Unlocking Insights into Traffic Collisions in Chicago: A Data-Driven Approach to Urban Safety

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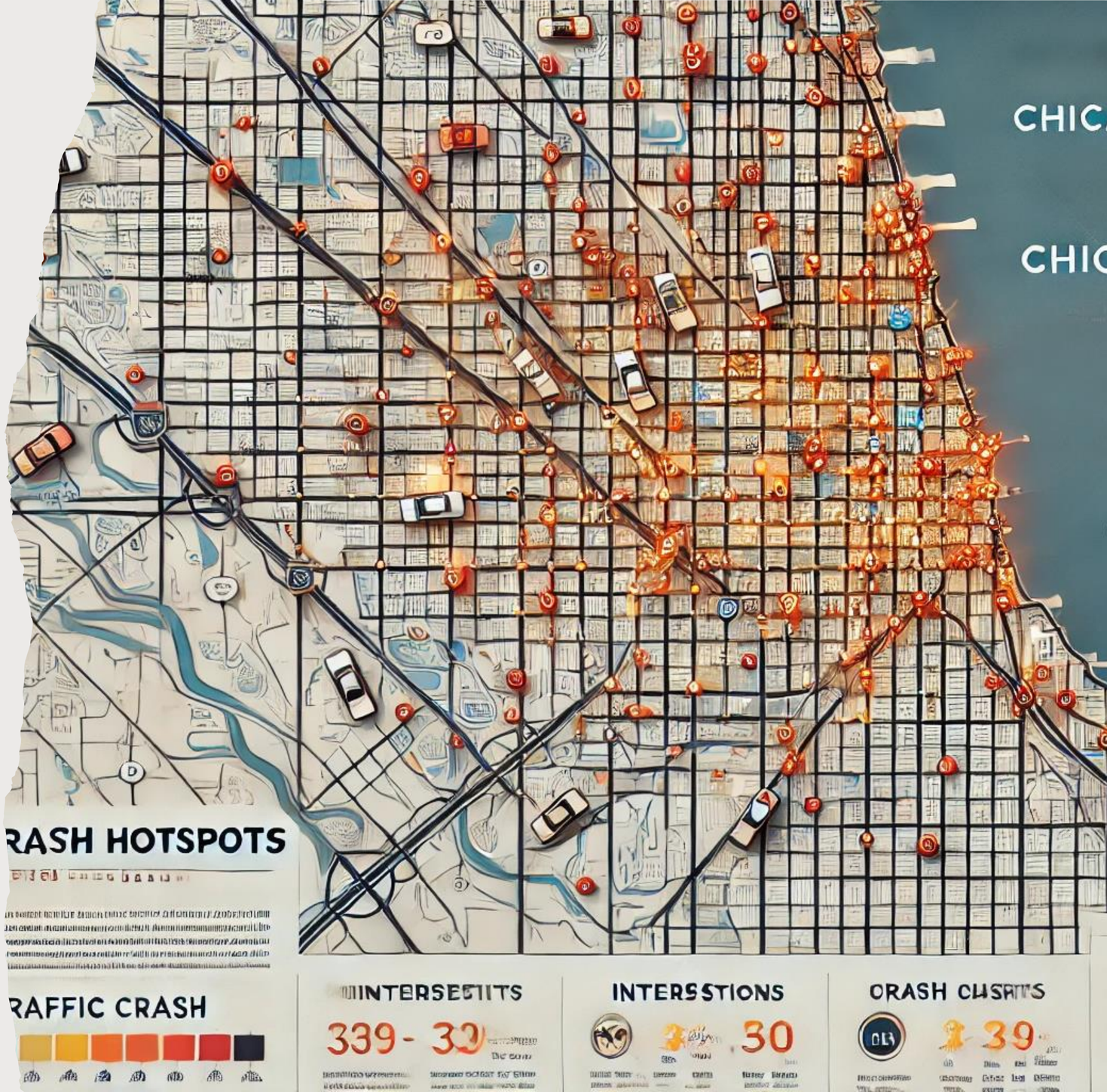
Course: Business Process Analytics (DSCI 5260)

Analysis of Traffic collisions in Chicago

- Scope: The study explores traffic collisions in Chicago with a focus on vulnerable road users—pedestrians and cyclists.

- Motivation: Traffic collisions are a pressing global issue, causing over 1.3 million fatalities annually and leaving many more injured (WHO, 2023).

- Objective: To identify patterns, evaluate the effectiveness of current safety measures, and recommend actionable interventions to enhance road safety.



Literature review

PAPER NAME	AUTHOR(S)	PROBLEM AND METHOD	SUMMARY
Crash Trends and Traffic Safety Analysis	National Highway Traffic Safety Administration (NHTSA), European Union Statistics	Examines global traffic crash trends, demographics, crash severity, and factors like human error, speeding, alcohol influence, and distracted driving.	NHTSA reports an 8-quarter decline in traffic fatalities, emphasizing safer infrastructure, $1.7 billion in funding, advanced safety technologies, updated policies, and collaboration to enhance road safety and reduce preventable deaths.
Understanding Pedestrian Safety in Urban Areas	World Health Organization (WHO), Global Road Safety Facility	Examines urban pedestrian safety, addressing distracted walking, crosswalk deficiencies, and disparities, recommending lanes, crossings, and education campaigns.	Road traffic injuries cause 1.19 million deaths annually, heavily impact low-income countries, cost 3% of global GDP, and require urgent action through proven measures and WHO-led global safety initiatives.
Effectiveness of Road Safety Interventions in Chicago	John Wiley and Sons Ltd., Vision Zero Action Plan	Analyzes Chicago's Vision Zero plan, emphasizing global strategies, safety technologies, public education, and phased goals to eliminate traffic fatalities.	The study draws from literature on Vision Zero’s system-based safety approach, policy design, diffusion, and critiques. Key insights include the shift from individual to systemic responsibility, policy transfer complexities, and ethical considerations influencing implementation across various safety sectors.
Road Safety Policies and Advanced Technologies for Traffic Control	Vision Zero Action Plan, Chicago Department of Transportation	It recommends automated braking, seatbelt sensors, speed control, barrier gates, flyovers, equitable policies, driver training, and community engagement.	The Vision Zero policy, adopted in Sweden in 1997, focuses on eliminating traffic fatalities through systemic design and shared responsibility. Research highlights its effectiveness in reducing road deaths, and inspiring cross-sectoral applications. Criticized for being ambitious and costly, it underscores challenges in adapting its principles across diverse safety domains and contexts.

