Texas A&M Transportation Institute

Crash, Congestion, and Air Quality: Unraveling NOx Emissions Patterns in Texas

Rohit Jaikumar, Rodolfo Souza, and Madhusudan Venugopal

Background

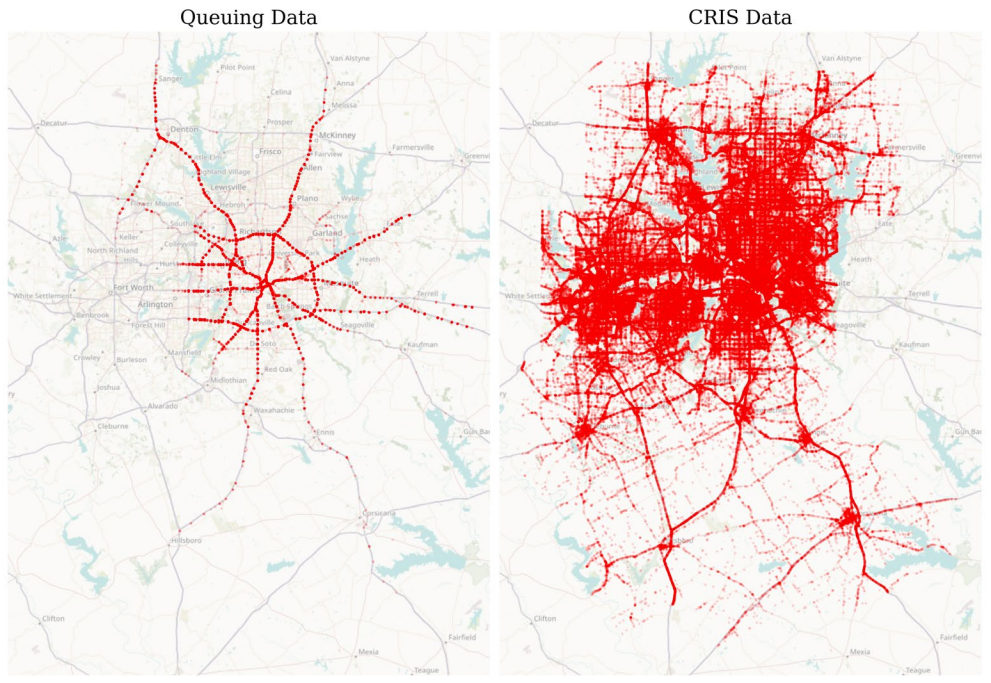
- Over 40,000 fatalities and 2.4 million injuries annually (2019-2023).
- Economic cost of crashes: $340 billion in 2019.
- Traffic incidents contribute to 25% of total congestion.
- Increased fuel consumption and emissions during congestion.

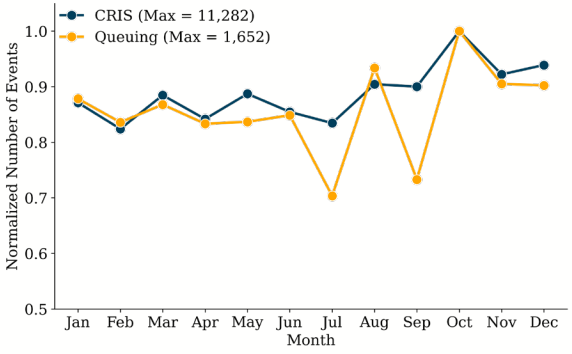
Motivation and Objective

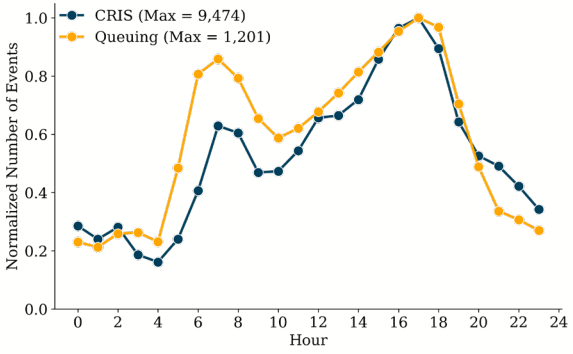
- Crashes not only result in fatalities and injuries but also contribute to increase congestion, higher fuel consumption, and degrade air quality.
- Addressing NOx emissions from non-recurring congestion is essential for improving environmental health.
- **Objective:**
  - Analyze the relationship between traffic incidents and NO_x emissions.
  - Develop predictive models using machine learning techniques.
  - Predict regional emissions due to crashes in Dallas Fort worth Area

