Evaluating School Bus Safety During Emergency Situations

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Final Report

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Glossary of Abbreviations

Abbreviations	Full Form
AADT	Annual Average Daily Traffic
ADAS	Advanced Driver Assistance Systems
AMR	Anisotropic Magneto-Resistive (sensors)
ASBC	American School Bus Council
ATS	Active Travel to School
BN	Bayesian Network
BSD	Blind Spot Detection
CDL	Commercial Driver's License
CHP	California Highway Patrol
CCTV	Closed-Circuit Television
CMV	Commercial Motor Vehicle
DOE	Department of Education
DOT	Department of Transportation
DT	Decision Tree
EV	Electric Vehicle
FCW	Forward Collision Warning
FARS	Fatality Analysis Reporting System
FMVSS	Federal Motor Vehicle Safety Standards
FN	False Negative
FP	False Positive
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GVWR	Gross Vehicle Weight Rating
HIC	Head Injury Criterion
IEP	Individualized Education Plan
ISA	Intelligent Speed Assistance
KABCO	Injury Severity Scale (K = Fatal, A = Severe, B = Moderate, C = Minor, O = Property Damage)
LDW	Lane Departure Warning
LED	Light-Emitting Diode
LPS	Lap/Shoulder Passenger Belt Systems
MVC	Motor Vehicle Commission
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
NJ	New Jersey
NJDHTS	New Jersey Division of Highway Traffic Safety
NJDOE	New Jersey Department of Education
NJMVC	New Jersey Motor Vehicle Commission
NJSP	New Jersey State Police

Abbreviations	Full Form
NJSBCA	New Jersey School Bus Contractors Association
OEM	Original Equipment Manufacturer
OSC	New Jersey Office of the State Comptroller
OSBS	Office of School Bus Safety
PDO	Property Damage Only
PTDI	Professional Truck Driving Institute
RFID	Radio Frequency Identification
RF	Random Forest
RBF	Radial Basis Function
SHAP	SHapley Additive exPlanations
SVM	Support Vector Machine
TP	True Positive
TWLTL	Two-Way Left-Turn Lane
UHF	Ultra-High Frequency
XGBoost	Extreme Gradient Boosting
ZINB	Zero-Inflated Negative Binomial

EXECUTIVE SUMMARY

School bus safety remains a significant concern in the United States, with school transportation-related crashes resulting in 1,282 fatalities between 2007 and 2016, including 281 school-age children (NHTSA). In New Jersey, from 2016 to 2024, around 16,000 crashes have been recorded related to school buses, out of which 89 crashes were fatal. School bus crashes occur 2.1 times more frequently on non-routine routes, highlighting the need for targeted interventions (O'Neal et al., 2014). Despite existing regulations, challenges persist, such as inconsistent driver training, where initial training is conducted by driving schools and private companies and includes the federal entry-level driver training requirements, along with weak seatbelt enforcement and financial constraints limiting safety technology adoption. Addressing these issues requires a comprehensive assessment of current policies, enforcement mechanisms, and technological advancements to enhance school bus safety.

P.L. 2019, c. 24 requires the Commissioner of Education to collaborate with various state officials and agencies to conduct or commission a comprehensive study on school bus safety, focusing on emergency situations, safety technologies, driver qualifications, and the evaluation of current statutory, regulatory, and operational practices. This report aims to identify key risk factors contributing to school bus crashes, evaluate the effectiveness of safety regulations, and recommend measures to reduce crash frequency and severity. The study focuses on improving regulatory compliance, strengthening driver training, and enhancing the use of safety technologies. It also provides actionable recommendations to improve student transportation safety by integrating data-driven insights with policy assessments.

The study follows a structured methodology, including a review of current practices, structured interviews with public agencies from the Tri-State area, a crash analysis, and an assessment of statutory and regulatory requirements. The crash analysis identified key trends, such as the higher likelihood of fatalities in fixed-object collisions and the increased occurrence of severe crashes during winter and early morning hours. Interviews revealed gaps in seatbelt enforcement, inconsistencies in driver certification, and challenges in ensuring contractor compliance with maintenance and safety regulations. Additionally, while onboard cameras and stop-arm enforcement systems are effective, financial and policy barriers limit their widespread adoption.

Based on these findings, the study recommends the following:

- Seatbelt Implementation and Compliance: Strengthen enforcement policies to ensure consistent seatbelt use and enhance bus safety by retrofitting vehicles with advanced seatbelt systems.
- Policy and Regulation Improvements: Standardize enforcement across districts and strengthen regulatory frameworks.
- Collaboration Between Agencies: Improve coordination between school districts, law enforcement, and transportation authorities for effective enforcement.
- Technology Implementation for Safety and Monitoring: Adopt advanced monitoring technologies to improve safety and compliance.
- Driver Training and Certification Requirements: Enhance driver training programs focused on safety and emergency preparedness.
- Enhanced Student Safety Training: Ensure updated and accessible safety information for students and increase frequency and effectiveness of safety drills.
- School Bus Maintenance Policies and Requirements: Strengthen maintenance policies and compliance checks to maintain vehicle safety.
- Reducing Bus Driver and Aide Distractions, Improve Transparency: Improve accountability and transparency measures for drivers and aides to help emergency response and safety.

By implementing these strategies alongside predictive analytics and real-time data monitoring, school transportation agencies can proactively enhance student safety, reduce crash risks, and improve regulatory compliance.

1. INTRODUCTION

School bus safety remains a pressing concern in the United States, with school transportation-related crashes accounting for 1,282 fatalities between 2007 and 2016, including 281 school-age children (NHTSA). According to School Bus Fleet, from 2013 to 2022, a total of 976 fatal crashes were recorded for school buses, resulting in 1,082 deaths. In 2018 alone, 117 fatalities and 13,000 injuries were reported due to school bus-related crashes, highlighting the persistent risks associated with student transportation. In New Jersey, from 2016 to 2024, approximately 16,000 crashes were recorded related to school buses, out of which 89 crashes were fatal. Despite existing regulations and safety measures, challenges such as inconsistent driver training, weak seatbelt enforcement, and financial barriers limiting the adoption of safety technologies continue to hinder progress. Given these risks, it is critical to assess current policies, enforcement mechanisms, and technological advancements to develop more effective countermeasures. This project evaluates key risk factors contributing to school bus crashes, assesses regulatory and enforcement gaps, and analyzes safety measures through structured interviews, crash data analysis, and policy reviews. By identifying deficiencies in enforcement, driver training, technology use, and maintenance practices, this study provides targeted recommendations to enhance school bus safety and reduce crash severity.

1.2 Methodology

This study employs a structured, multi-faceted methodology to evaluate school bus safety, focusing on crash analysis, policy assessment, enforcement practices, driver training, and the use of safety technologies. The research follows a systematic task order consisting of four key components:

1. Review of Current State of Practice and Research – A comprehensive literature review was conducted to assess existing school bus safety policies, regulatory frameworks, and advancements in safety technologies. This step provided a foundational understanding of the industry's best practices, safety challenges, and enforcement inconsistencies across different states.
2. Structured Interviews with Public Agencies – Interviews were conducted with key stakeholders, including transportation agencies, enforcement officials, and school district representatives from the Tri-State area. These interviews provided insights into the

effectiveness of current policies, challenges in implementation, and potential areas for improvement in school bus safety management.

3. Crash Analysis and Risk Assessment – Using historical crash data, the study analyzed trends, contributing factors, and the severity of school bus-related incidents. Specific attention was given to the impact of collision types, time of occurrence, and environmental conditions. The analysis revealed that fixed-object crashes were more likely to be fatal, while head-on collisions primarily resulted in injuries and property damage. Seasonal and time-based patterns, such as the higher occurrence of fatal crashes in winter and early morning hours, were also identified.
4. Assessment of Statutory and Regulatory Requirements – A comparative analysis of state and federal school bus safety regulations was conducted to evaluate inconsistencies in enforcement, driver certification standards, and vehicle maintenance protocols. This assessment helped identify policy gaps and areas where regulatory improvements could strengthen school transportation safety.

By integrating these research components, this study provides a data-driven approach to identifying weaknesses in current school bus safety practices. The findings inform targeted recommendations aimed at improving enforcement mechanisms, standardizing training and certification, expanding safety technology adoption, and ensuring rigorous maintenance oversight to enhance student transportation safety.

2. LITERATURE REVIEW

A comprehensive review of 58 resources, including 49 journal papers and 9 technical reports, was conducted to explore various aspects of school bus safety. The literature review focused on several key areas, such as contributing factors to school bus crashes, the role of safety technology, driver characteristics, and the regulatory framework governing school bus operations. The literature synthesis aims to provide a better understanding of the factors influencing school bus safety and the measures used to mitigate risks.

2.1 Contributing Factors to School Bus Crashes

2.1.1 Factors Related to Crash Severity and Crash Type

School bus crashes are influenced by various factors that impact their severity. Research reveals that head-on, rear-end, and side-impact crashes pose higher injury risks (Lidbe et al., 2022; Rahman et al., 2011). A detailed study on serious road traffic crashes highlighted that poor visibility at night at intersections increases the risk of side-impact crashes, with school buses being more prone to rear-end collisions (Chen et al., 2016). Driver distraction has been identified as a critical risk factor for head-on crashes, highlighting the importance of driver behavior in collision prevention. Among the most severe crash types for school buses are rollovers, which often result in serious head, neck, and shoulder injuries (Lapner et al., 2003). Additionally, most crashes occur at low speeds near schools, typically involving backing or turning maneuvers and resulting in property damage with few injuries (Brebbia et al., 2005). However, severe crashes at higher speeds are linked to buses failing to yield at stop signs or running off the road. While school buses are generally safe, fatal crashes are more likely in rear-end or side-impact scenarios (Lidbe et al., 2022). Speeding, impaired driving, and negotiating curves are associated with higher injury outcomes. Data from a study reveal that fatal school bus-related crashes have not decreased despite advancements in vehicle safety systems, emphasizing the high risk to non-bus occupants, especially pedestrians and school-aged children (Donoughe et al., 2015). Weather conditions play a crucial role in all types of bus collisions, although adverse weather surprisingly results in fewer injuries (Rahman et al., 2011). Finally, Yasmin et al. (2013) found that factors such as frontal impacts, head-on crashes, unrestrained drivers, foggy weather, rural areas, and traffic signals increase crash severity, while dry road surfaces, and older drivers aged 65 or older , due to experience and more skills, tend to reduce it.

2.1.2 Factors Related to Roadway Features

Highway-related factors such as grades, sag curvatures, and narrow shoulder widths are known to increase crash severity (Rahman et al., 2011). The zero-inflated negative binomial (ZINB) model, utilized by Chimba et al. (2024), found that the presence of median and outside shoulders significantly reduces the likelihood of large bus crashes, while curbs, high-speed limits, multilane segments, and congestion increase crash probabilities. Crashes at signalized intersections, particularly right-angle, angular, head-on, and rear-end collisions, are more likely to result in severe injuries, especially when running into the back of a slowed vehicle (Obeng, 2007). On rural roads, Kim et al. (2007) identified major predictors of angle crashes at signalized intersections, such as horizontal curves and reduced sight distance. Additionally, crashes involving a school bus in the inner lane or on left-turn lanes at signalized intersections may also lead to severe injuries due to the larger turning radius of the bus, which can obstruct the vision of oncoming or following vehicles and prolong the time needed to clear the intersection. The study from Chimba et al. (2024) found that high traffic volume in the form of annual average daily traffic (AADT), more through lanes, higher speed limits, and the presence of curbs and gutters increase the likelihood of school bus crashes. Curb and gutter segments, often accompanied by sidewalks, could reduce school bus crash risks, but they might also be linked to minor curb-related crashes. The link between having curbs and gutters and the number of crashes may be because these features are more common in places with a lot of people, especially where school buses travel often. Hazardous road conditions, such as slippery surfaces and poor visibility, also contribute to the risk of crashes (Melrose, A., 2023).