Research Questions

1. What is the relationship between speed limits and crash types?

2.a. How effective are traffic signals in reducing crashes compared to other control devices?

b. How does a traffic control device affect the chances of rear-end collisions?

3. How do crash severity and contributory causes vary by time and day of the week?

4. Effects of Weather on Motor Vehicle Accidents: How do weather characteristics affect crash rates and severity?

Research Methodology

Data Analysis

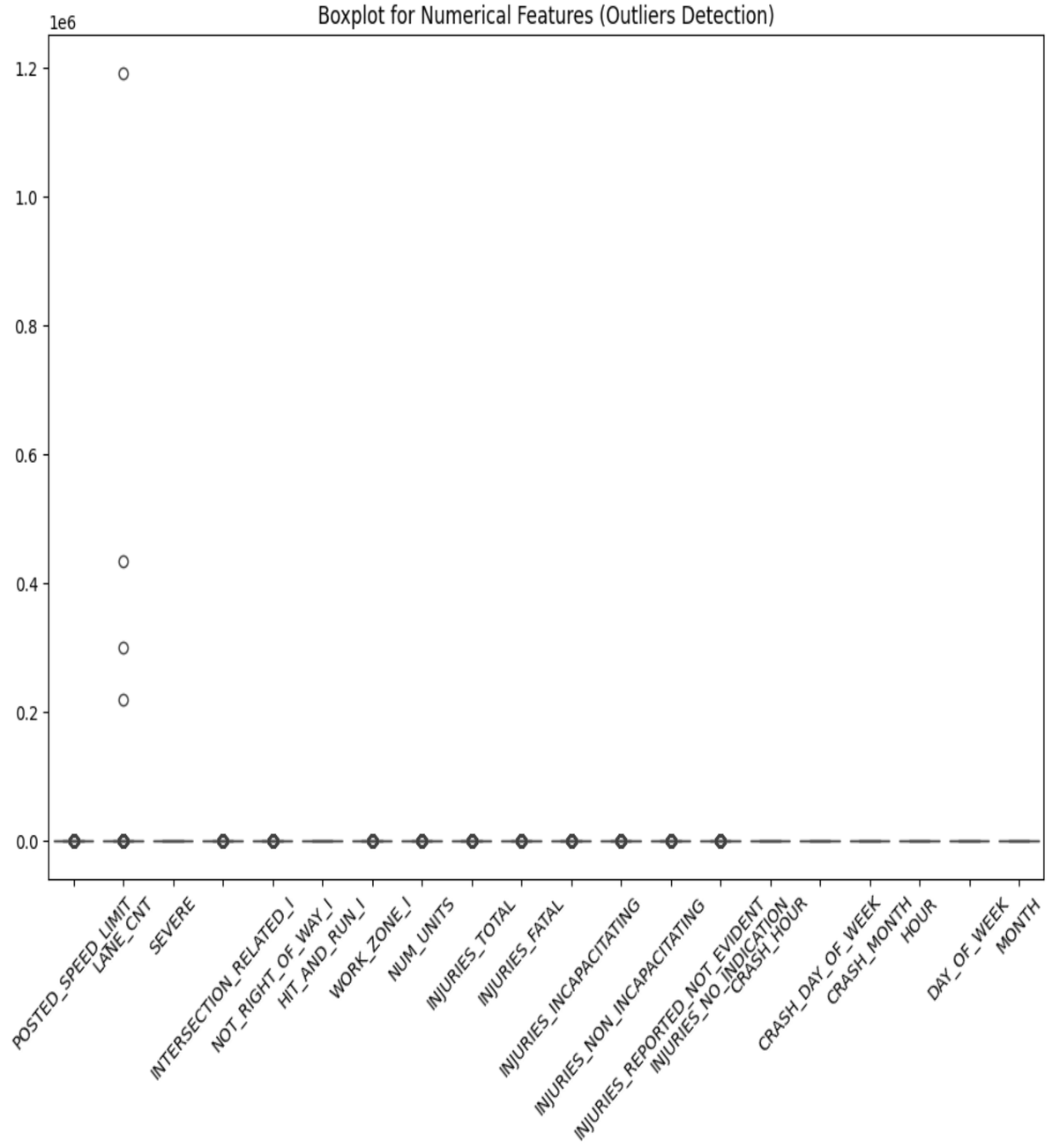
1.Preprocessing:
- Addressing 9M+ missing data points.
- Feature engineering for temporal and spatial insights.

