Statistical and Spatial Analysis of Precipitation-Related Crashes in Hennepin County, Minnesota from 2018 to 2022

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NSF REU

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1. Background

The Federal Highway Administration's National Statistics of weather-related crashes found:

- **Rainfall alone accounts for about 46% of all weather-related crashes in the United States on average (FHWA).**

Andreescu & Frost (1998) studied weather-related Montreal, Canada:

- **Temperature exhibited a negative correlation-value with accidents.**
- **Precipitation types have a positive association with car-crashes events.**

Pisano et al, (2008) studied statistics of adverse weather-related crashes in the U.S:

- **The Midwest and the South have more rainfall than other parts of the U.S.**
- **On wet days, the number of car-crashes was twice as frequent compared to dry days.**

Yannis & Karlaftis, (2023) investigated weather-related crashes in Athens, Greece using Autoregressive integrated moving average (ARIMA) modeling :

- **High volume of precipitation is associated with fewer accidents (motor vehicle and pedestrian related).**
- **Both precipitation amount and lag value were significantly influential variables.**
- **Findings suggests that lower traffic volume and decreased speeding contribute to lower accident rates during heavier precipitation.**
- **Positive correlation between higher temperatures and increased accidents, whereas they link lower temperatures to reduced traffic volume and speed.**

2. Methodology: Five-Year Analysis (2018 – 2022)

1. Check for Statistical Significance using Correlation Coefficients
- Relationship between Crashes and Precipitation types (Rain & Snow, Respectively).
- Relationship between Crashes and Temperature.

2. Locating Anomalies w/ Statistical Analysis
- Calculate Difference from the Mean.
- Calculate >3rd Standard Deviations.

3. Spatial Analysis
- Locate Area(s) of Greatest Crashes.
- Difference Between Precipitation Crash Locations.

4. Surface and Radar Analysis
- Find Trends in Surface Patterns.
- Find Trends in Storm Behavior.

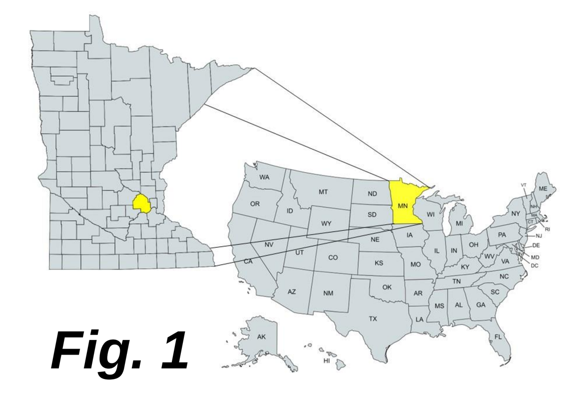


Figure 1: Location of Hennepin County within the United States and Minnesota.

Data

- **Surface Maps from *National Centers for Environmental Prediction & Weather Predication Center* anomalous days. Select days 00z to 06z the following day.**
- **Radar Images from the *National Center for Atmospheric Research* Select days 00z to 06z the following day every 0030z.**
- **Minnesota Department of Transportation crash data from 2018 to 2022.**

Domain: Hennepin County, Minnesota in figure 1, highlighted in yellow.

What type of weather patterns are associated with the most precipitation-related crashes?

3. Results

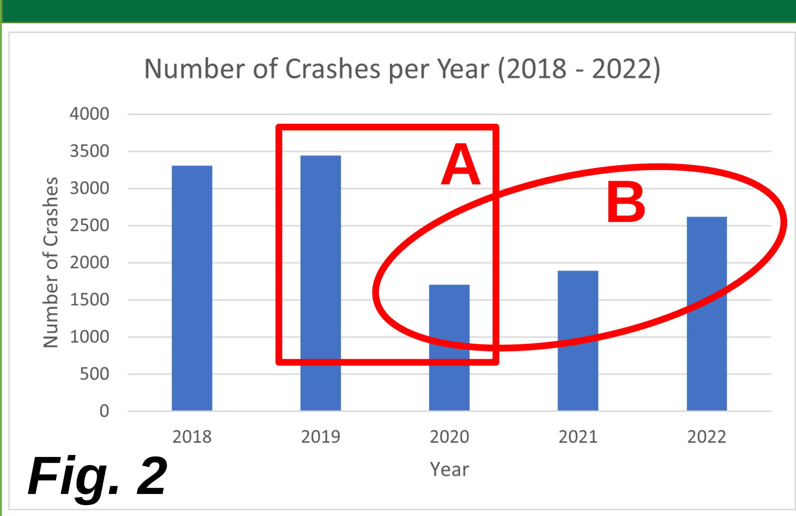


Figure 2: Number of crashes per year.