2.1.3 Factors Related to Driver Behavior

Driver characteristics, including age and violations, play a crucial role in determining crash outcomes for school buses (Yasmin et al., 2013; Rahman et al., 2011). Research has found that school bus drivers are more likely to make driving errors than their non-school bus counterparts (Lidbe et al., 2022). Analyzing data from the Buses Involved in Fatal Crashes (BIFA) database using an ordered logistic model, Feng et al. (2016) discovered that factors like season, day of the week, and driver traits influence crash severity. In Iowa, school bus crashes were 2.1 times more likely on nonroutine routes, where drivers were more prone to losing control, speeding, and aggressive driving, compared to routine routes, where failures to yield and traffic sign violations were more common (O'Neal et al., 2014).

Wiegand et al. (2010) proposed that improvements in bus driver training, traffic management, and the use of Intelligent Transportation Systems could enhance safety for concerns that include illegal passing of buses, passenger behavior, and driver skill level. Yasmin et al. (2013) found that violations by school bus drivers, such as disobeying traffic signs or failing to yield, are associated with increased crash severity. Additionally, violations like crossing the centerline can lead to severe head-on crashes, while tailgating reduces the time to crash and increases impact force.

Kostyniuk et al. (1998) suggested that younger drivers' risk-taking behavior and greater exposure contribute to severe crashes. While other distracted behaviors like phone use and eating also contribute to crashes (Wiegand et al., 2010). Feng et al. (2016) highlighted those factors, such as roadway segments' geometrical features and roadway profile, particularly affecting younger and older drivers with a history of traffic violations for large bus driving. Deering et al. (2021) found that school bus driver negligence, including distractions and unsafe practices, is a common cause of crashes, often due to pressure to transport children safely and on time. Finally, Yasmin et al. (2013) noted that school bus drivers commit more violations than non-school bus drivers, often due to distractions caused by children inside the vehicle.

2.1.4 Miscellaneous Factors

Several risk factors, including older buses, dark conditions, and sun glare, significantly contribute to crash severity (Rahman et al., 2011). Insights from Poland et al. (2015) focused on the movement of lap-belted school bus occupants during crashes, revealing that injuries were notably more severe in the rear of the bus, with the severity ranging from mild to fatal. Their analysis of a severe crash involving a truck-tractor semitrailer and a school bus with 30 children highlighted that head displacements and neck injuries were significantly higher in the rear compared to the front.

Furthermore, Bina et al. (2021) emphasized that behavioral factors have a profound impact on road safety. In school areas where risky behaviors, such as crossing outside designated crosswalks and walking among maneuvering cars, were common, the likelihood of bus accident near misses increased. On the other hand, the presence of a 30 km/h (20 mph) speed limit zone was associated with fewer near misses. Wu et al. (2019) developed a Bayesian network model assessing school bus crashes and identified that using trucks or minibuses for student transportation, along with vehicle breakdowns, significantly raises crash risk, especially when combined with overspeeding, overloading, driver fatigue, and misoperation. Adverse weather and traffic conditions further contribute to crash severity, with human error, particularly vehicle overspeeding, being the most critical factor. Yasmin et al. (2013) found that multivehicle crashes involving school buses on rural roads generally result in higher severity.

2.1.5 Safety Efforts

To reduce school bus crashes, several key safety countermeasures should be implemented that enforce safe driving guidelines, implement comprehensive training programs for school bus drivers, mandate well-documented training programs for refreshers, and increase awareness among other vehicle drivers. First, enhancing driver training programs is crucial, as well-trained drivers are better equipped to handle the unique challenges of transporting children. Moreover, training programs and resources for school bus safety aim to enhance preparedness for both children and parents. The National Safety Council, for instance, integrates emergency evacuation drills with educational materials, fostering a clear understanding of safety procedures. Similarly, the American School Bus Council (ASBC) provides various safety videos to reinforce safe practices. They also create brochures that outline key safety tips, such as staying visible to the driver and following the school's safety rules. Additionally, the ASBC promotes School Bus Safety Week, during which they distribute materials and engage with communities to raise awareness about safe practices on and around school buses (ASBC, 2024). Police enforcement should be emphasized, with consideration for an Attorney General directive requiring all law enforcement agencies in New Jersey to implement Random Bus Violator Programs, periodic enforcement operations designed to identify and penalize drivers who illegally pass stopped school buses. Ignoring a school bus in New Jersey (not stopping during the drop-off or pick-up) carries a severe penalty, resulting in a 5-point violation of the offender's driver’s license (Marshall, 2023).

To further reduce the likelihood of school bus crashes, Lap/Shoulder Passenger Belt Systems (LPS) make school buses safer by keeping both the lap and upper body secure. This lowers the likelihood of significant head, neck, and spinal injuries in rollovers, rear-end, and side-impact incidents. LPS also reduces secondary collisions inside the bus by keeping passengers safely restrained. Companies like Blue Bird, Thomas Built Buses, and IC Bus offer LPS options that are installed at the factory and exceed FMVSS regulations. In areas like California and Texas, where these alternatives are used, injuries are less severe. LPS is an important part of a complete school bus safety plan when used with adequate enforcement, driver training, and other safety technologies.

Additionally, improving school zone design to enhance visibility and reduce traffic conflicts can lower the probability of unsafe conditions. and integrating advanced safety technologies such as automatic emergency braking systems, collision avoidance systems, and blind-spot monitoring on school buses can significantly reduce the likelihood of crashes by providing real-time assistance to drivers. School zone design should also be revisited, with a focus on improving visibility and minimizing conflicts between vehicles, pedestrians, and cyclists. This can be achieved through better signage, reduced speed limits, and the installation of pedestrian crosswalks and signals.

Maintaining a strict schedule for regular bus inspections and maintenance is essential to ensure that all safety-critical components are functioning optimally. Currently, the NJMVC conducts biannual audits of each school bus operator and terminal, which include driver roster checks, medical certification (under 70/over 70), fingerprinting, random drug testing, and vehicle records such as maintenance and daily pre-/post-trip inspections. While the New Jersey State Police (NJSP) has legal authority to inspect motor vehicles under N.J.S.A. 53:2-1, they do not routinely perform school bus inspections. To further strengthen safety, an annual audit should be conducted to ensure regular bus inspections and maintenance compliance by NJMVC and the New Jersey Department of Education (NJDOE) with the support of the NJSP. Finally, maintenance staff must be properly qualified and regularly tested to confirm they are adequately prepared to perform these tasks effectively by the school districts. The National Highway Traffic Safety Administration (NHTSA) has set higher safety standards for school buses compared to regular buses to ensure maximum safety for children. They also provide safety guidelines for parents, drivers, and children regarding school bus and school zone safety. Additionally, following the investigation of the April 2014 collision and post-crash fire on Interstate 5 in Orland, California, it was recommended that Federal Motor Vehicle Safety Standard (FMVSS) 302 be revised by NHTSA to adopt stricter standards for interior flammability and smoke emissions, similar to those used in commercial aviation and rail passenger transportation (Poland, K., 2019).

2.2 Safety Technology in School Bus Transportation

Ensuring the safety of children during their daily commute to and from school is of paramount importance, and recent advancements in technology are playing a critical role in improving safety. From Radio Frequency Identification (RFID) systems that monitor and track students on school buses to advanced driver-assistance systems (ADAS) that prevent collisions and enforce speed limits, these innovations are transforming the way school buses operate. By integrating wireless communication, obstacle detection, and safety cameras, these technologies provide comprehensive solutions that not only protect children but also offer peace of mind to parents and school administrators. These technologies are discussed in detail below.

Different RFIDs present tradeoffs on costs and features. Passive RFID tags are affordable, costing between $0.10 and $1.50, and can last for many years without needing batteries, though they only detect a tag's presence, not its exact location. In contrast, active RFID tags are more expensive, exceeding $10 each, but have a less costly reader infrastructure. Ultra-High Frequency (UHF) readers range from $500 to $2,000 depending on features, and active systems often include tags and mapping software (RFID Journal, 2020). RFID scanning systems come in two types: handheld and fixed scanners. Handheld scanners, priced between $500 and $2,000, are mobile and commonly used in retail, healthcare, and transportation for inventory and asset management, with relatively low ongoing maintenance costs. Fixed scanners, which cost $2,000 to $10,000, are stationary devices used in manufacturing and logistics, offering automated tracking but requiring more maintenance (Cotter, 2024). Implementing RFID systems involves both initial and ongoing investments.

The cost of ADAS in buses varies based on the technology and scale. In Florida, the initial cost for ADAS implementation in buses was $8,900, with an annual maintenance cost of $240 (ITS

Deployment Evaluation, 2023). The Federal Transit Administration (FTA) offers up to $5 million in competitive funding for ADAS demonstration projects in transit buses. ADAS technologies use sensors and cameras to detect obstacles and driver errors, with the European Union estimating that ADAS will cost nearly $36 billion over 15 years for its fleet for all types of vehicles, which is estimated at around 250 million cars, along with 680,000 buses. In the U.S., the Department of Transportation (DOT) allocated $94 million through the SMART Grant Program to support transportation improvements (Adaptive Cruise Control, 2024). Specific ADAS technologies for school buses include Automatic Emergency Braking (AEB) systems, costing $1,000 to $3,000 per bus, Lane Departure Warning (LDW) systems, priced between $500 and $2,500 per bus, and Blind Spot Detection (BSD) systems, ranging from $1,000 to $3,000 per bus. Other systems like 360-degree cameras, driver monitoring, and adaptive cruise control range from $500 to $3,000 per bus. Total costs for retrofitting existing fleets can range from $3,000 to $10,000 per bus, while integrating ADAS into new buses could be cheaper due to economies of scale (The Brake Report, 2023).

2.2.1 Radio Frequency and Wireless Communications

Ensuring the safe transportation of millions of children between home and school is crucial, and advancements in technology are playing a key role in enhancing this safety. A study by Asha et al. (2016) explored the use of RFID technology for tracking and monitoring children on school buses, addressing issues like children being locked in buses, missing buses, or boarding the wrong ones. The Asha et al. research also proposed a system to prevent crashes at curves and hairpin bends by using Radio Frequency (RF) technology to control bus speed through fuel rate adjustments, which promises safer transportation.

The rise in school bus usage has unfortunately led to an increase in crashes due to driver and caregiver negligence. To counteract these issues, Kim et al. (2020) introduced a safety management system that includes features like verifying seatbelt use, automatically adjusting seatbelts to fit children's heights, and ensuring all children disembark safely. This system, which uses facial recognition through camera images, aims to prevent injuries in the event of a crash and provides real-time location updates to parents. Tested successfully on a bus model using Raspberry Pi and various sensors, this system has proven effective in improving school bus safety. Some U.S.

school districts, like the Texas City Independent School District, have implemented facial recognition technology on school buses. This system aims to enhance security by identifying unauthorized individuals, such as expelled students or persons of interest, boarding the bus. While technology aims to improve safety, it has raised ethical concerns regarding privacy and civil liberties, with some arguing that it could lead to misuse or racial bias (Simonite & Barber, 2019).