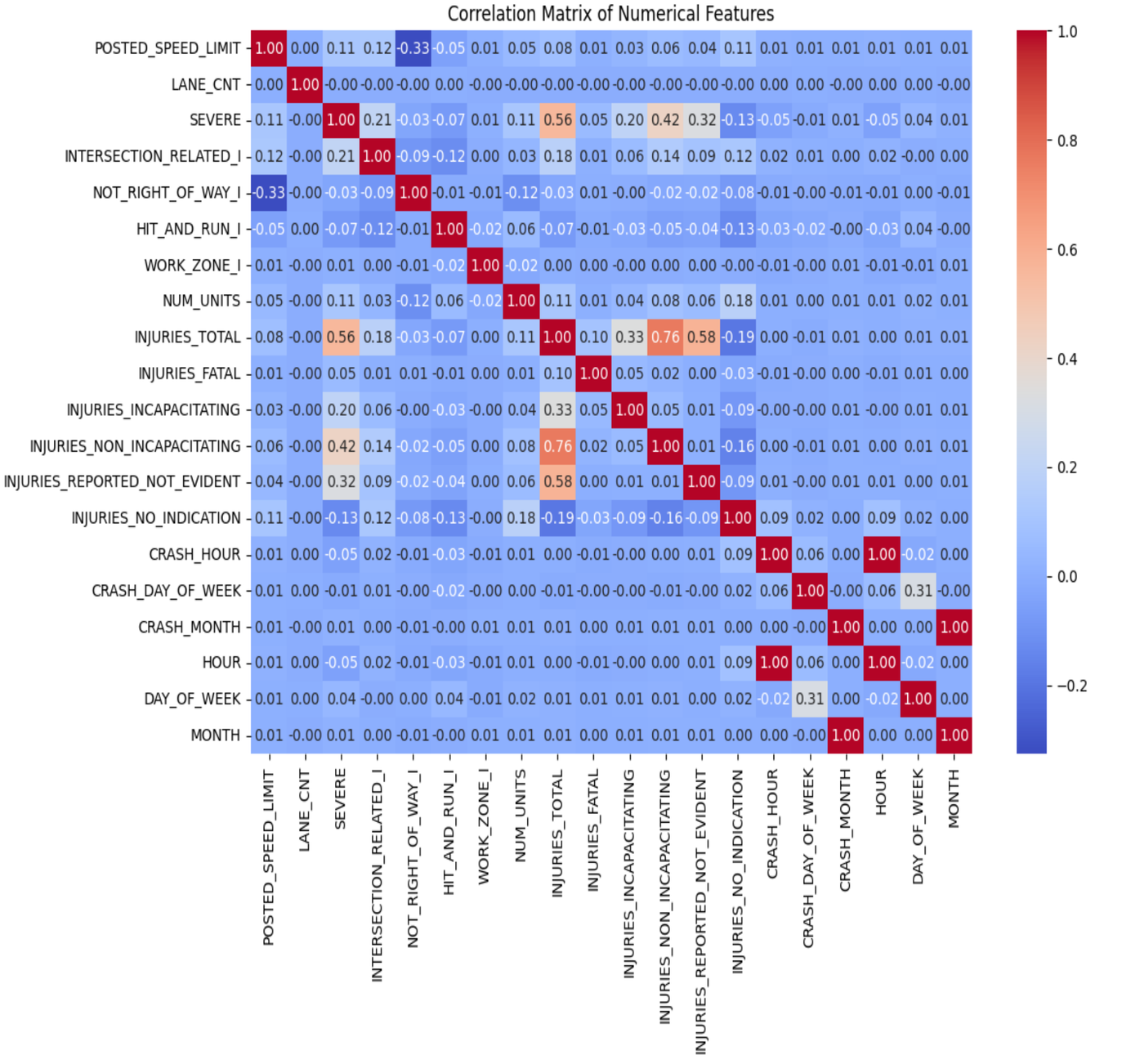
2.Visualizations:
- Boxplots, scatterplots, and heatmaps to detect trends and outliers.

3.Predictive Modeling:
- Logistic Regression, Decision Trees, and Random Forests to evaluate crash severity predictors.

Research Design

- Quantitative Analysis: Focused on descriptive and inferential methods to evaluate crash patterns and safety measure efficacy.
- Data Source: Chicago Police Department’s E-Crash system- a comprehensive repository with over 880,000 records since 2017.


Boxplot for Numerical Features (Outliers Detection)
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
POSTED_SPEED_LIMIT
LANE_CNT
SEVERE
INTERSECTION_RELATED_I
NOT_RIGHT_OF_WAY_I
HIT_AND_RUN_I
WORK_ZONE_I
NUM_UNITS
INJURIES_TOTAL
INJURIES_FATAL
INJURIES_INCAPACITATING
INJURIES_NON_INCAPACITATING
INJURIES_REPORTED_NOT_EVIDENT
INJURIES_NO_INDICATION
CRASH_HOUR
CRASH_DAY_OF_WEEK
CRASH_MONTH
HOUR
DAY_OF_WEEK
MONTH