- **Significant drop in crashes from 2019 to 2020 (Fig. 2 A).**
- **Steady increase in crashes since 2020 as restrictions were removed (Fig. 2 B).**

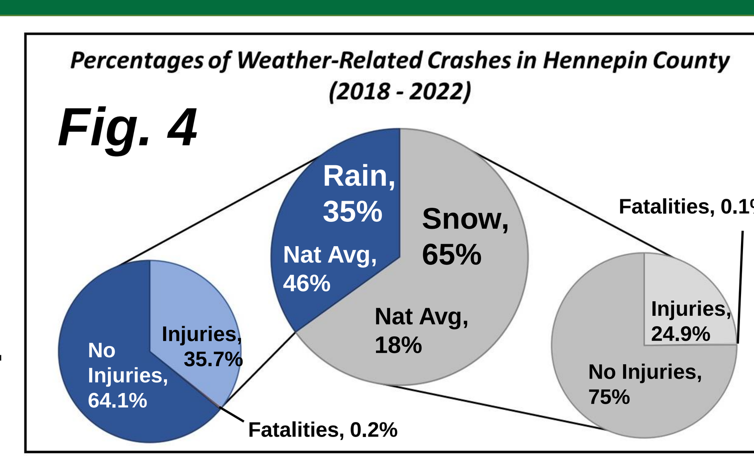


Figure 4: Hennepin County rain and snow crashes by percentage and national average for comparison.

- **February is the only month to go above two standard deviations (Fig. 5 A).**
- **Summer and fall months have more crashes occurring during evening rush hour (Fig. 5 B).**

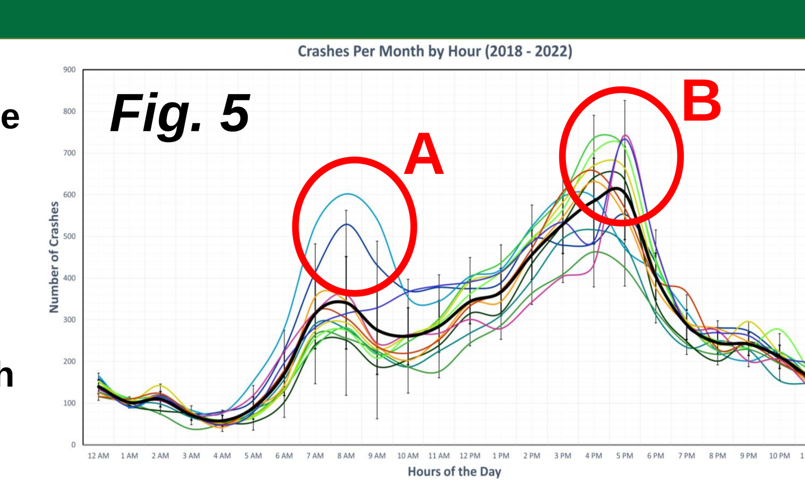


Figure 5: Sum of crashes per month by hour with a moving average and two standard deviations