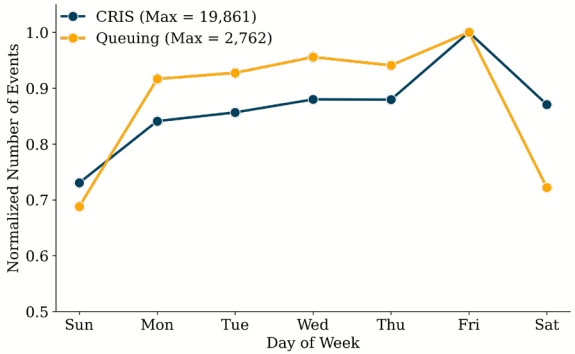
Methodology

- Data Sources:
  - **Crash Record Information System (CRIS)**: 601,537 incidents.
  - **Queuing Data from ITS sensors (2019-2023)**: Detailed traffic flow and emission data.
- Merging datasets using spatial-temporal proximity.
- Additional NOx emissions caused by an incident, calculated by subtracting the historical baseline emissions from the emissions during the incident.
- Analysis Tools: Machine learning models to predict NO_x emissions.



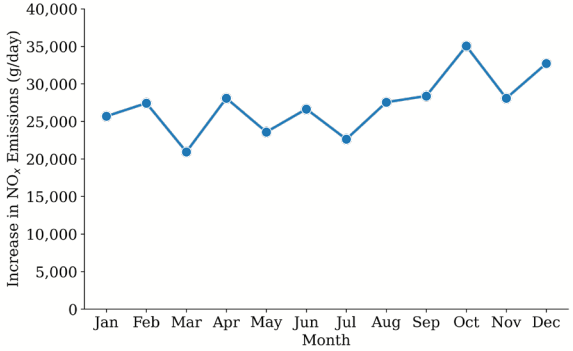


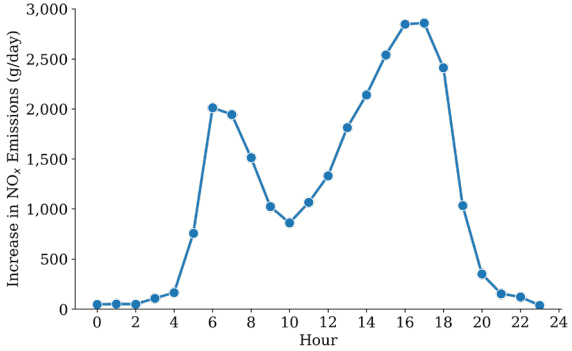


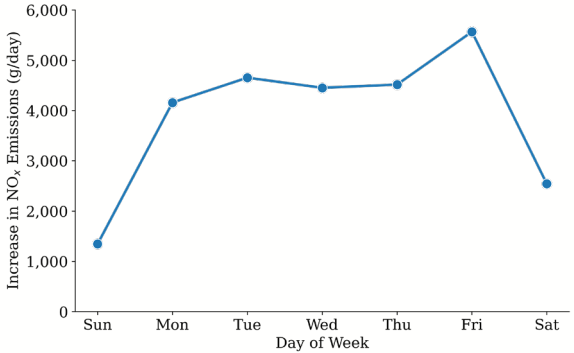


Incident Characteristics

- Queuing and CRIS data exhibit consistent temporal patterns.
- 63% of incidents result in no injuries.
- Traffic incidents peak in October, on Fridays, and during morning (7–8 AM) and afternoon (3–6 PM) commute hours.