Correlation Matrix of Numerical Features
POSTED_SPEED_LIMIT 1.00 0.00 0.11 0.12 -0.33 -0.05 0.01 0.05 0.08 0.01 0.03 0.06 0.04 0.11 0.01 0.01 0.01 0.01 0.01 0.01
LANE_CNT 0.00 1.00 -0.00 -0.00 -0.00 0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 0.00 0.00 -0.00 0.00 0.00 -0.00
SEVERE 0.11 -0.00 1.00 0.21 -0.03 -0.07 0.01 0.11 0.56 0.05 0.20 0.42 0.32 -0.13 -0.05 -0.01 0.01 -0.05 0.04 0.01
INTERSECTION_RELATED_I 0.12 -0.00 0.21 1.00 -0.09 -0.12 0.00 0.03 0.18 0.01 0.06 0.14 0.09 0.12 0.02 0.01 0.00 0.02 -0.00 0.00
NOT_RIGHT_OF_WAY_I -0.33 -0.00 -0.03 -0.09 1.00 -0.01 -0.01 -0.12 -0.03 0.01 -0.00 -0.02 -0.02 -0.08 -0.01 -0.00 -0.01 -0.01 0.00 -0.01
HIT_AND_RUN_I -0.05 0.00 -0.07 -0.12 -0.01 1.00 -0.02 0.06 -0.07 -0.01 -0.03 -0.05 -0.04 -0.13 -0.03 -0.02 -0.00 -0.03 0.04 -0.00
WORK_ZONE_I 0.01 -0.00 0.01 0.00 -0.01 -0.02 1.00 -0.02 0.00 0.00 -0.00 0.00 0.00 -0.00 -0.01 -0.00 0.01 -0.01 -0.01 0.01
NUM_UNITS 0.05 -0.00 0.11 0.03 -0.12 0.06 -0.02 1.00 0.11 0.01 0.04 0.08 0.06 0.18 0.01 0.00 0.01 0.01 0.02 0.01
INJURIES_TOTAL 0.08 -0.00 0.56 0.18 -0.03 -0.07 0.00 0.11 1.00 0.10 0.33 0.76 0.58 -0.19 0.00 -0.01 0.01 0.00 0.01 0.01
INJURIES_FATAL 0.01 -0.00 0.05 0.01 0.01 -0.01 0.00 0.01 0.10 1.00 0.05 0.02 0.00 -0.03 -0.01 -0.00 0.00 -0.01 0.01 0.00
INJURIES_INCAPACITATING 0.03 -0.00 0.20 0.06 -0.00 -0.03 -0.00 0.04 0.33 0.05 1.00 0.05 0.01 -0.09 -0.00 -0.00 0.01 -0.00 0.01 0.01
INJURIES_NON_INCAPACITATING 0.06 -0.00 0.42 0.14 -0.02 -0.05 0.00 0.08 0.76 0.02 0.05 1.00 0.01 -0.16 0.00 -0.01 0.01 0.00 0.01 0.01