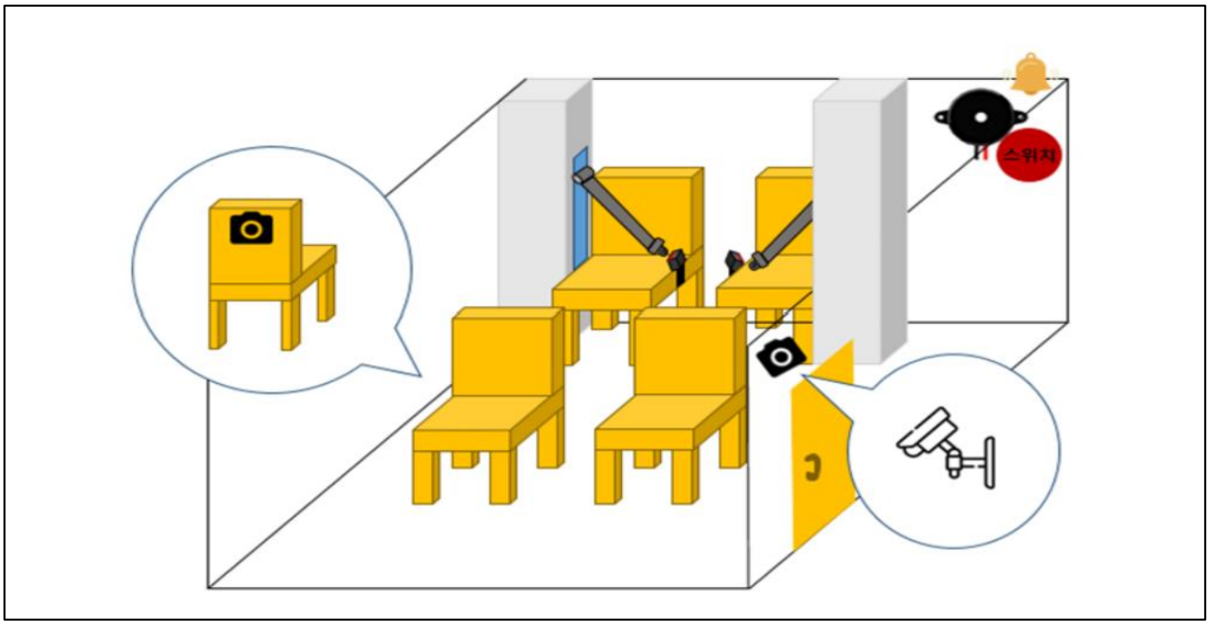


Figure 1 RFID-based seatbelt detection system (Kim et al., 2020)

Globally, many school districts are adopting technology to enhance both learning and safety during school bus commutes. One prominent initiative is the "Connected School Bus," which integrates mobile gateways, onboard global positioning system (GPS), Wi-Fi, and video cameras. RFID technology is employed, with each bus equipped with RFID readers and antennas to detect tags embedded in children's bags. This data, including time, date, and location, is transmitted to a secure database, and parents receive SMS alerts when their child boards the bus and when the bus is 10 minutes away from pick-up or drop-off locations. This system greatly benefits students, parents, drivers, and school administrators by improving safety and communication (Singar et. al., 2022). Additionally, wireless communication keeps school principals updated on bus status, while Global System for Mobile Communications (GSM) technology informs parents about their child's attendance and return, effectively addressing security challenges in school transportation. Gadekar et al. (2020) introduced a reliable school bus tracking and safety solution via an Android application and website. This system offers real-time location tracking for parents and school authorities, including authentication and notification mechanisms, detects anomalies to raise alerts, and features route optimization and traffic-based delay prediction, thereby enhancing the overall travel experience.

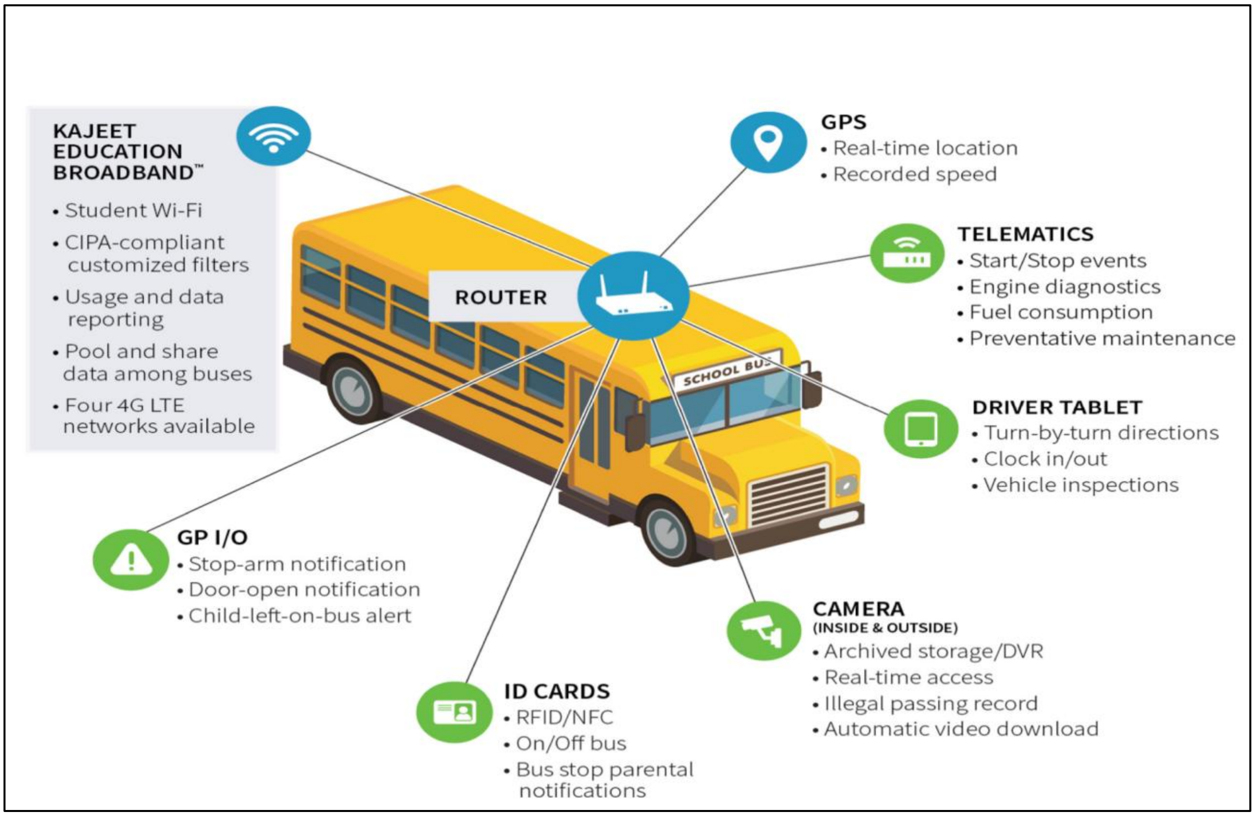


Figure 2 Safety technology used in a school bus (Kajeet Educational Board, 2024)

2.2.2 Collision Prevention and Safety Enhancement Sensors

Vidyasagar et al. (2015) proposed a comprehensive security system for school buses, integrating range and obstacle detection sensors on the front of the bus to prevent collisions with other vehicles. This system also features unique student tags tracked by entrance and exit counters to ensure accurate monitoring of students. Expanding on such advancements, Karr et al. (2004) outlined key projects under the Intelligent Vehicle Initiative, which aims to address high-frequency crashes. These projects include forward collision warning and adaptive cruise control systems that use electronic sensors, GPS, and radar, along with radar-based lane-change and road-departure warning technologies. Additionally, the initiative features a bundled safety package with

electronically controlled braking and collision warning systems for transit buses, intelligent intersection technology, and radar detectors at rural unsignalized intersections.
Further enhancing collision prevention, Sreevishakh and Dhanure (2015) developed a sensor system capable of predicting vehicle collisions by estimating the planar position and orientation of vehicles. This system utilizes anisotropic magneto-resistive (AMR) and sonar/ultrasonic sensors to measure magnetic fields and assess vehicle positions. It also includes a camera that captures images of nearby vehicles when a collision is predicted, sending alerts with the crash location and images to nearby hospitals or police stations via a GSM module. Meanwhile, Donoughe (2016) proposed a concept of operations for a connected vehicle application using dedicated short-range communication to improve safety around stopped school buses, especially in areas with limited visibility. This includes a naturalistic driving experiment to evaluate driver reactions to in-vehicle warnings about school buses stopped around curves and a microsimulation to assess the impact of specialized speed control algorithms on vehicle speeds, travel time, and emissions near bus stops, either as a pre-timed speed limit or a connected vehicle system.

2.2.3 Driver Assistance Technology

Blades et al. (2020) reviewed the adoption of ADAS in the bus sector, revealing significant findings from on-road trials and bus crash statistics. Their research highlights that passive forward collision warning (FCW) and intelligent speed assistance (ISA) systems effectively reduce imminent pedestrian and vehicle collision events while improving compliance with speed limits. However, they also note that unsafe braking events, though rare, can exceed safe deceleration limits, posing risks to passengers. To address this, the study suggests that using vehicle retarders instead of service breaks for emergency stops can maintain deceleration within safer limits, offering a more reliable alternative for ISA systems in buses.

Meanwhile, Anund et al. (2010) investigated how a driver support system integrated with intelligent bus stops impacted speed, routines, hazard detection, and child security. Their findings showed that the speeds of other road users decreased at one of the bus stops, and bus drivers found the system useful for improving routines and monitoring children more effectively, leading to greater security and reduced stress for the children. Mandala et al. (2022) discussed the potential of advanced technologies like Artificial Intelligence (AI) to enhance vehicle safety and efficiency, noting that while predictive analytics and AI could significantly prevent crashes and save lives, the shift from traditional methods will be gradual. They also emphasize the growing need for cybersecurity awareness as vehicles become more connected.

2.2.4 Diagnostics and Internal Safety

Distinguishing between diagnostic approaches for vehicle safety and manufacturing is crucial for advancing automotive safety. Traditional diagnostics, which rely on user intervention, often fall short in predicting potential issues. Therefore, future advancements must focus on identifying faults early in the manufacturing process. This shift toward predictive diagnostics is vital for improving vehicle safety and preventing crashes before they occur. Ji and Zhou (2015) examined how seat spacing and restraint types of impact occupant protection in school buses during frontal crashes. Their study, using finite element modeling, showed that smaller seat spacing generally reduces head injury criteria (HIC) for non-belted dummies. Conversely, appropriately chosen seat spacing minimizes HIC for belted dummies. However, the effect of seat spacing on the chest was minimal compared to the presence or absence of lap belts. This indicates that both seat spacing and restraint types are essential for optimizing occupant safety in school buses, particularly in preventing severe injuries during crashes.

2.2.5 Safety Cameras

Cameras are becoming increasingly vital for enhancing school bus safety and preventing crashes by discouraging motorists from illegally passing buses when stop arms are extended. Infraction cameras are designed to discourage motorists from illegally passing a school bus when its stop arm is extended, thereby improving student safety during boarding and deboarding. Meanwhile, exterior 360° cameras give drivers a comprehensive view of their surroundings, allowing them to spot vulnerable road users like pedestrians or cyclists when the bus is stopped or moving slowly.