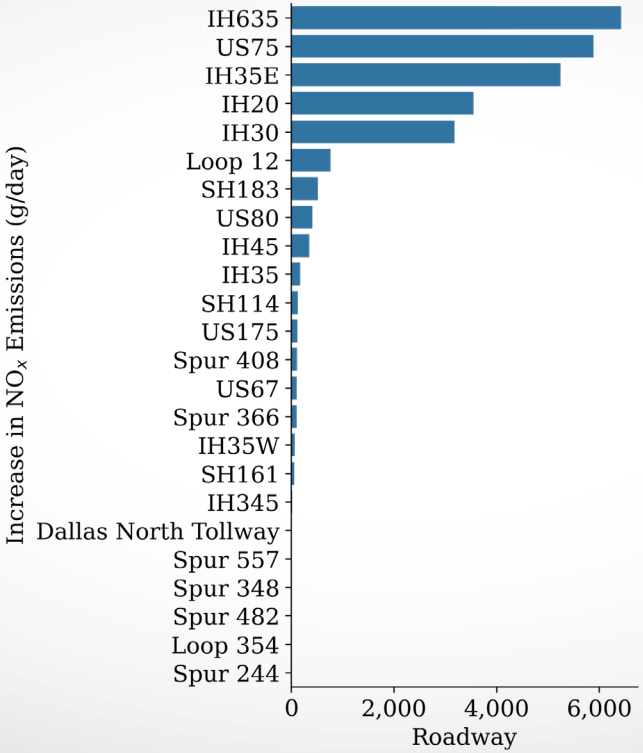


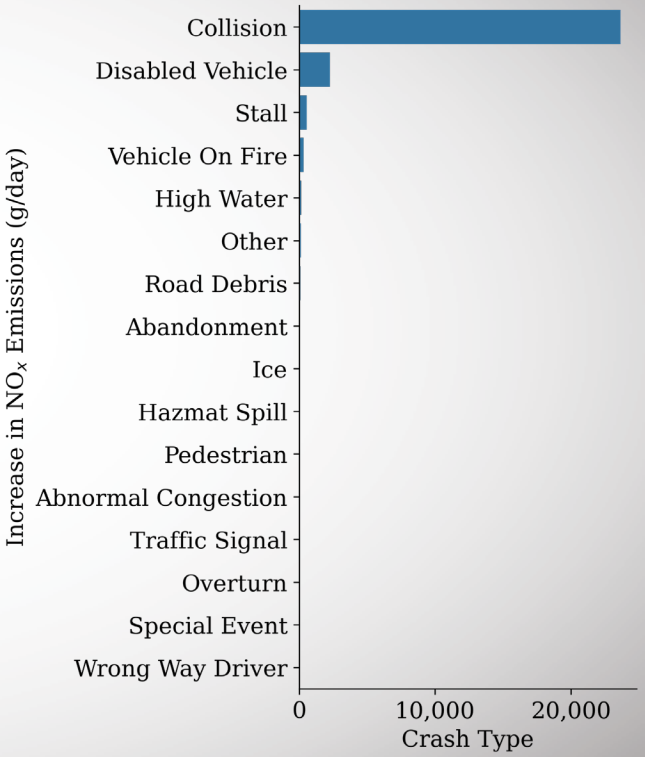
Impact on Emissions

- Queuing data shows NO_x emissions increase aligns with incident patterns.
- Monthly NO_x increases exceed 20,000 g/day.
- Emission trends analyzed by time, roadway, and incident type reflect congestion impacts.

Impact on Emissions

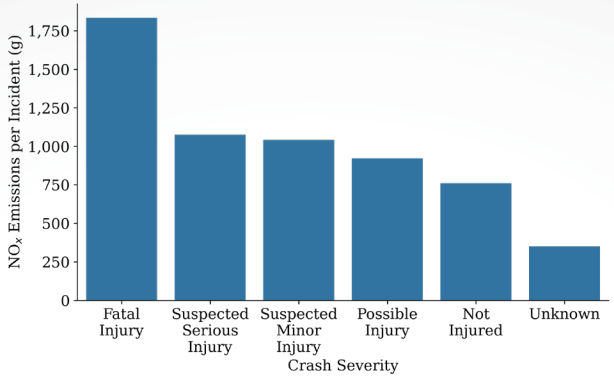
- Major highways (IH635, US75) show the highest emissions.
- Collisions as the primary contributors.