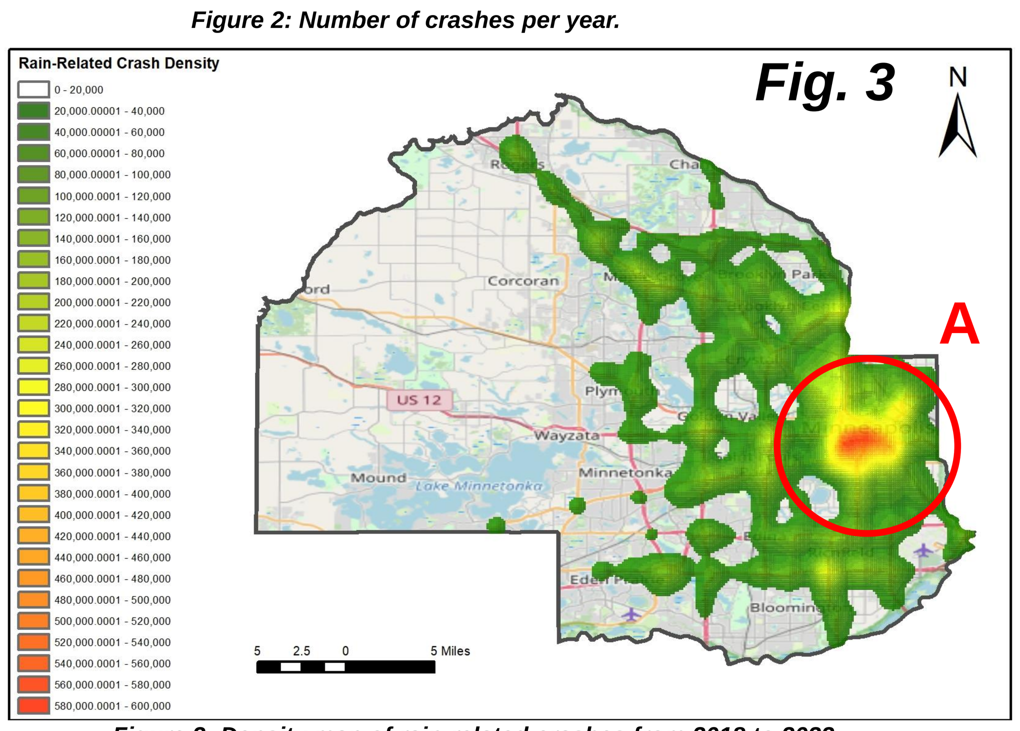


Figure 3: Density map of rain-related crashes from 2018 to 2022

- **Most rain-related crashes occur in downtown Minneapolis (Fig. 3 A).**
- **Precipitation related crashes in Hennepin County, only 35% are rain-related. The national average is 46% (Fig. 4).**
- **Most of the precipitation related crashes are snow-related at 65%. The national average is 18% (Fig. 4).**
- **Winter months have more crashes occurring during morning rush hour (Fig. 5 A).**
- **Most snow-related crashes occur in downtown Minneapolis, however unlike rain, more occur on the highways and interstates and areas of traffic confluence (Fig. 6 A).**
- **Difference between figure. 3 & figure. 6 are visualized in figure. 4.**

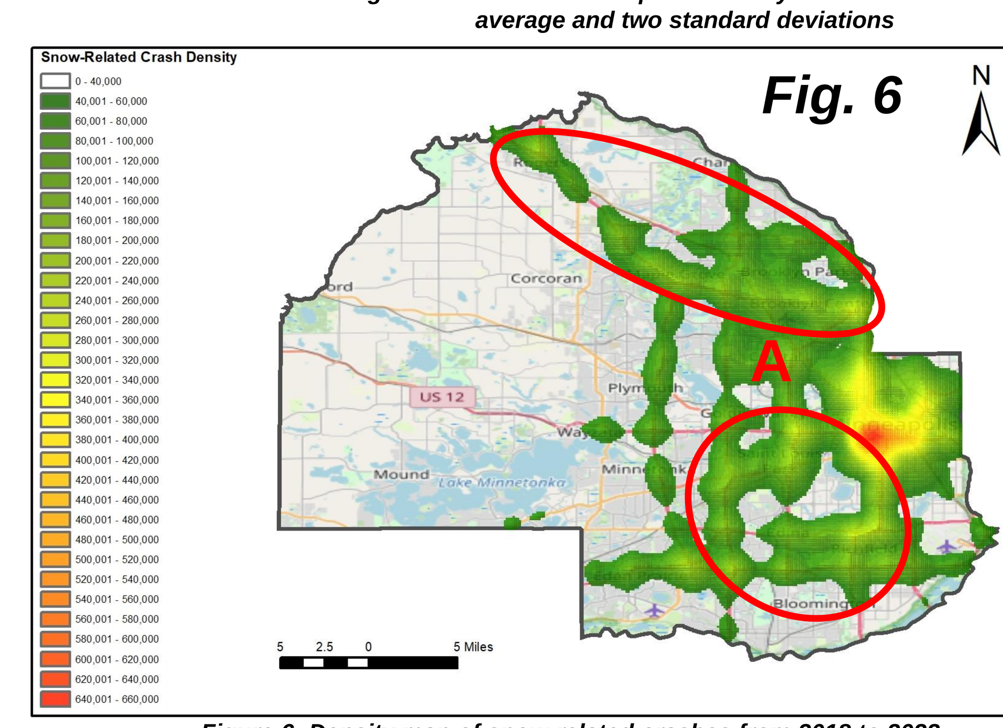


Figure 6: Density map of snow-related crashes from 2018 to 2022

4. Case Study: Rain-Related Crashes on October 26, 2018

October 26, 2018, had 0 fatalities, 25 injuries, 61 crashes, 0.5 mm.