Currently, New Jersey has no statute authorizing school bus stop-arm camera enforcement. Pending legislation (S3858, 2023–2024 session) would require the installation of school bus cameras and establish enforcement procedures, but it has not yet been enacted (New Jersey Legislature, 2024). As such, there is no uniform requirement at present for law enforcement to review footage, issue summonses, or follow specific retention policies in New Jersey. Where school bus cameras are used in other jurisdictions, law enforcement review of footage is generally required before a summons can be issued, and local statutes prescribe retention schedules (e.g., New York Vehicle and Traffic Law §1174-a; Maryland Transportation Code §21-706.1). These frameworks typically limit the use of recorded images to adjudicate the specific traffic violation, but rules vary by state.

While NJMVC regulates vehicle safety equipment under federal standards (N.J.A.C. 13:20-33.45), it does not have the authority to issue moving violation summonses. Similarly, while the NJSP has broad inspection authority under N.J.S.A. 53:2-1, they do not have a defined role in regulating or enforcing camera programs. If S3858 or similar legislation is enacted, responsibilities for administration would likely fall to the Division of Highway Traffic Safety (NJDHTS), NJMVC, and local law enforcement agencies, but these roles remain undefined. A digital camera system must capture at least two images per violation. One image must show: (1) the violation scene, (2) the vehicle, (3) the license plate, (4) the date, (5) the time, (6) the red-light duration, and (7) the frame sequence code. This info should be imprinted at the edge without blocking the image (Justia Us Law, 2023).

Figure 3 Infracted camera on a school bus (ksat.com, 2023)

Figure 4 360-degree camera on a school bus (Thomas Built Buses, 2018)

2.3 Driver Certifications and Requirements

Niewiadomski (2013) outlined the formal requirements for hiring drivers in school transport, highlighting the importance of meeting age, licensing, training, and health/psychological testing standards. Candidates are required to be of a higher statutory age, hold a specific driving license category, undergo mandatory and periodic training, and pass rigorous health and psychological evaluations. Krueger et al. (2007) found that health and wellness issues are relevant to recruiting commercial truck, bus, and motorcoach drivers, focusing on factors like cardiovascular illness, diabetes, epilepsy, obesity, vision and hearing requirements, drug effects, stress, mental health issues, sleep disorders, and fatigue from long work hours. Their discussion links these health issues to federal regulations and provides practical safety management guidance while pointing out gaps in current knowledge that need further research. Kotecha et al. (2008) suggest that newer tests of visual field and visual attention may better predict driving performance. They found a strong link between reduced visual fields and poorer driving performance, with individuals having a visual field of less than 100 degrees horizontally at a higher risk of crashes.

In New Jersey, school bus driver candidates must first hold a basic New Jersey driver's license before applying for a Commercial Driver's License (CDL). Candidates must hold at least a Class C Commercial Driver License (CDL), School Bus (S) endorsements, be 21 years old, possess three years of driving experience, and meet vision requirements. They must also undergo a criminal background check and carry a medical examiner's fitness statement renewed every two years. Drivers must undergo background checks when first applying and renewing their licenses, with transfers requiring an online request. While they can hold other district positions without new checks, substitute teaching credentials require a fresh criminal history review. Contractors apply through the Office of Student Protection, aides follow separate protocols, and expired endorsements can only be renewed if the driver is employed by an educational facility (NJDOE, 2024). Moreover, New Jersey school bus drivers have no mandatory retirement age, but older drivers face stricter medical exam requirements. Those aged 70–74 must submit an annual medical examination by June 1, while drivers 75 and older must provide an initial state exam and repeat it every six months. All medical exams are reviewed during biannual bus inspections (NJMVC, 2023). Georgia requires candidates to be at least 18 years old, while Florida mandates a clean driving record with no more than 4 points accumulated in the past three years. Delaware DOE (2017) emphasized that school bus drivers must pass a comprehensive medical evaluation covering critical health areas such as cardiovascular illness and diabetes to ensure they are fit to safely transport students. Duke et al. (2010) addressed age-related safety issues, noting that younger and older drivers experience higher crash and fatality rates compared to middle-aged drivers, influenced by factors like long work hours and fatigue.

Moreover, a recent comptroller report revealed that nearly 300 New Jersey school bus companies failed to submit required proof of driver qualifications before the 2023–24 school year, with dozens still noncompliant months into 2024–25. The report urges stronger enforcement and earlier compliance checks, prompting new operator training and statewide monitoring tools (Marshall, 2025). The New Jersey Office of the State Comptroller (NJOSC) conducted a two-year review of data from the 2023–24 and 2024–25 school years to assess whether third-party school bus companies were meeting state law requirements to annually certify that their drivers are qualified. The review revealed extensive non-compliance in 2023–24, with nearly 300 bus companies failing to submit the mandated "bus packages" to county superintendents by the August 31 deadline. These packages must include proof of each driver's licensing, training, background checks, and the history of drug and alcohol violations. Although NJDOE and its Office of School Bus Safety (OSBS) introduced new measures for 2024–25; such as a standard operating procedure for tracking compliance, mandatory training for new operators, optional statewide training for existing companies, and a notification system for late submissions, 109 companies across 14 counties still missed the 2024–25 deadline, and 28 remained noncompliant two months into the school year. NJOSC also identified at least 16 companies that failed to comply in both years reviewed, and noted that enforcement options are currently limited, making it difficult to impose penalties without risking transportation disruptions (NJOSC, 2025). The report recommends automating compliance notifications, setting earlier or staggered deadlines, incentivizing early compliance, improving county tracking systems, and strengthening legislative authority to impose sanctions or publicly identify persistently noncompliant companies. While compliance has improved, NJOSC concludes that additional action is necessary to ensure that only qualified drivers transport students and to prevent last-minute compliance gaps that jeopardize school transportation safety.

The Transportation Research Board and National Academies of Sciences, Engineering, and Medicine reviewed various commercial motor vehicle (CMV) driver training programs aimed at enhancing safety, though school bus driver qualifications were not covered. Key findings included the widespread adoption of Professional Truck Driving Institute (PTDI) standards for entry-level drivers and trainers, the reliance on industry partnerships for advanced training, and the use of multimedia and simulation tools to boost training effectiveness (National Academies of Sciences, Engineering, and Medicine, 2004).

School bus driver training requirements also vary significantly across states. For example, California mandates at least 20 hours of each classroom and behind-the-wheel training, with an additional 10 hours of refresher training annually (California Department of Education, 2023). In Illinois, while training is required, there is no minimum hour requirement, typically involving 8 hours of instruction and 2 hours of annual refresher training (Lake County Regional Office of Education, 2024). Nebraska requires 11 hours of initial training and 3 hours of refresher training (Nebraska Department of Education, 2025). New York drivers must complete a 3-hour pre-service and a 30-hour basic training course within their first year (New York State Education Department, 2019). Pennsylvania requires 20 hours of initial training and 10 hours of refresher training every four years (Pennsylvania Department of Transportation, 2021). Virginia mandates 24 hours of classroom and behind-the-wheel training, plus 4 hours of annual refresher training (Virginia Department of Education, 2024). Washington's training typically ranges from 48 to 58 hours with a 4-hour annual refresher course, though there is no set minimum (Washington Office of Superintendent of Public Instruction, 2019).

2.4 Statutes and Regulations Governing School Bus Safety

2.4.1 Compartment and Seatbelts

School bus transportation is regarded as one of the safest modes of travel in the United States, with an impressively low crash rate of 0.01 per 100 million miles, as noted by Abulhassan et al. (2021). However, Whitehead (2015) pointed out a significant security gap in the industry, revealing that school buses lack minimum security standards despite transporting more passengers daily than other mass transit modes combined. To address this gap, the research suggests adopting critical infrastructure methodologies and global security strategies used in other transportation sectors. Since October 1992, all new school buses nationwide have been required under federal regulations to be equipped with lap-type seatbelts or child restraint systems (FMVSS 222). In 2018, New Jersey enacted P.L. 2018, c.118 (codified at N.J.S.A. 39:3B-10), requiring that all new school buses be equipped with three-point lap and shoulder seatbelts or other federally compliant child restraint systems for each seating position (New Jersey Legislature, 2018). This mandate applied to buses manufactured on or after February 21, 2019, as specified in N.J.A.C. §13:20-50B.32. These rules align with FMVSS 210, which governs seatbelt assembly performance, and build on federal compartmentalization standards (FMVSS 222).

Research by Peleg and Goldman (2008) indicated that lap-only belts can increase the risk of severe injuries among children in mild crashes, as young children may not withstand the forces exerted by these restraints. Lap-shoulder belts, however, may reduce abdominal injuries by up to 50% compared to lap-only belts. In New Jersey, the law now requires school buses to be equipped with three-point lap and shoulder seatbelts or other child restraint systems for each seat, aligning with federal standards and taking effect for buses manufactured after 180 days of the Governor's signature P.L. 2018, c. 118). A crash test observed by CBS News at Indiana Mills and Manufacturing Inc. (IMMI)'s Indiana facility demonstrated the advantage of three-point seatbelts; dummies with these belts remained securely in place during a collision, while unbelted dummies were violently thrown around (Strassmann et al., 2024). Several states, including California, Florida, Louisiana, New Jersey, New York, and Texas, mandate seatbelts on school buses.

California requires three-point seatbelts on buses manufactured after July 1, 2005, for buses carrying more than 16 passengers and for all other buses made after July 1, 2004. Florida's law requires seatbelts or other federally approved restraint systems on new school buses purchased after January 1, 2001, and mandates that each passenger wear a properly adjusted belt while the bus is in operation. Louisiana's regulations, effective by June 30, 2004, require all buses used primarily for transporting students to be equipped with seatbelts. New York's law, in effect for buses manufactured after July 1, 1987, requires seatbelts and increased seatback padding. In 2016, ten states considered bills for school bus seatbelts, though none were enacted. The Connecticut bill, HB 5462, aimed to require all school buses to have three-point seatbelts starting with the model year 2021 (Connecticut General Assembly, 2022).

Figure 5 Blue Bird three-point seatbelt-equipped bus (BlueBird, 2024)

Manufacturers are set to enhance bus safety with a range of new features. For example, according to Ekbatani (2024), Blue Bird will introduce high-intensity light-emitting diode (LED) lighting both inside and outside the bus, along with high-resolution front and rear cameras from Rosco Vision Systems. Additionally, the new buses will be equipped with lighted stop arms, school bus signs, and strobe lights to increase visibility. Blue Bird is also integrating a collision mitigation system with its current standard electronic stability control, aiming to further improve safety on the roads.

Policies regarding seatbelt use vary greatly by state. New Jersey and New York both require seatbelts on all buses, with New Jersey mandating student use of lap belts and New York relying on districts to enforce compliance. Arkansas requires seatbelts for new buses if they are funded by the state, but seatbelt use is not mandatory unless funding is provided. In California, three-point seatbelts are required on new buses, though student use is not always enforced, with districts typically handling monitoring and enforcement. Florida mandates seatbelts on buses purchased after 2000, and students are required to wear them. Louisiana has no mandatory rules for wearing seatbelts, despite requiring them if funded. Nevada requires three-point seatbelts on new buses and enforces seatbelt use, while Texas mandates the installation of seatbelts only if funded, without a specific rule requiring their use. Iowa mandates both seatbelts on buses and their use by students.