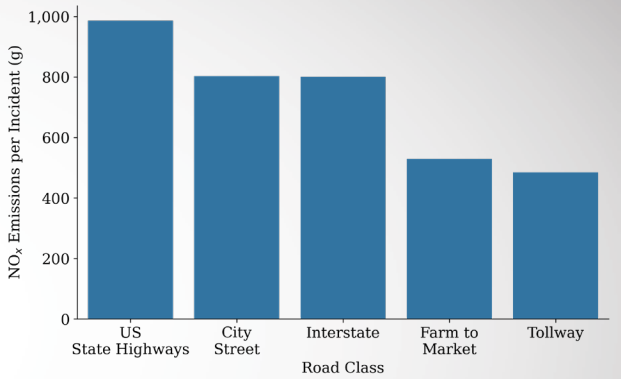


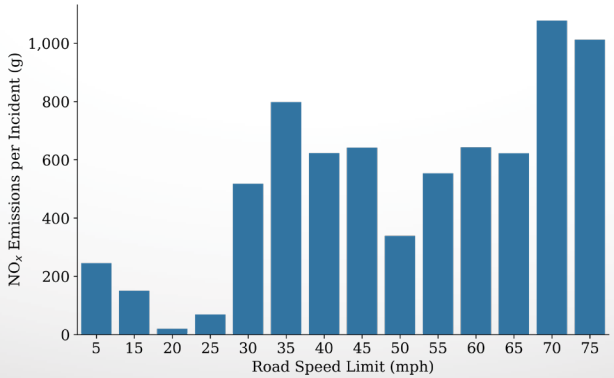


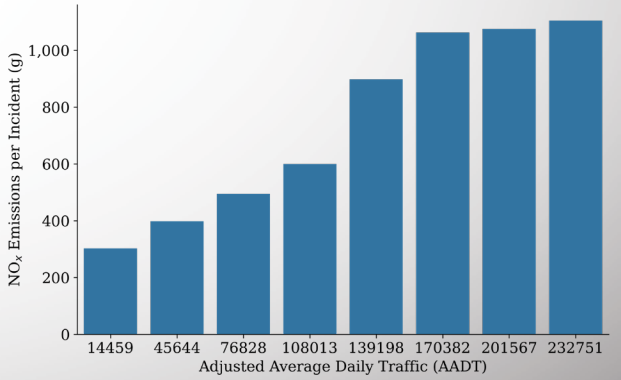
Impact on Emissions

- Crashes involving fatalities generate the highest NO_x emissions.
- US and State highways exhibit the highest NO_x emission levels.
- Roads with speed limits of 35 mph or over 70 mph show increased emissions per incident.
- Emissions rise proportionally with AADT, exceeding 170,000 vehicles.