- **Surface Analysis: Low, trough, and stationary front (Fig. 7a).**
- **Radar Analysis: two waves of scatter showers (Fig. 7b).**
- **Inverse relationship of temperature and crashes (Fig. 8).**
- **Highest number of crashes during rainy months (Fig. 8).**
- **Evening precipitation and most crashes (Fig. 9).**
- **Positive relationship of crashes and hourly rainfall (Fig. 9).**

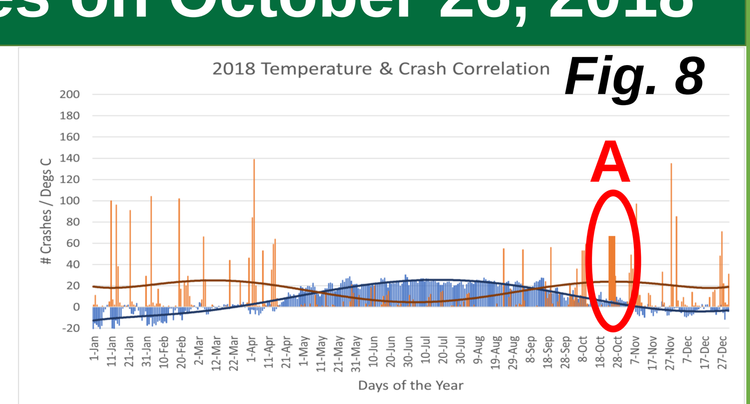
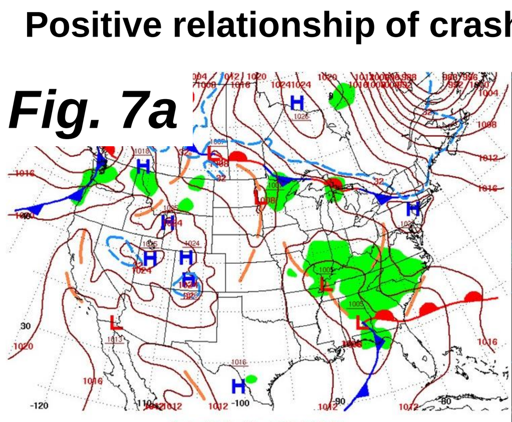


Figure 8: 2018 yearly average temperature and sum of crashes per day. Each with a six-order polynomial averaging.



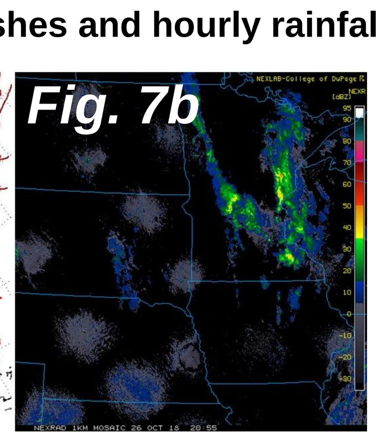


Figure 7: October 26, 2018: a) Surface analysis at 7am EST. b) Radar image, at 2055 UTC.

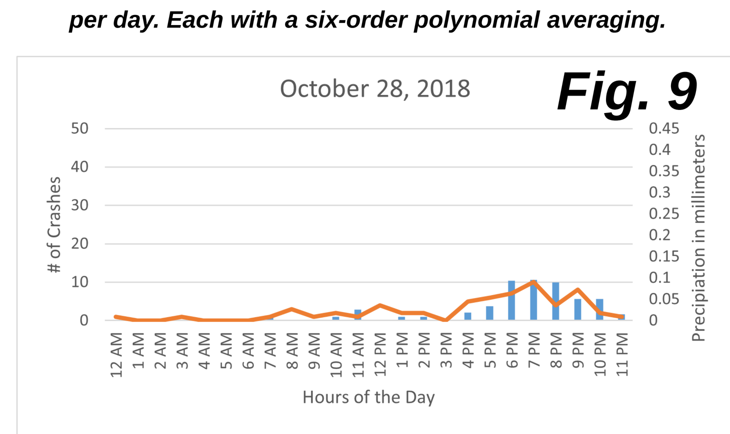


Figure 9: October 26, 2018: Precipitation (mm) visualization correlation with sum of crashes by hour.

5. Case Study: Snow-Related Crashes on Nov 14, 2022

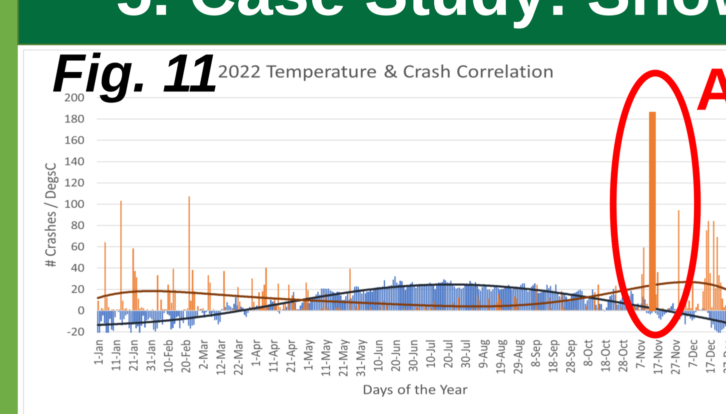


Figure 11: 2022 yearly average temperature and sum of crashes per day. Each with a six-order polynomial averaging.