INJURIES_REPORTED_NOT_EVIDENT 0.04 -0.00 0.32 0.09 -0.02 -0.04 0.00 0.06 0.58 0.00 0.01 0.01 1.00 -0.09 0.01 -0.00 0.01 0.01 0.00 0.01
INJURIES_NO_INDICATION 0.11 -0.00 -0.13 0.12 -0.08 -0.13 -0.00 0.18 -0.19 -0.03 -0.09 -0.16 -0.09 1.00 0.09 0.02 0.00 0.09 0.02 0.00
CRASH_HOUR 0.01 0.00 -0.05 0.02 -0.01 -0.03 -0.01 0.01 0.00 -0.01 -0.00 0.00 0.01 0.09 1.00 0.06 0.00 1.00 -0.02 0.00
CRASH_DAY_OF_WEEK 0.01 0.00 -0.01 0.01 -0.00 -0.02 -0.00 0.00 -0.01 -0.00 -0.00 -0.01 -0.00 0.02 0.06 1.00 -0.00 0.06 0.31 -0.00
CRASH_MONTH 0.01 -0.00 0.01 0.00 -0.01 -0.00 0.01 0.01 0.01 0.00 0.01 0.01 0.01 0.00 0.00 -0.00 1.00 0.00 0.00 1.00
HOUR 0.01 0.00 -0.05 0.02 -0.01 -0.03 -0.01 0.01 0.00 -0.01 -0.00 0.00 0.01 0.09 1.00 0.06 0.00 1.00 -0.02 0.00
DAY_OF_WEEK 0.01 0.00 0.04 -0.00 0.00 0.04 -0.01 0.02 0.01 0.01 0.01 0.01 0.00 0.02 -0.02 0.31 0.00 -0.02 1.00 0.00
MONTH 0.01 -0.00 0.01 0.00 -0.01 -0.00 0.01 0.01 0.01 0.00 0.01 0.01 0.01 0.00 0.00 -0.00 1.00 0.00 0.00 1.00
POSTED_SPEED_LIMIT
LANE_CNT
SEVERE
INTERSECTION_RELATED_I
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HIT_AND_RUN_I
WORK_ZONE_I
NUM_UNITS
INJURIES_TOTAL
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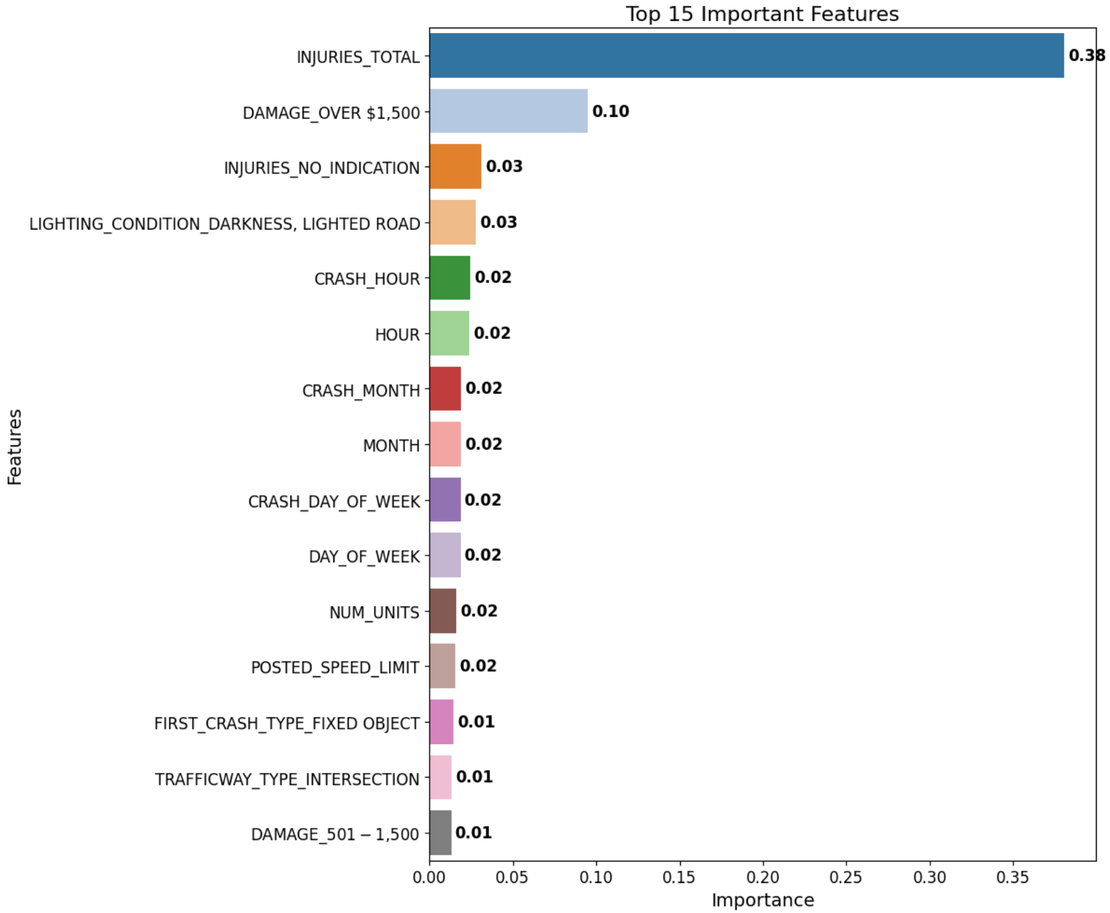
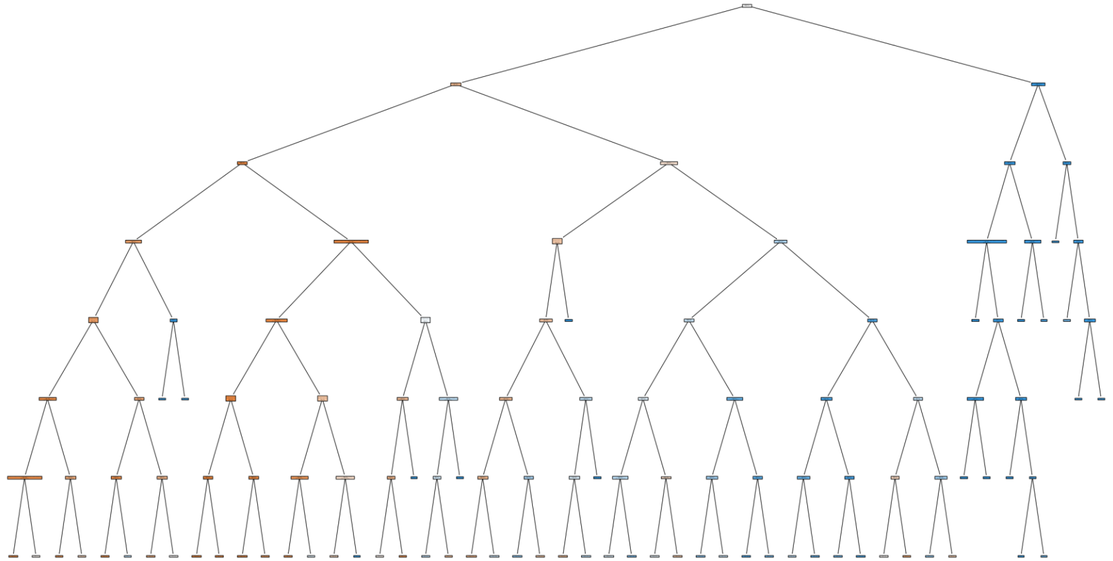
INJURIES_REPORTED_NOT_EVIDENT
INJURIES_NO_INDICATION
CRASH_HOUR
CRASH_DAY_OF_WEEK
CRASH_MONTH
HOUR
DAY_OF_WEEK
MONTH
1.0
0.8
0.6
0.4
0.2
0.0
−0.2