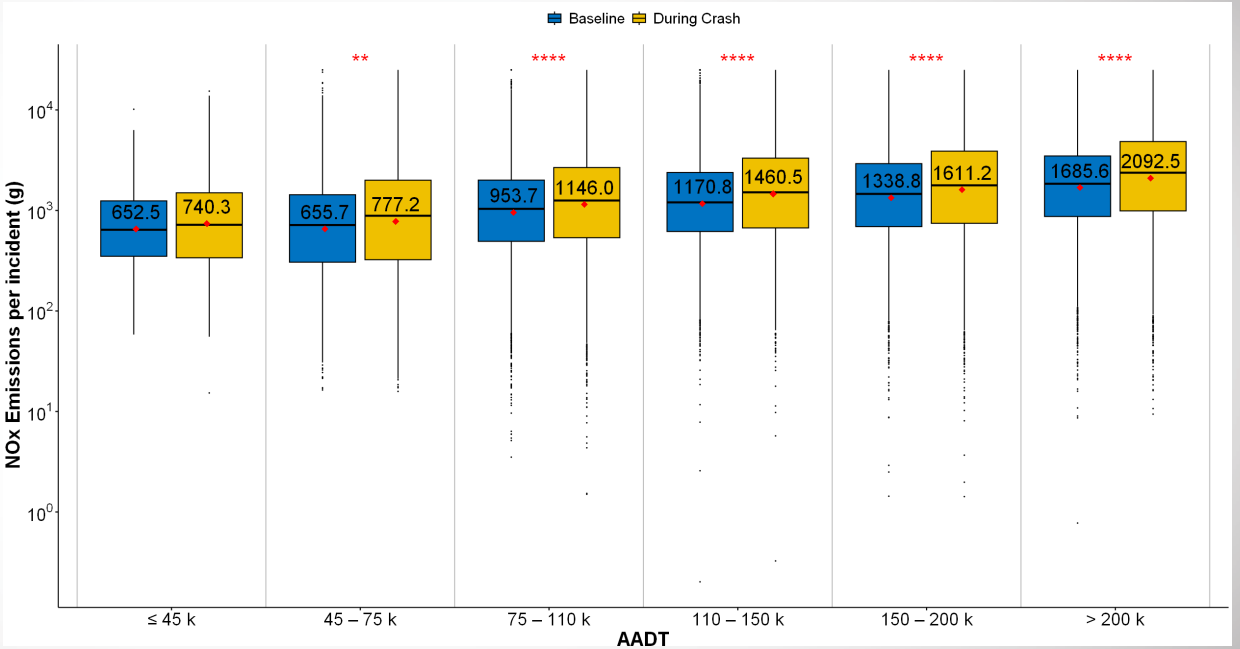






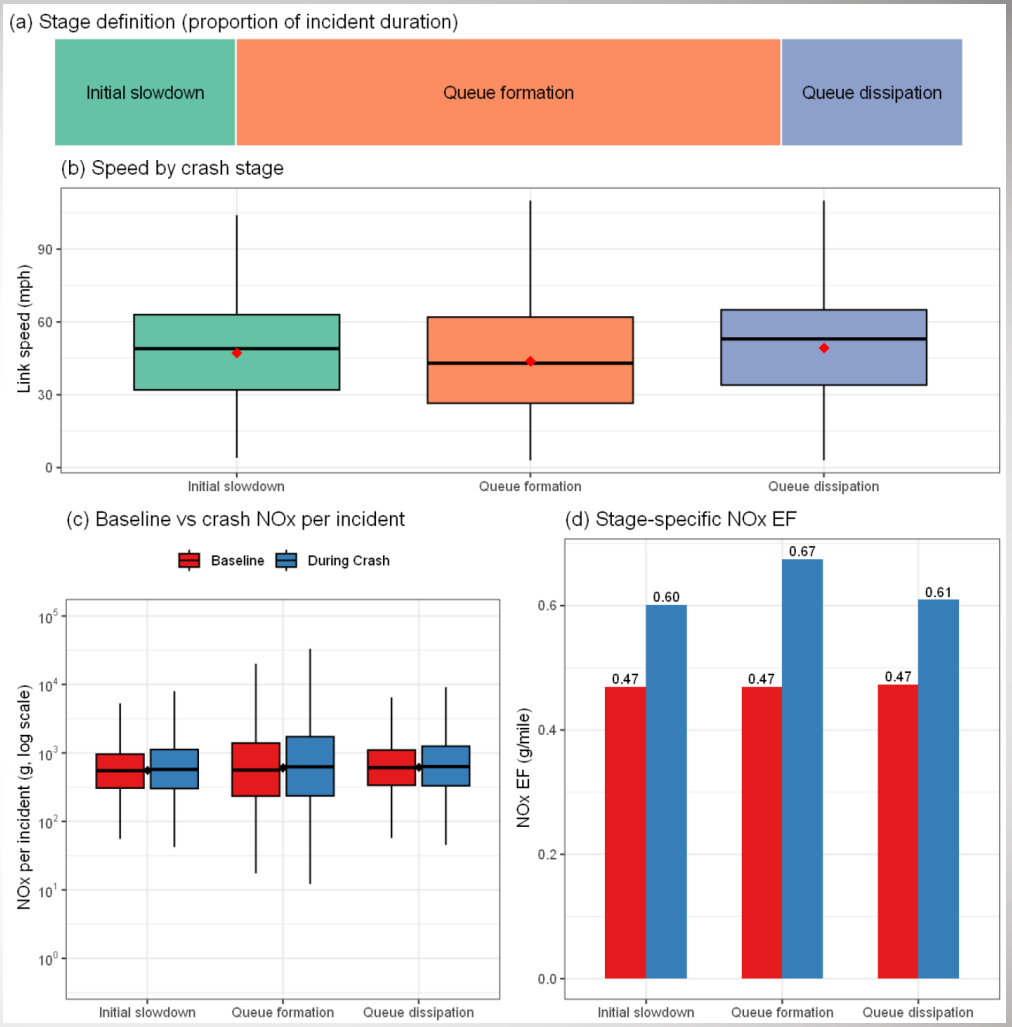
Isolating the Crash Impact on Emissions

- **Matched-Pair Analysis:** Isolates the direct impact of a crash by comparing its emissions to a normal, historical baseline for the exact same time and location.
- **Key Finding:** Crashes cause a statistically significant increase in NO x emissions.
- **Impact by Volume:** On the busiest roads, this increase is ~24% above normal emission levels.



The Stages of an Incident

- **Three Phases of an Incident:** Crashes were analyzed in three stages: initial slowdown, queue formation, and queue dissipation.
- **Initial Spike is Critical:** The first 20% of the incident alone causes 46% of the excess NOx emissions.
- **Sustained Emissions:** The emission rate peaks during the queue formation stage due to inefficient traffic flow.