November 14, 2022, had 1 fatality , 35 injuries, 184 crashes, 1.3mm.

- **Surface Analysis: Low, trough, and cold front (Fig. 10a).**
- **Radar Analysis: Long lasting snowstorm (Fig. 10b).**
- **Inverse relationship of temperature and crashes (Fig. 11).**
- **Highest number of crashes during snowy months (Fig. 11).**
- **Most crashes occurred during morning rush hour (Fig. 12).**
- **Positive relationship of crashes and hourly snow (Fig. 12).**

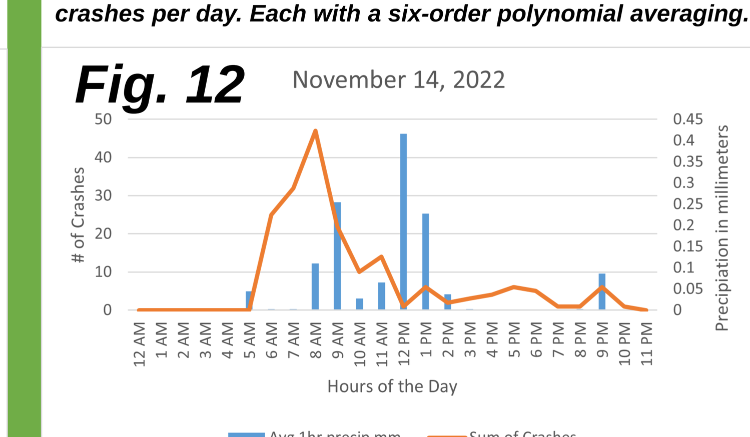
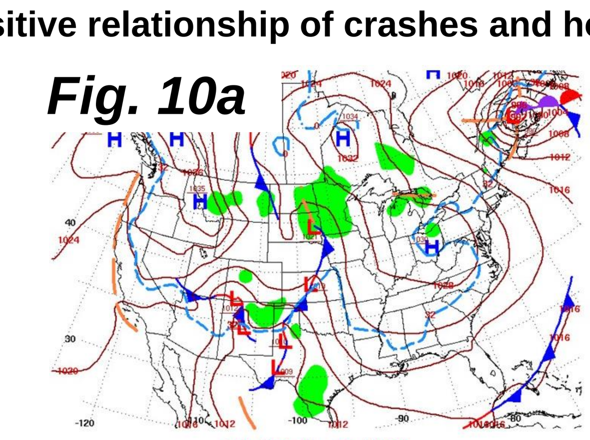


Figure 12: November 14, 2022: Precipitation (mm) visualization correlation with sum of crashes by hour.



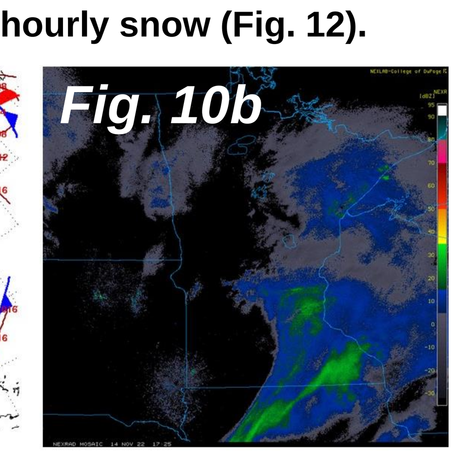


Figure 10: November 14, 2022: a) Surface analysis at 1100 UTC. b) Radar image on the right at 1725 UTC.

6. Conclusion

1. **A surface low and surface trough in proximity to a cold or stationary front are seen in both case studies.**
2. **Radar observations of long duration storms or waves of precipitation are shown to increase the number of crashes.**
3. **Statistically significant positive correlation between precipitation (rain and snow) and traffic accidents.**

7. Future Work

- ***Autoregression Models & Poisson*: Probability occurrence of traffic accidents and meteorological influences.**
- ***Morphology of Weather Systems*: In-depth analysis of radar and surface evolution.**
- ***Comparable Latitudinal Climates*: Study other cities at the similar latitudes and climate for verifying results.**

8. References

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