Models

Metric Parameter	Logistic Regression (Without SMOTE)	Logistic Regression (With SMOTE)	Grid Search Decision Tree (With SMOTE)	Decision Tree (Without SMOTE)	Decision Tree (With SMOTE)	Random Forest (Without SMOTE)	Random Forest (With SMOTE
Accuracy	88.72%	88.72%	84%	84.69%	84.69%	~88%	~88%
F1-Score (Class 0)	High	High	0.89	0.92	~0.92	0.92	~0.92
F1-Score (Class 1)	0.65	0.75	0.72	0.74	~0.77	0.75	~0.77

Decision Tree with Grid search

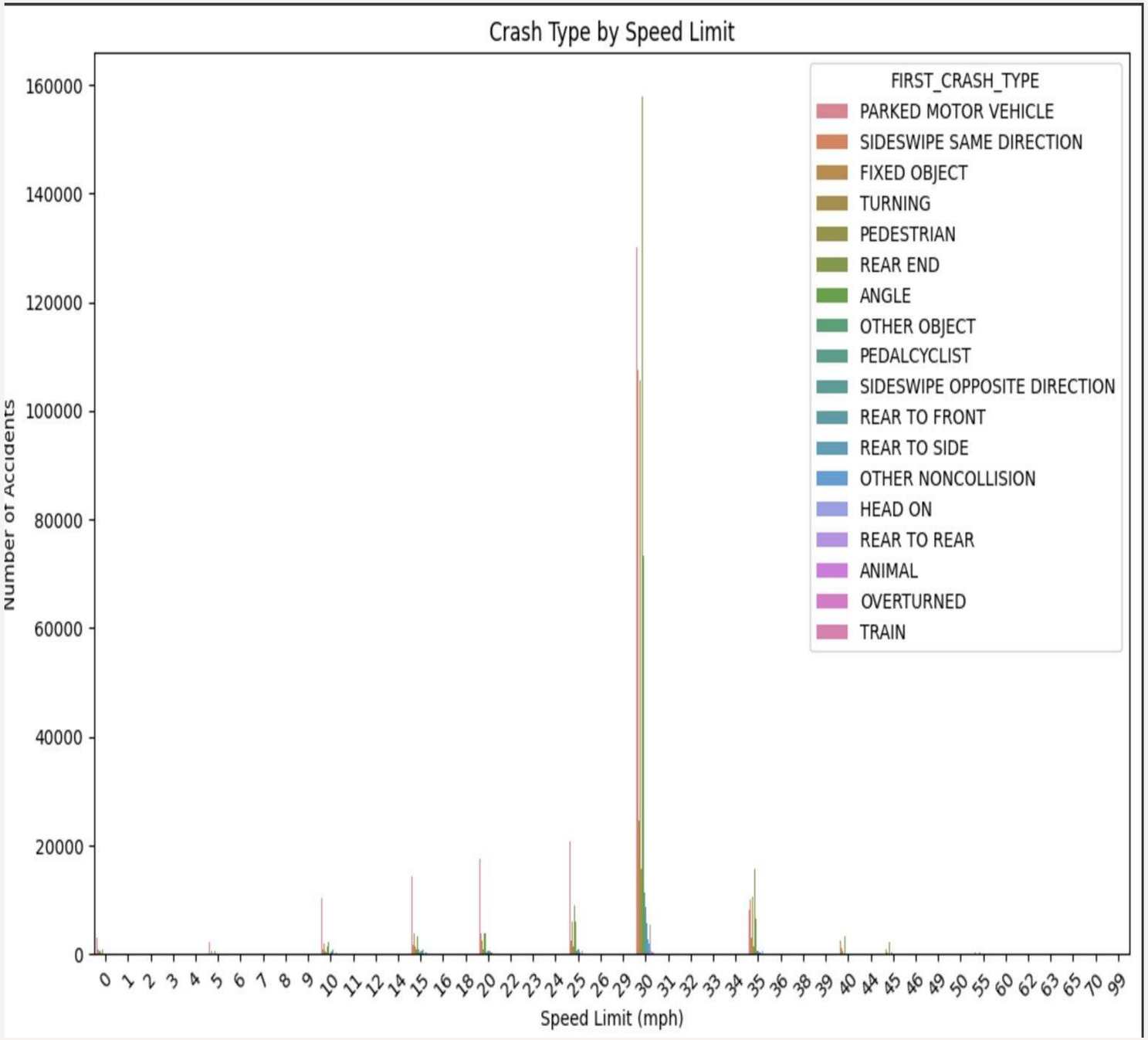


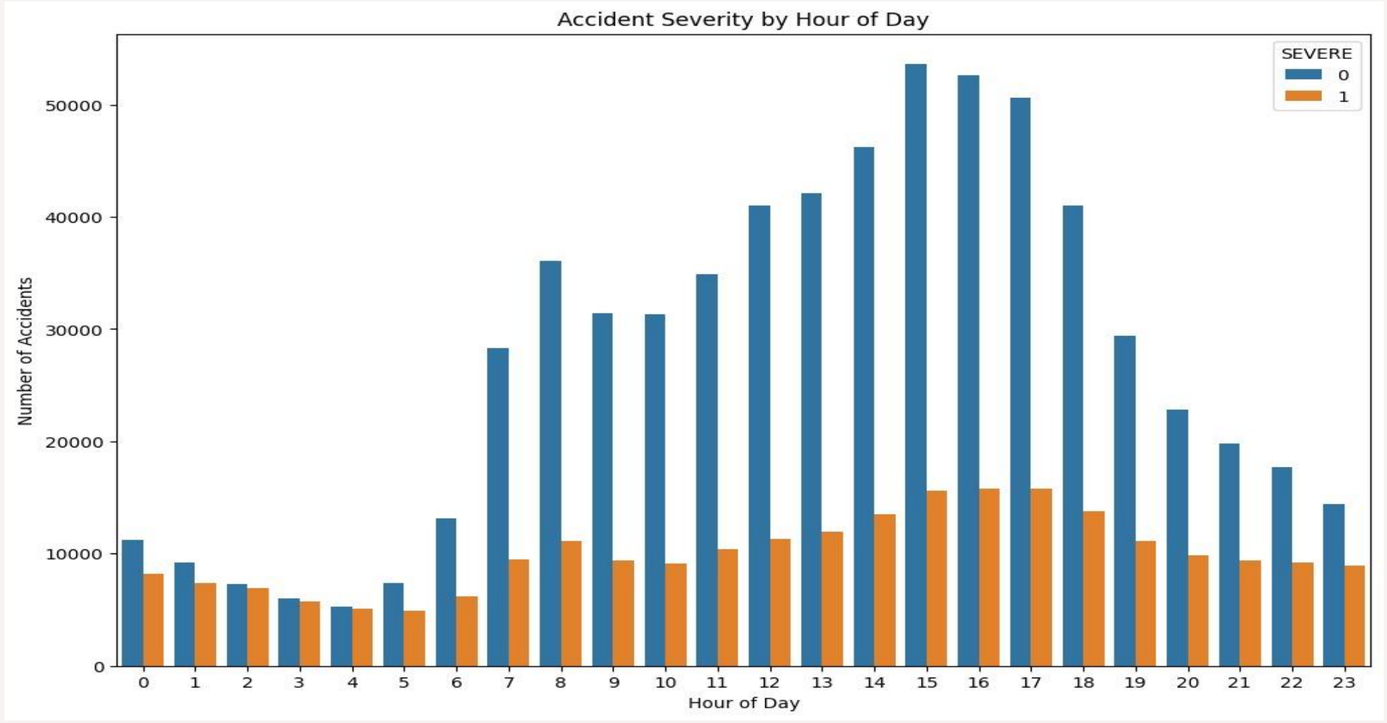


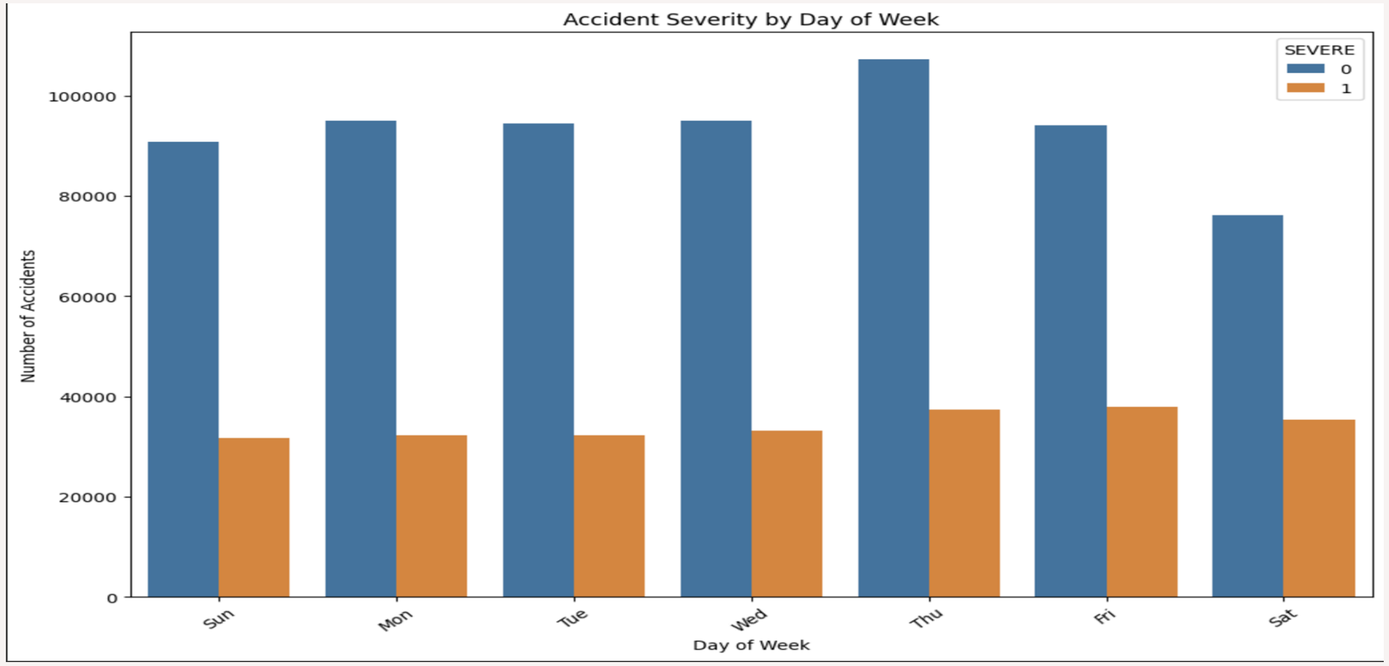
What is the relationship between speed limits and crash types?

- **Urban Zones (20–40 mph)**: severity level is low. This might be due to the high traffic density and frequent interaction with pedestrians and cyclists.