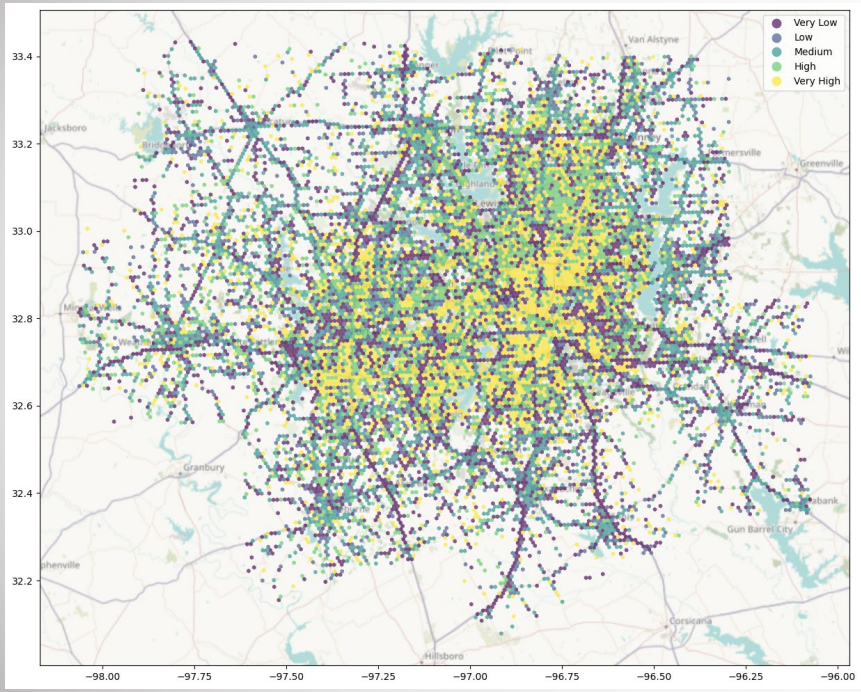


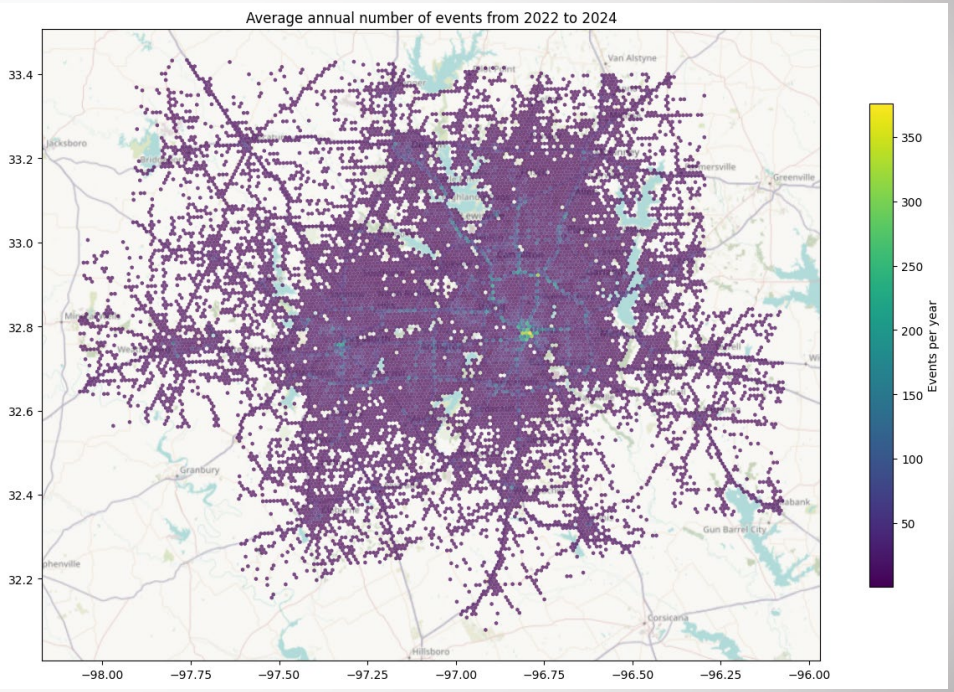
Predictive Modeling

- Models Used:
  - Logistic Regression, **XGBoost**, Random Forest, GBM, Neural Networks.
- Key Features:
  - Hour of day, incident duration, road class, traffic volume, crash severity, day of week, month.
- Performance:
  - Moderate accuracy (42%).
  - Duration, Hour of Day and Average Daily Traffic are top predictors.
- Implications:
  - Potential for refinement using real-time data.