The penalties for not wearing a seatbelt on a school bus vary across states. In New Jersey, students must wear seatbelts on buses, and if they fail to comply, the school faces penalties. In California, the first offense results in a fine of up to $20, and subsequent offenses can lead to fines of up to $50. Additionally, a student who fails to wear a seatbelt may be suspended from riding the bus for three days, with enforcement overseen by bus drivers, aides, or cameras. New York mandates that drivers ensure passengers under 16 wear seatbelts, with fines ranging from $25 to $100, and drivers can receive three penalty points on their license for violations (Occupant Restraint Law, 2018). In Texas, three-point seatbelts are required, and drivers can be fined between $25 and $200 if a student is found not wearing a seatbelt, with penalties varying based on circumstances (Mena & Haskins, 2023).

Seatbelt use liability and enforcement vary by state. In Florida, no liability is assigned to the state, schools, or bus operators if passengers fail to wear seatbelts (Frisman, 2022). California exempts schools and staff from liability unless students were not instructed on proper seatbelt use

(California Department of Transportation, 2021). In Virginia, drivers can be fined for failing to ensure seatbelt use by passengers under 18 (Virginia Department of Motor Vehicles, 2022). Arizona imposes a civil penalty of up to $10 per violation, but buses with over 10 passengers are exempt, with additional exceptions for medical conditions. Maryland fines drivers $83 per unbuckled passenger and issues two tickets if no one under 16 is restrained (Hogan et al., 2015). Texas enforces fines of $25-$50 for bus operators or passengers aged 15-17 and $100-$200 for adults responsible for unrestrained children (Safe Ride 4 Kids, 2024).

The NJMVC reports that approximately 17,000 school buses in the state lack lap and shoulder seatbelts. Transitioning to buses equipped with these belts, which have lower seating capacities than lap-only belts, may require additional buses and drivers. However, the overall impact on fleet sizes is uncertain due to unclear purchasing preferences and many existing routes already operating at peak capacity. The estimated cost for this transition is between $7.5 million and $10 million annually over 11 years (NJ State Law Library, 2018).

2.4.2 Legal and Institutional Recommendations

Kang (2023) focused on both domestic and international laws to identify legal and institutional shortcomings in school safety regulations. By reviewing government policies, research reports, and prior studies, the research proposes several key improvements. Recommendations include the effective implementation of school safety zones, stricter sanctions for non-compliance with safety education requirements, and the development of robust institutional plans to address safety regulation violations. These suggestions aim to enhance the overall effectiveness of safety measures and ensure better protection for students.

2.4.3 Impact of State Laws on Active Travel

Chriqui et al. (2012) investigated how various state laws related to minimum bussing distances, hazardous route exemptions, sidewalks, crossing guards, speed zones, and traffic control measures influenced active travel to school (ATS) in U.S. public elementary schools from 2007 to 2009. By analyzing state laws and school data through multivariate logistic and zero-inflated Poisson regression methods, the study found that most categories of state laws, except for those concerning sidewalks, were significantly associated with ATS policies and practices. This indicates that these laws, along with formal safe routes to school programs, play a crucial role in shaping ATS behavior.

2.4.4 Surveillance Camera Implementation

The installation of surveillance cameras on American school buses is becoming more common, though it is not yet universal. An increasing number of states are implementing laws to catch and penalize motorists who illegally pass stopped school buses by allowing stop-arm cameras to be installed on the exterior of the buses. Currently, at least 25 states have enacted such laws. Florida and Tennessee were the most recent states to pass stop-arm camera legislation in 2023. Delaware and Michigan followed suit in 2020 and 2021. In 2019, states like Indiana, Maine, New York, Oklahoma, Tennessee, and West Virginia authorized local use of these cameras, while Pennsylvania, Arkansas, and Utah passed similar legislation between 2017 and 2018. Alabama expanded its camera program in 2016, and South Carolina and Wyoming enacted stop-arm camera laws in 2014 (Verramobility, 2025). Earlier legislation in the 2011 and 2012 sessions introduced these measures in Connecticut, Georgia, Maryland, Rhode Island, Virginia, and Washington (State School Bus Stop-Arm Camera Laws, 2014).

2.4.5 Transporting School Children In Vehicles Other than School Bus

State regulations on student transportation vary significantly. In Pennsylvania, students may walk up to 1.5 miles (elementary) or 2 miles (secondary) to school, and vehicles used for student transport are not required to have specific colors or flashing lights unless they are federally mandated (Pennsylvania Public School Code, 2015). School-chartered vehicles are permitted for transporting special needs students to comply with ADA, and school bus drivers must hold "P" and "S" endorsements, while non-school event drivers need only the "P" endorsement (CONVAL School Board, 2019). California emphasizes driver safety, requiring a valid license, background checks, medical exams, first-aid training, and pre-trip inspections. Students must also be trained in the use of restraint systems. Options for special education transportation include regular buses, public transit, or parental reimbursement (California Department of Transportation, 2021). Florida restricted vehicles' seating capacity to less than 10 students and adhered to seating and crash protection rules, with written parental consent and clear school board policies required for transportation arrangements (Florida Senate, 2021). Finally, in New Jersey, vehicles must pass biannual inspections and meet NJMVC standards (N.J.A.C. 6A:27-7.1, 2025), with small vehicles defined as seating 10 or fewer and meeting a minimum gross vehicle weight rating (GVWR) of 3,000 pounds (N.J.A.C. 6A:27-7.4[a–b], 2025). According to N.J.A.C. 6A:27- 7.6,7.7, Private vehicles for school activities may be used under district-approved policies, and parents transporting only their own children are exempt from commercial licensing and health exams (N.J.A.C., 2024).

The regulations and policies for transporting students in vehicles other than school buses across different states. In California, drivers must have a valid license, a satisfactory driving record, and pass a criminal background check, with no specified seating capacity; vehicles must be in a safe condition, equipped with seatbelts or child safety seats, and maintained like a school bus (California Department of Education, 2021). In New York, parents need only a valid driver's license, and the vehicle can carry up to 10 adults, with the vehicle not subject to school bus inspections (New York State Education Department, 2021). In Florida, drivers need a valid license and must pass a physical exam, and the vehicle should accommodate fewer than 10 students, with children under age 8 using child safety seats (Florida Statutes, 2022). Pennsylvania prohibits the use of 11–15 passenger vans for school student transport unless grandfathered, requiring adherence to vehicle capacity limitations (Pennsylvania Department of Education, 2024). Texas permits personal vehicles to carry up to 15 students with proper child safety seats, while New Jersey stipulates that private vehicles carrying up to 8 passengers for their children should meet district-specific requirements, including insurance and safety regulations (Texas Education Code, 2024), (N.J.A.C., 2024).

2.4.6 Seat Capacity and Spacing Regulations

Federal regulations do not specify the number of passengers per school bus seat, leaving this decision to manufacturers and school transportation providers. Typically, manufacturers design seats based on the assumption of three small elementary students per 39-inch seat, a standard used for calculations related to vehicle weight and emergency exits (NHTSA, 2025). The NHTSA recommends that passengers be seated fully within their seats while the bus is in motion. Federal Motor Vehicle Safety Standard No. 222 mandates that large buses are protected through closely spaced, energy-absorbing seats, though individuals not fully seated do not benefit from this protection (NJDOE, 2024). However, School bus types vary, with Types A and B being smaller and Types C and D being larger, as illustrated in Figure 6. Generally, the capacity of a school bus increases from Type A to Type D, with Type D buses accommodating up to 90 students (School Bus Fleet, 2025).

Regulations on the maximum age and seating capacity of school buses vary by state. For instance, California and Pennsylvania do not impose explicit statutory requirements regarding either the maximum age of school buses or their seating capacity. In Illinois, passenger loads must comply with the manufacturer's recommended capacity (Illinois Administrative Code, 2002). Nebraska also sets no maximum vehicle age but requires adherence to manufacturer-specified capacity standards (Nebraska Department of Education, 2025). In New York, seating capacity is capped at 84 students, though there are no age restrictions for school buses (New York State Education Department, 2019). Virginia and Washington likewise do not enforce maximum age or seating capacity limits, but both states provide guidance through funding programs that encourage regular replacement cycles, 15 years in Virginia (Virginia Board of Education, 2024.) and 8 years for Type A buses and 13 years for Types C and D in Washington (Washington Office of Superintendent of Public Instruction, 2025).

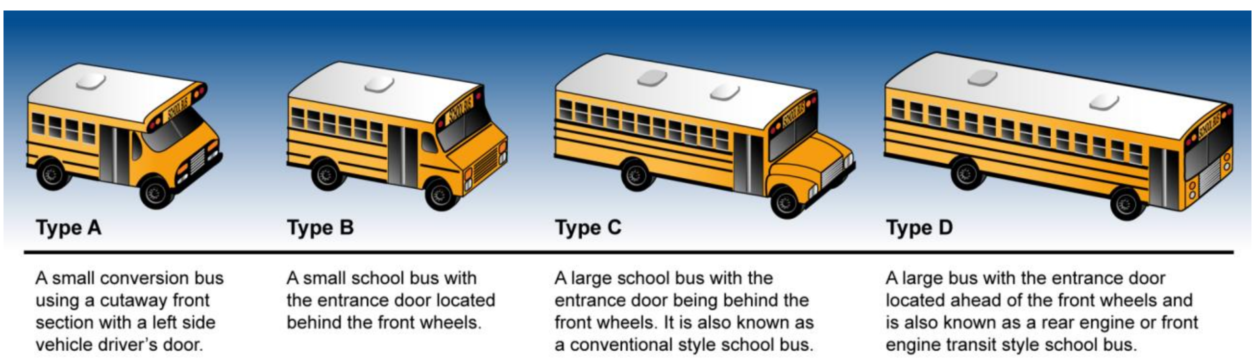


Figure 6 Different types of school buses (GAO, 2015)

2.4.7 Bus Lifetime and Characteristics

School buses are subject to different usage limits based on their type and weight. Standard school buses can be used for up to 12 years from the date of manufacture or until the end of the school year in which that date occurs. Buses that meet specific emission standards may be used for up to

15 years. Transit-type school buses, which have a gross vehicle weight of over 25,000 pounds, are permitted a lifespan of up to 20 years (NJDOE, 2024).

FMVSS imposes stringent safety features for new vehicles designed to transport 11 or more people for school-related events. FMVSS No. 108 requires buses to be equipped with signal lights that meet specific safety standards to enhance visibility and alert surrounding drivers when the bus stops to pick up or drop off students. The bus must feature two alternately flashing red lights mounted at both the front and rear, visible from 500 feet in normal sunlight. These red lights should only be activated when the bus is stopped for loading or unloading students, with exceptions in designated off-road loading areas or at controlled intersections. Additionally, the bus must have alternately flashing yellow lights near the red lights, also visible at 500 feet, which should be activated 100 to 500 feet before a stop. The bus must also include indicator lights visible to the driver to confirm when the flashing lights are active (NHTSA, 2023a).