- **High-Speed Zones (50+ mph)**: Fewer but more severe crashes, including overturned vehicles. The possible actions for these crashes are intoxicated drivers and over speeding.

•**Implication**: in order to eradicate such collisions interventions like traffic signals and sign boards are placed.







How do crash severity and contributory causes vary by time and day of the week?

Time and Day Patterns:

Orange bars = Severity

Blue bars = Non-severity

- **Peak Day**: Thursdays see the highest crash frequency with more than 10,000 crash records. However **Weekends particuary Saturday and friday recorded** Lower overall cashes but with higher severity due to riskier driving behaviors.

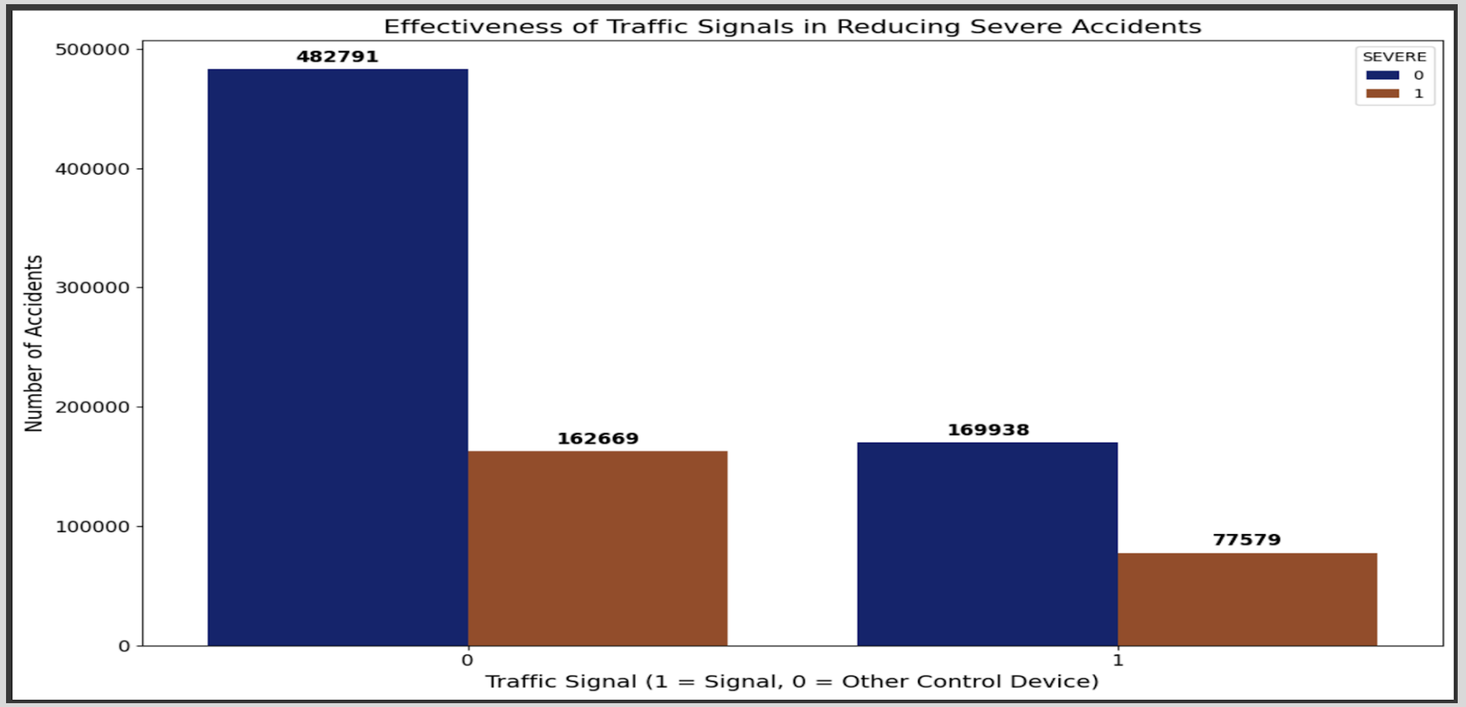
- Some of the implictaions can be performed by targeted awarness capaign for weekend drivers and enhance enforcements druing peak traffic days.