Emission Level	Threshold (g/incident)	Precision
Very Low	2	0.54
Low	37	0.33
Medium	234	0.31
High	762	0.33
Very High	3,225	0.50
Accuracy	-	0.42

Regional Emission Impacts (Predicted) in DFW area





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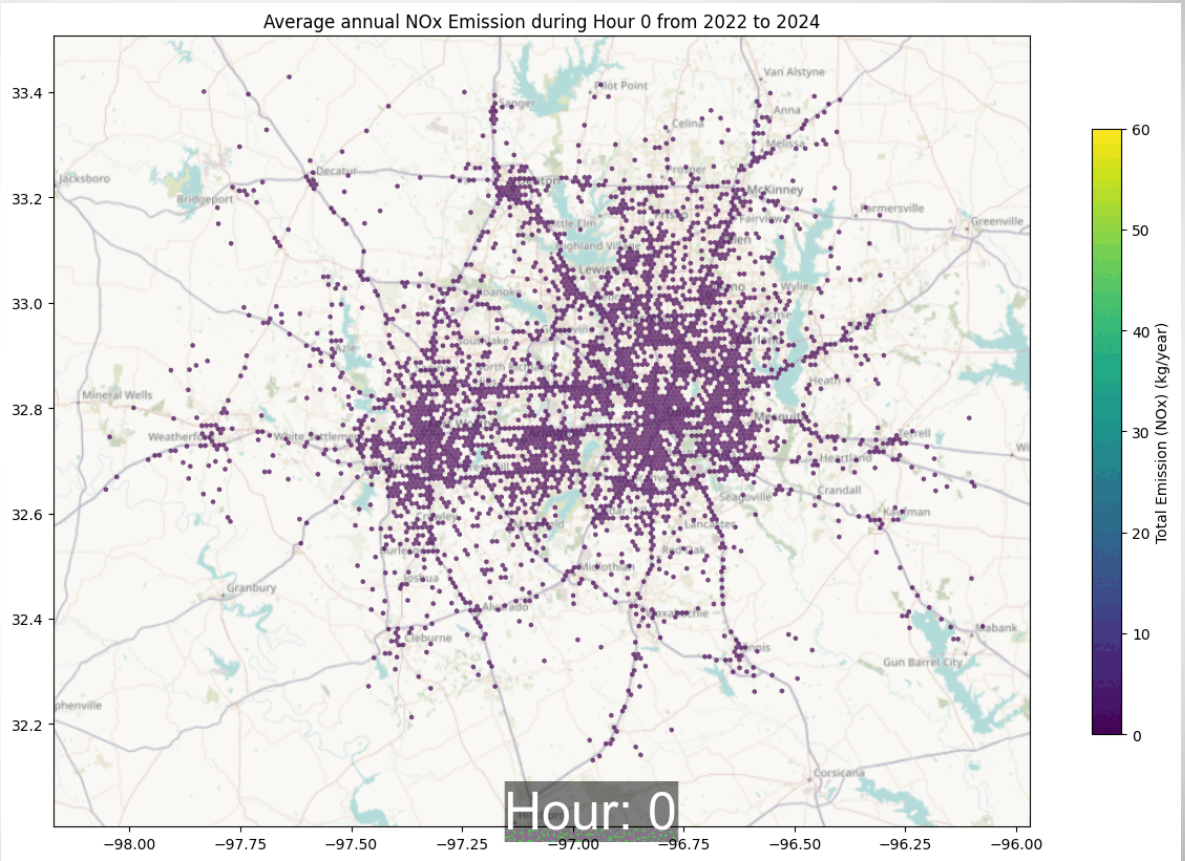

Traffic Management Implications

Faster clearance of high-emission incidents (e.g., collisions).

Targeted responses during peak hours and major highways.

Variable speed limits to manage upstream congestion.

Adaptative traffic systems for emissions hotspots.

Conclusions

- Traffic crashes peak NO_x emissions during rush hours and Fridays.
- Highways (e.g., IH635, IH35E) and severe crashes drive the most emissions.
- Incorporate non-recurring congestion to the emission inventories.
- Future focus: real-time data, electric/autonomous vehicles, and sustainable strategies.

Acknowledgements

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Questions?

Madhusudan Venugopal
Email: M-Venugopal@tti.tamu.edu