According to NHTSA highway safety program guideline No. 17, school buses should be marked with "School Bus" in letters at least eight inches high and painted National School Bus Glossy Yellow. They must have black bumpers, safety equipment like fire extinguishers, and devices such as stop signal arms (NHTSA, 2023b). Compliance with FMVSS No. 108 for signal lamps and No. 111 for mirrors is also required (Uniform Guidelines for State Highway Safety Programs). In New Jersey, strict safety standards for school buses include the use of stop arms for loading and unloading and restrictions on carrying large musical instruments to prevent injuries. Only eligible students, chaperones, and authorized personnel may ride the bus, with specific eligibility criteria for non-public school students. All student transportation must be covered by a minimum of $1,500,000 in liability insurance. Additionally, while boards of education are not required to provide buses for nearby students, they may choose to do so, and nonpublic schools can optimize vehicle use by staggering schedules (NJDOE, 2024).

2.4.8 Bus Maneuver and Inspection

Visibility is the most critical factor in ensuring a safe school bus stop. Effective visibility encompasses three main aspects: motorists' ability to see the bus stop and students, the school bus driver's ability to see students and oncoming traffic, and students' ability to see the bus while remaining safely away from the road.

The practice of having a bus travel down a road and then turning around after a stop should be avoided if possible. When unavoidable due to road design or student locations, several safety measures are crucial. These include clear signage alerting motorists to the turnaround, visible speed limit signs to reduce speeding, adequate space for the bus to maneuver, and sufficient sight distances for all drivers to see the bus during the turnaround. Ensuring these factors can help enhance the safety of bus route turnarounds (NHTSA, 2022).

According to N.J. Admin. Code § 13:20-30.39, all registered school buses must undergo systematic inspections and maintenance to ensure their safety and proper operation. Operators are required to keep detailed records for each bus, including identification details, inspection and repair logs, lubrication records, and the schedule for upcoming maintenance. Daily condition reports completed by drivers must be retained for at least one year, while other records are kept for the vehicle’s lifespan. These records must be made available for review by the New Jersey Motor Vehicle Commission (NJMVC), the New Jersey State Police (NJSP), or the Office of Student Transportation in the Department of Education (Law and Public Safety, 2012). N.J.A.C. 13:20-30.39 provides that NJSP may participate in inspections but does not require NJSP to conduct them; the primary responsibility for bus inspections lies with NJMVC’s Bus Inspection Unit.[1] In practice, the NJMVC Bus Inspection Unit conducts regular inspections at least semiannually, with results reported to the Chief Administrator. Daily pre-trip inspections, required under 49 CFR 392.7, 392.8, and 396, remain the responsibility of drivers and operators, who must review, certify, and address any defects. Federal requirements do not assign NJSP or police any role in pre-trip inspections, though inspection reports may document whether drivers have complied with these obligations.

[1] Similarly, N.J.A.C. 13:20-30.5(a) recognizes that every State Police officer and every NJMVC school bus inspector is authorized to inspect school buses, but NJSP does not have a mandate to perform routine inspections, and its role is typically limited to enforcement actions or joint operations (Law and Public Safety, 2012).

In the United States, school bus inspection requirements vary by state. In California, school buses must be inspected every 3,000 miles or 45 days, whichever comes first. Illinois mandates that private, certified inspectors examine school buses every six months or 10,000 miles, whichever is sooner. Nebraska requires inspections before the school year starts and every 80 days during the year. The New York State Department of Transportation conducts inspections every six months. Pennsylvania performs spot checks on school buses from October to May, while Virginia mandates inspections every 45 days or 5,000 miles. Washington requires an additional unannounced inspection rate of 25% of each operator's fleet annually. Additionally, school buses must undergo systematic preventive maintenance and be inspected at least semiannually. Drivers are required to perform daily pre-trip inspections and report any safety issues promptly. Pre-trip inspections for buses under FHWA regulations must comply with 49 CFR 392.7, 392.8, and 396. An operator or their designee must review reports of any defects or deficiencies, ensure the necessary repairs are made, certify on the report that the repairs have been completed, and sign the report to confirm their review and certification. Moreover, inspection reports from the NJMVC Bus Inspection Unit and the NJSP Transportation Safety Bureau will indicate whether drivers completed the required pre-trip inspections before being subjected to an inspection. Additionally, all student transportation must be covered by a minimum of $1.5 million in liability insurance from July 1st, 2025.

2.4.9 Passing and Stopping

According to New Jersey law N.J.S.A. 39:4-128.1, motorists must stop at least 25 feet away from a stopped school bus with flashing red lights on a two-lane highway or any road without a physical divider, regardless of the direction of travel. On a divided highway, drivers must stop at least 25 feet from the bus if they are on the same side of the highway. Vehicles approaching from the opposite side of a divided highway may pass the stopped bus at a speed of 10 mph or less. When passing a stopped bus at a school, day camp, or similar activity, drivers must maintain a speed of 10 mph or less. Violations result in a $100 fine and up to 15 days (about 2 weeks) in jail or community service for a first offense, with subsequent offenses carrying a $250 fine or more and up to 15 days (about 2 weeks) in jail. Each offense also adds five points to the driver's record (Bus Safety, 2023) (N.J.S.A. 39:4-128.1).

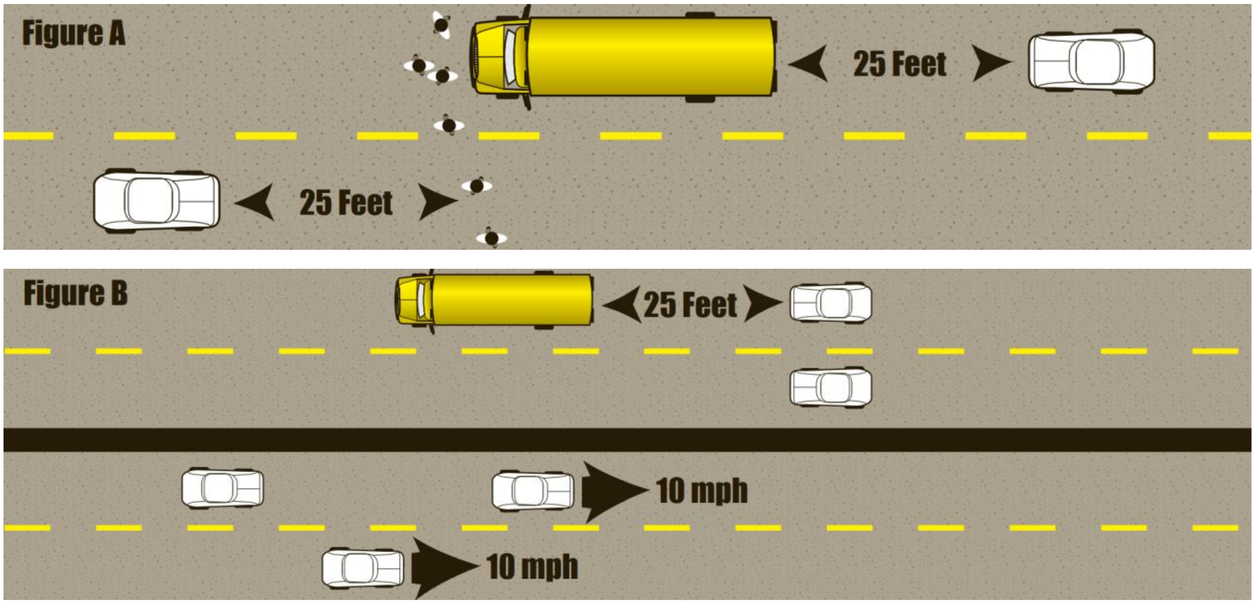


Figure 7 Stopping and passing regulations for school buses in New Jersey (Bus Safety, 2023)

2.4.10 Bus Stop Environment

According to the NHTSA, the environment around a school bus stop is critical for its safety. When planning bus routes and stops, various risks must be assessed, including proximity to intersections, railroad crossings, and non-vehicle hazards. Bus stops should be placed away from intersections, especially on roads with speed limits exceeding 35 mph. They should also be positioned at least 300 feet away from railroad crossings. Additional concerns, such as high-crime areas or locations with potentially dangerous wildlife, should be avoided to maximize student safety (NHTSA, 2023). The American Association of State Highway and Transportation Officials (AASHTO) provides guidelines on stopping sight distances, which vary with speed limits and road conditions. School districts may adopt more conservative visibility requirements than those recommended by AASHTO. If visibility is inadequate, posting a "School Bus Stop Ahead" sign can help, but this should be done with care to avoid sign overload. Various obstructions, such as vegetation and parked vehicles, can hinder visibility, making it essential to choose bus stop locations that minimize these issues (NHTSA, 2022).

2.5 Conclusion

The analysis of contributing factors to school bus crashes highlights the persistent challenges posed by human error, driver characteristics, roadway conditions, environmental factors, and vehicle-related issues. Despite stringent safety regulations and technological advancements, reducing school bus crashes requires a multifaceted approach that integrates training, enforcement, technological improvements, and infrastructure enhancements.

Enhancing driver training programs ensures that school bus operators are well-equipped to handle various challenges, including emergencies and diverse student needs. Mandatory refresher training programs should be implemented, incorporating defensive driving techniques, emergency evacuation drills. Organizations such as the National Safety Council and the ASBC provide valuable safety materials, videos, and awareness campaigns, reinforcing safe practices for both drivers and students.

Strengthening law enforcement efforts plays a vital role in ensuring school bus safety and preventing violations that put students at risk. Random Bus Violator Programs, periodic enforcement operations designed to identify and penalize drivers who illegally pass stopped school buses, should be mandated through an Attorney General directive. New Jersey's severe penalty for such violations, a 5-point license penalty, serves as a deterrent, but increased police presence and automated enforcement tools, such as onboard cameras, can further enhance compliance.

Advancements in vehicle safety technologies provide an opportunity to mitigate crash risks and improve overall school bus safety. Automatic emergency braking, collision avoidance systems, and blind-spot monitoring can provide real-time assistance to drivers, reducing the likelihood of accidents. GPS tracking and onboard cameras improve safety monitoring and support enforcement efforts by documenting violations and incidents. Furthermore, revising FMVSS to adopt stricter flammability and smoke emission standards, as recommended by past crash investigations, can improve post-crash survivability.

Well-designed infrastructure and school zone improvements are crucial in minimizing conflicts between school buses, pedestrians, and other vehicles. Implementing clearer signage, lowering speed limits, and installing pedestrian crosswalks and signals can enhance visibility and safety. Roadway design modifications that prioritize bus routes and minimize potential hazards can further reduce the risk of crashes in school zones.

Regular vehicle maintenance and strict inspection protocols ensure that school buses remain in optimal working condition and meet the highest safety standards. Annual audits should be conducted to verify compliance with safety regulations, and maintenance personnel should undergo regular assessments to confirm their qualifications. NHTSA sets higher safety standards for school buses compared to other vehicles, reinforcing the importance of ongoing maintenance to uphold these safety measures.

A comprehensive approach that combines rigorous driver training, proactive enforcement, advanced safety technologies, well-designed infrastructure, and stringent vehicle maintenance is essential to minimizing the risks associated with school bus transportation. Continued collaboration among school districts, transportation agencies, law enforcement, and policymakers will be critical in ensuring the highest level of safety for school children.