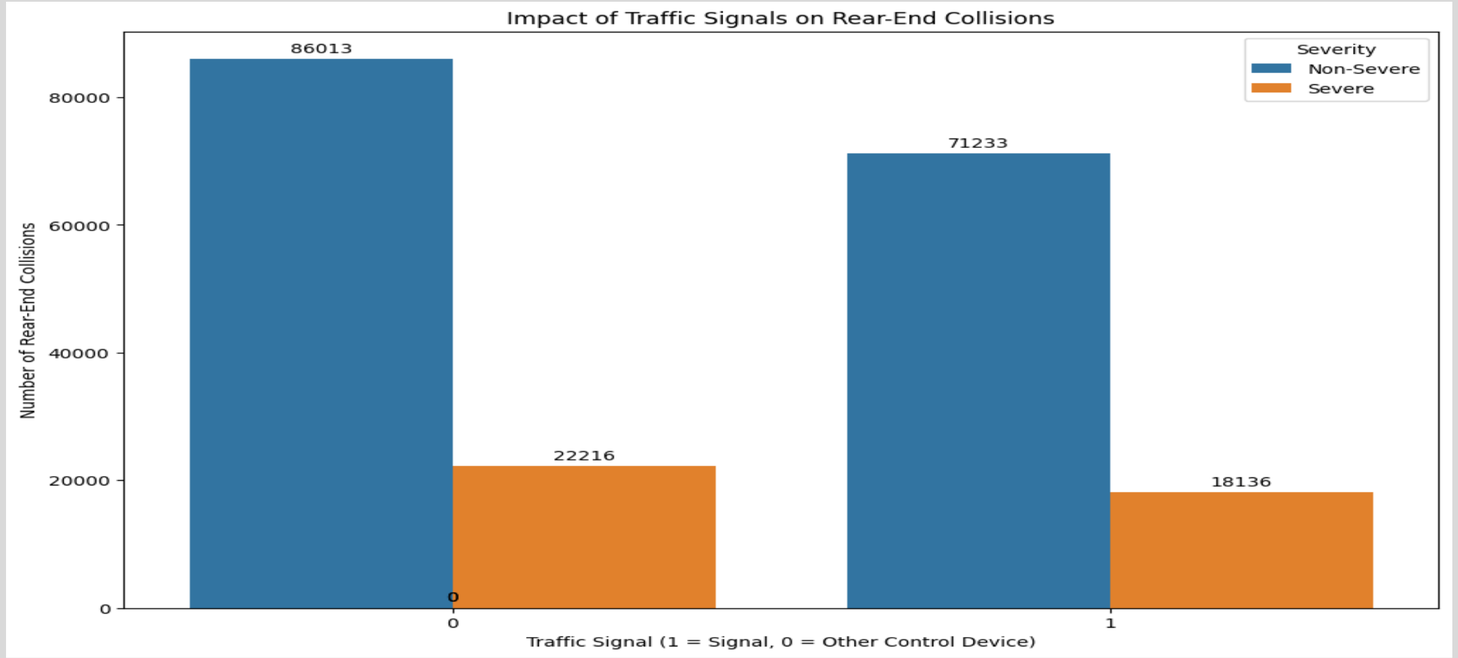
A. How effective are traffic signals in reducing the severity of accidents?

B. How does a traffic control device affect the chances of rear-end collisions?

Without traffic signals	With traffic signals
4,82,791 (non - severe). 1,62,699 (severe)	30% fewer severe crashes. 1,69,938 (non-severe). 77,579 (severe)
High incidents of rear-end collisions due to abrupt stops and driver unpredictability.	Highly effective, recorded fewer collisions.

Implication: Prioritize installing signals at high-risk intersections.





Discussion

- **Interpreting Findings**:

- Moderate speed zones (20–40 mph) emerge as critical for intervention.
- Traffic signals are the most effective control devices, drastically reducing rear-end and severe collisions.
- Weather influences severity, underscoring the need for seasonal traffic safety measures.

- **Relation to Literature**:

- The findings corroborate WHO’s stance on behavioral and environmental crash factors.
- The success of Vision Zero interventions mirrors global trends advocating for localized safety solutions.

- **Limitations**:

- **Data Imbalance**: Severe crashes are underrepresented.
- **Temporal Scope**: Post-2017 trends might not reflect pre-existing crash dynamics.
- **Reporting Bias**: Self-reported crashes might exclude unreported incidents.

Recommendations

1. **Enhance Infrastructure**:
   - Expand signalized intersections.
   - Install traffic-calming measures in urban zones.

2. **Adaptive Technologies**:
   - Implement weather-responsive systems.
   - Deploy AI-driven monitoring at high-risk intersections.

3. **Public Awareness Campaigns**:
   - Target Thursdays and weekends with education on safe driving practices.
   - Collaborate with community organizations to promote Vision Zero.

Conclusion

Summary:

- Urban zones with moderate speed limits require immediate attention.
- Traffic signals effectively mitigate crash severity.
- Seasonal adjustments to safety measures can address weather-related risks.

Significance:

- Insights guide policymakers in optimizing safety investments, urban planning, and infrastructure design.
- Reinforces the need for data-driven approaches to achieve Vision Zero goals by 2026.

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