Hennepin County and MnDOT.

Figure 9-Traffic Crash Counts by Weekday and Weekend (2021–2024). The bar charts compare the number of traffic crashes occurring on weekdays versus weekends for the years 2021 to 2024. Across all years, crashes are significantly higher on weekdays compared to weekends, reflecting weekday traffic patterns. Data Source: Hennepin County and MnDOT.

Conclusion

The results reveal persistent hot spots near urban centers, emphasizing the need for targeted traffic safety interventions in these areas. Cold spots in rural regions remain relatively unchanged, suggesting low traffic volumes and crash occurrences. The combination of heat maps and grid-based density analysis provides a comprehensive understanding of crash patterns, both visually and statistically.

These findings can serve as a foundation for policymakers, urban planners, and transportation safety officials to prioritize resources and implement target measures aimed at reducing traffic crashes in high-risk areas.

References

1. Cheng, W., & Washington, S. P. (2005). Experimental evaluation of hot spot identification methods. *Accident Analysis & Prevention, 37*(5), 870–881.
2. Lin, G., Ji-biao, Z., et al. (2018). Analysis of urban road traffic accidents based on improved K-means algorithm. *China Journal of Highway and Transport, 31*(4), 270–279.
3. Ma, Q., Huang, G., & Tang, X. (2021). GIS-based analysis of spatial–temporal correlations of urban traffic accidents. *European Transport Research Review*, *13*(1), 50. https://doi.org/10.1186/s12544-021-00509-y.