3. ANALYZING SCHOOL BUS-RELATED CRASHES IN NEW JERSEY

3.1 Introduction

School bus safety is a critical concern in the United States, where school transportation-related crashes have resulted in significant fatalities and injuries. According to the NHTSA, from 2007 to 2016, 4% of all fatal motor vehicle crashes were school-transportation-related, resulting in 1,282 deaths. Among these fatalities, 281 were school-age children, including 116 occupants of other vehicles, 98 pedestrians, and 58 occupants of school vehicles. In 2018, the Fatality Analysis Reporting System (FARS) reported 117 fatalities and 13,000 injuries due to school bus-related crashes nationwide. Despite various safety initiatives, crashes involving school children remain a pressing national issue, highlighting the need for continued research and improvement in school bus safety measures. The literature further indicates that factors such as head-on, rear-end, and side-impact collisions present heightened risks of injury, and driver characteristics, including age and traffic violations, are crucial in determining crash outcomes (Lidbe et al., 2022).

From 2016 to 2020, three people were killed in school bus-related crashes in New Jersey. Additionally, nearly one-sixth of the pedestrians involved in motor vehicle crashes in New Jersey during this period were under 18 years of age. A recent analysis shows that school bus crashes are 2.1 times more likely on non-routine routes compared to routine routes (O'Neal et al., 2014). These figures underscore the importance of targeted research to address the safety of school bus passengers in the state.

This study aims to evaluate the factors influencing school bus crashes in New Jersey from 2016 to 2024, utilizing data from the NJDOT Safety Voyager database. Employing advanced machine learning models, including XGBoost, Random Forest (RF), Support Vector Machine (SVM), Decision Tree, and AdaBoost, the research has analyzed crash data to predict contributing factors and assess model performance and accuracy. Additionally, SHapley Additive exPlanations (SHAP) analysis has been used to interpret the impact of various factors on crash outcomes, such as property damage, injury, and fatality. The findings will provide critical insights into school bus crash dynamics and offer data-driven recommendations for improving safety measures, thereby contributing to the protection of school children and informing future safety policies and interventions.

3.2 Data

The School Bus Crash Severity Data used in this study was obtained from the Safety Voyager Crash Report, accessible via Safety Voyager (2024), Crash Records.[2] The initial dataset was substantial, comprising 155 columns and 16,603 rows of unprocessed data, offering a comprehensive picture of incidents related to school buses. To enable thorough analysis, a rigorous data-cleaning procedure was implemented to rectify any inconsistencies and inaccuracies. Additionally, the dataset was categorized using a meticulous selection of characteristics, organizing the information into pertinent subsets.

3.2.1 Data Description

The dataset comprises a total of 16,603 recorded crashes spanning from 2016-2024. These incidents have been classified into three categories according to the KABCO injury severity scale: Fatal, Injury, and Property Damage Only. Of the total recorded crashes, 89 (0.54%) were fatal, 577 (3.47%) involved injuries, and 15,936 (95.2%) resulted in property damage. The dataset encompasses 19 attributes, which include roadway features, environmental characteristics, and speed-related features. In addition, in the NJ Safety Voyager dataset, "Hazardous Material Involved" refers to incidents where vehicles carrying substances that pose risks to health, safety, or the environment, such as flammable liquids, toxic chemicals, explosives, or radioactive materials, were involved in crashes. More description has been presented in Appendix H, the explanatory variables along with their respective categories.

3.2.2 Data Processing

After reviewing relevant literature, 21 key characteristics were retained for their importance in evaluating school bus crash severity. The dataset was rigorously cleansed by excluding irrelevant data fields, and records with missing values, those labeled as 'Other' or 'Unknown', and entries

[2] Safety Voyager is an engineering-focused software application that was designed to provide a quick and easy visual perspective of crash data. By providing 2D and 3D graphical displays, Safety Voyager can quickly show a comparative view of crashes with a defined area, municipality or county as determined by the user. In addition, various filters are available to create detailed user defined queries.

with zero values. This process ensured the dataset's integrity and relevance for a detailed analysis of factors influencing the severity of school bus crashes. In the analysis, characteristics were clustered and categorized based on similarities, using specialized coding for organization and easier interpretation. To verify the data's accuracy, the team cross-referenced it with the NHTSA's FARS for school bus-related crashes in New Jersey, confirming the dataset's reliability.

3.3 Methodology

Various statistical analysis methodologies and models were used to analyze the dataset and identify significant factors associated with crashes and crash severity, as set forth below.

3.3.1 Random Forest (RF)

The random forest (RF) ensemble learning technique has exceptional performance and effectively mitigates overfitting in comparison to many other commonly employed classifiers (Breiman, 2001). In 2001, Breiman enhanced this classification algorithm by using bagging, a technique that improves the efficiency and accuracy of machine learning algorithms, together with random feature selection, a widely recognized method in the field of machine learning (Breiman, 2001). Bagging creates several training subsets by randomly selecting samples with replacements from the original training dataset, while random feature selection builds individual decision trees on each of these independent training subsets. The outcome of the model is decided by analyzing the majority voting of the training subgroups.

3.3.2 Support Vector Machine (SVM)

A support vector machine is a classifier that uses statistical learning theory to categorize data, whether separable or non-separable, by employing a kernel-based approach. The references cited are (Boswell, 2002) and (Cortes and Vapnik, 1995). To do the analysis, the Support Vector Machine (SVM) attempts to transform the input features into a space with a higher number of dimensions. The program subsequently attempted to discern a hyperplane capable of differentiating the dataset on different sides of the plane. The Lagrange multiplier is utilized to expand the margin of the hyperplane from the nearest data point. If a linear classification approach fails to categorize the dataset, the hyper SVM offers an inhomogeneous polynomial function, a Gaussian radial basis function (RBF), and a non-linear transformational kernel.

3.3.3 Decision Tree (DT)

The decision tree (DT) is a machine-learning algorithm used for classification and regression. It splits data into subsets based on feature values, forming a tree-like structure of decisions (Quinlan, 1986). Each node represents a test, branches represent outcomes, and leaves represent class labels or values. Decision trees are simple and interpretable, but can overfit complex datasets, which pruning can help mitigate.

3.3.4 AdaBoost

Adaptive Boosting (AdaBoost) is an ensemble method that combines weak classifiers to form a strong one. Introduced by Freund and Schapire in 1997, AdaBoost iteratively trains classifiers on weighted data, increasing weights for misclassified instances to focus on hard examples (Freund and Schapire, 1997). The final model is a weighted sum of these classifiers, enhancing performance and reducing overfitting.

3.3.5 Extreme Gradient Boosting (XGBoost)

XGBoost is a highly efficient and scalable machine learning algorithm for classification and regression developed by Chen and Guestrin in 2016 (Chen and Guestrin, 2016). It enhances traditional gradient boosting by implementing parallel processing and regularization techniques to improve speed and performance. XGBoost builds models sequentially, correcting errors from previous models and minimizing the loss function using gradient descent. Its robustness and efficiency make it ideal for large and complex datasets.

3.4 Variable Selection

Correlated explanatory variables can significantly degrade the performance of a deep learning model. Therefore, it's essential to remove correlated input features before introducing data into the model. Feature selection is crucial for eliminating redundant features from explanatory variables (Heinze et al., 2018). In this context, a multiple classifier model from the scikit-learn ensemble library was employed to identify attributes that exhibit significant correlation with the dependent variable.

3.5 Evaluation Matrix

When dealing with imbalanced datasets, accuracy is an inadequate metric for evaluating the performance of a deep learning algorithm in classification challenges. The model exhibits superior performance in the class that is overrepresented compared to the class that is underrepresented. To address this problem, the F1-score has been adopted as the evaluation metric in this article. The F1-Score calculates the harmonic mean of precision and recall, as determined by equations (1) to (3) (Yu et al., 2010). Recall quantifies the error resulting from false negatives (FNs), whereas precision quantifies the error resulting from false positives (FPs). The F1 score quantifies the overall error resulting from false positives (FPs) and false negatives (FNs) in a model. It takes into account both accuracy and recall values in its calculation, providing a comprehensive measurement score for the model. The F1-score ranges from 0 to 1. The lower and higher F1-score indicate proportional decreases and increases in model accuracy, respectively.

$$\text{Precision} = \frac{\text{TP}}{\text{TP+FP}} \tag{1}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP+FN}} \tag{2}$$

$$\text{F1 Score} = \frac{2\times\text{Presicion}\times\text{Recall}}{\text{Precision}\pm\text{Recall}} \tag{3}$$

Where, $\text{TP} = \text{True Positive (Predicted the positive classes correctly)}$

$\text{FP} = \text{False Positive (Predicted the positive classes incorrectly)}$

$\text{FN} = \text{False Negative (Predicted the negative assess incorrectly)}$

3.6 Interpretable Machine Learning (SHAP)

The SHAP (Shapley Additive exPlanations) method, developed by Lundberg and Lee, allows for the interpretation of output from machine learning models (Lundberg and Lee, 2017). According to the explanations provided by local researchers and the principles of game theory, SHAP offers a technique for determining the individual impact of each attribute. (Lundberg and Lee, 2017) Improved the model by employing tree explainer techniques to efficiently evaluate the global and local risk variables of a SHAP value (Ayoub et al., 2021).

3.7 Result

To analyze the significance of variables influencing the crash severity of young pedestrians within the intersection boundaries of school districts, the XGBoost, K-Nearest Neighbour (KNN), and Classification and Regression Tree (CART) classifier from the ensemble library of Scikit-learn was utilized.

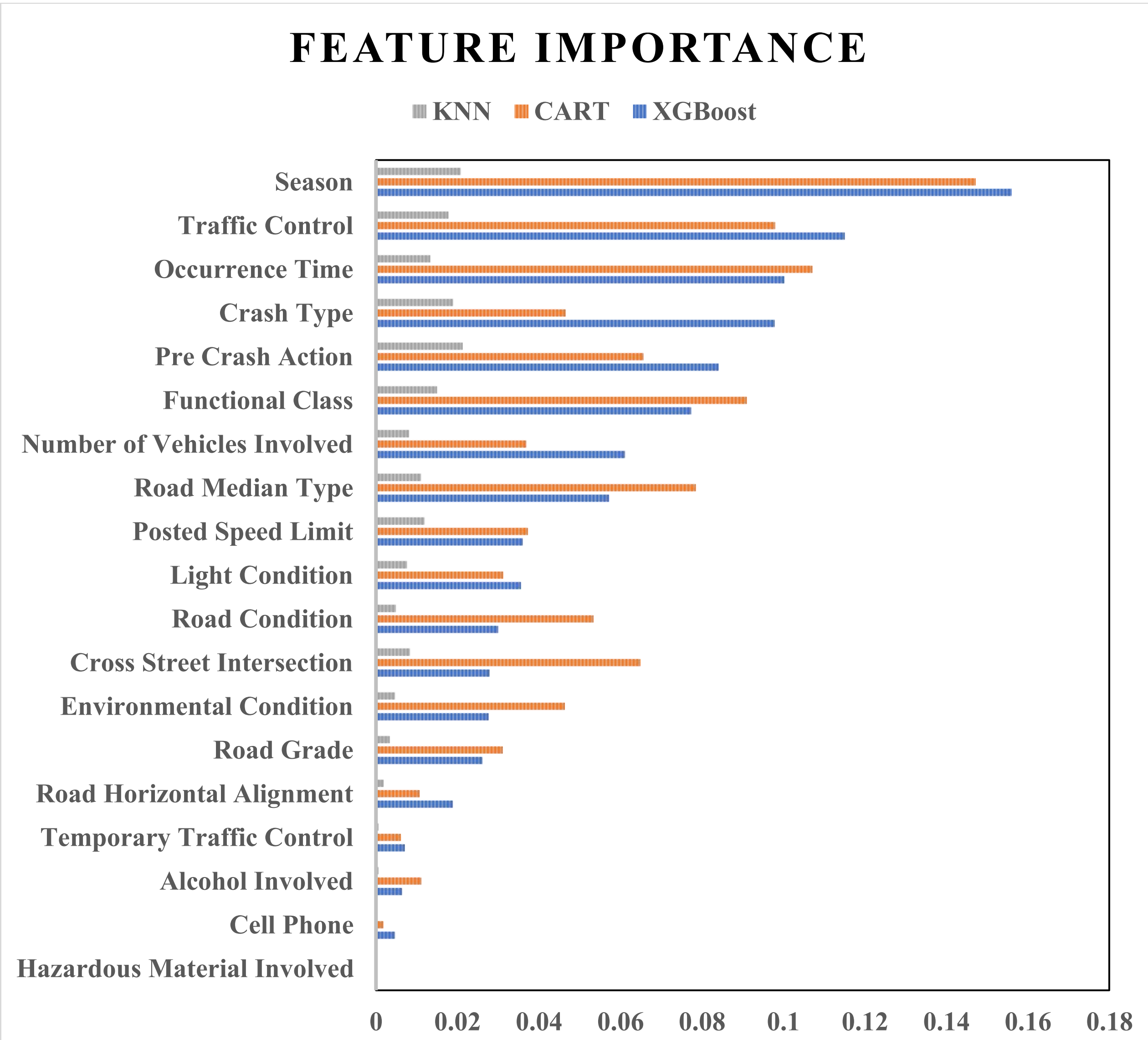


Figure 8 Feature importance for the selected variables.

Figure 8 displays the variable importance results from three classifiers. For the XGBoost classifier, the most critical parameter for predicting crash severity is 'Season,' followed by 'Traffic Controls,' with relative importance factors of 0.156 and 0.115, respectively. The other two classifiers show similar results. In contrast, 'Hazardous Material Involved' and 'Cell Phone Use' have the lowest relative feature importance for the XGBoost classifier, at 0.0046 and 0.000025, respectively, among all the features.

3.8 Correlation Matrix

To analyze the correlations among the dependent variables, a correlation matrix was plotted. When two features are highly correlated (values close to 1), they should not be included together in the same model to avoid multicollinearity. Figure 2 highlights the correlations between features, revealing that road conditions and environmental conditions are highly correlated, with a correlation value of 0.72. Given that road condition is a more critical feature according to the variable importance results, with a relative importance of 0.029 compared to 0.027 for environmental conditions, the road condition feature was selected for the final analysis.

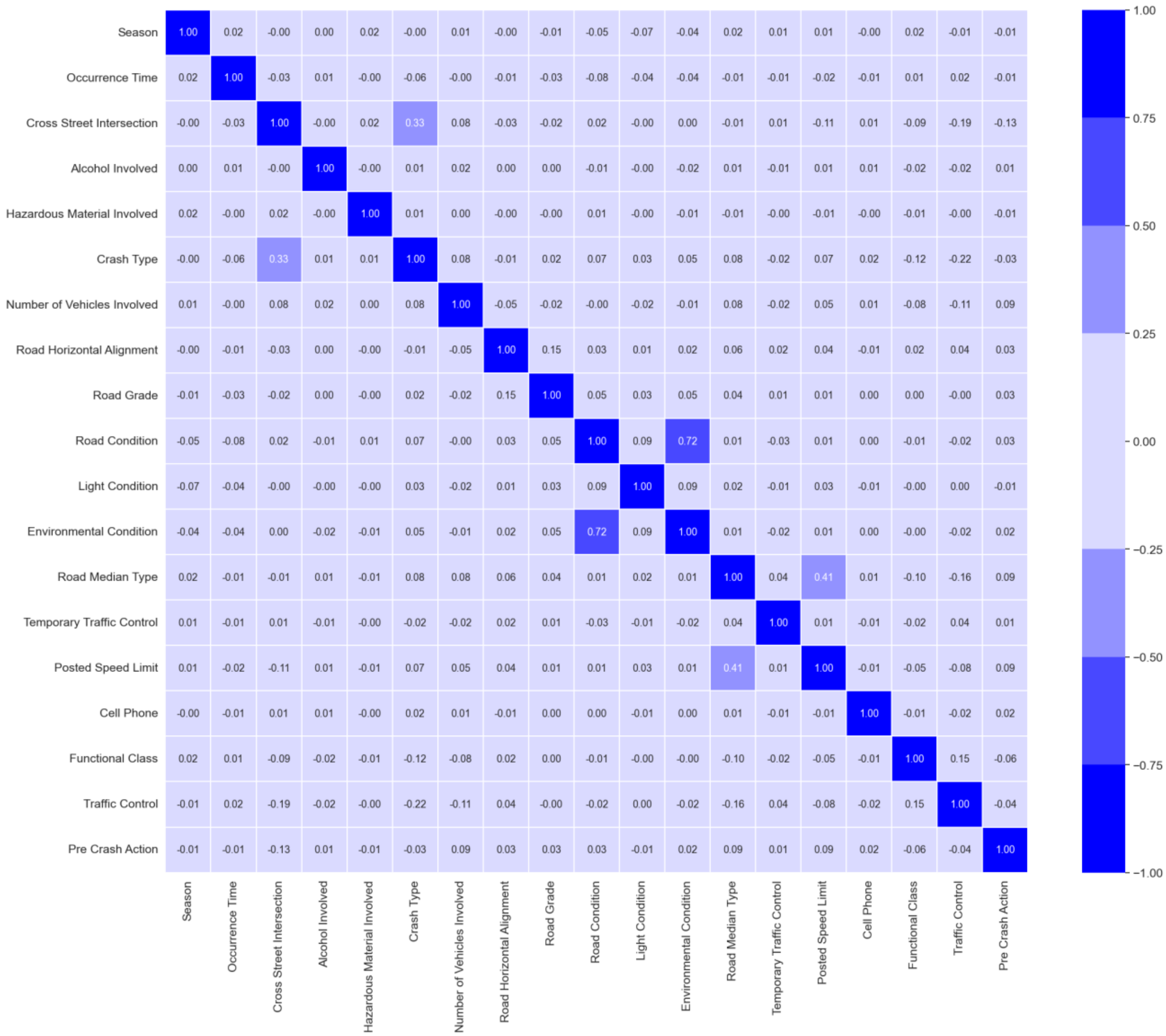


Figure 9 Correlation matrix between the independent variables

3.9 Model Performance

A correlation matrix was generated for the independent variables to address the sensitivity of machine learning models to multicollinearity. Variables showing high intercorrelation were excluded before inputting data into the machine learning algorithms. The classification report for the five models indicates that the XGBoost, Random Forest, and Decision Tree models yield the most accurate results for the training dataset, achieving an accuracy of 96%. These models also show strong predictive capability across the three severity types (PDO, Injury, and Fatal), with accuracies ranging from 93% to 99% for the training dataset.

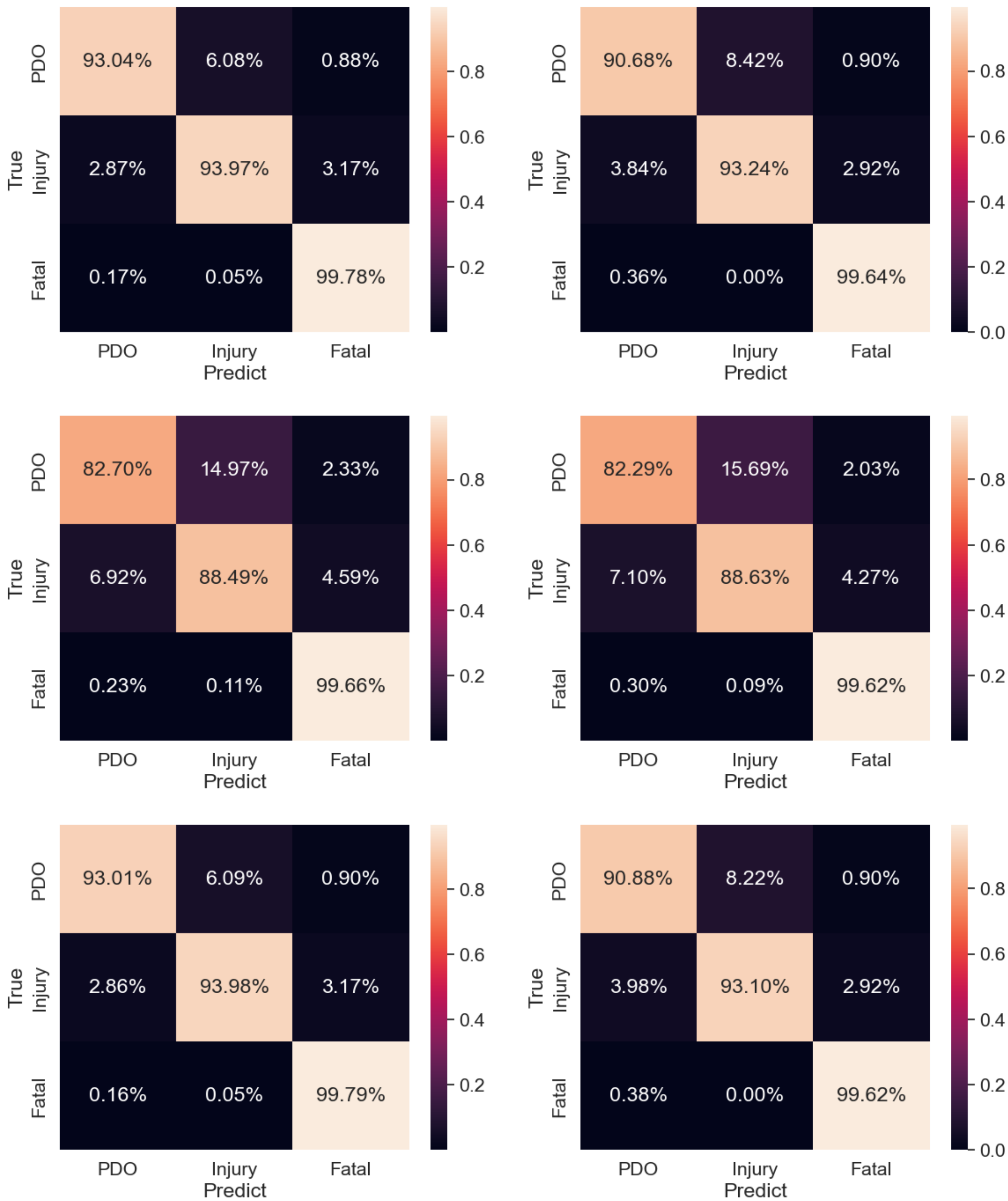
For the testing dataset, both XGBoost, Random Forest, and Decision Tree models maintain the highest overall accuracy at 94%. They demonstrate robust performance in predicting crash severities, with accuracies between 89% and 99% for PDO and Injury. For fatal crashes, the XGBoost model outperforms Random Forest and Decision Tree models with a precision score of 96%, making it the top performer among all five models. In contrast, the AdaBoost model performs the poorest, with overall accuracies of 70% for the training and testing datasets, respectively. Table 1 describes all the performance values for all five models. One reason for the better performance of the XGBoost is that it excels in handling imbalanced datasets for crash prediction due to its gradient-boosting framework, which focuses iteratively on difficult cases (Jamal et al., 2021).

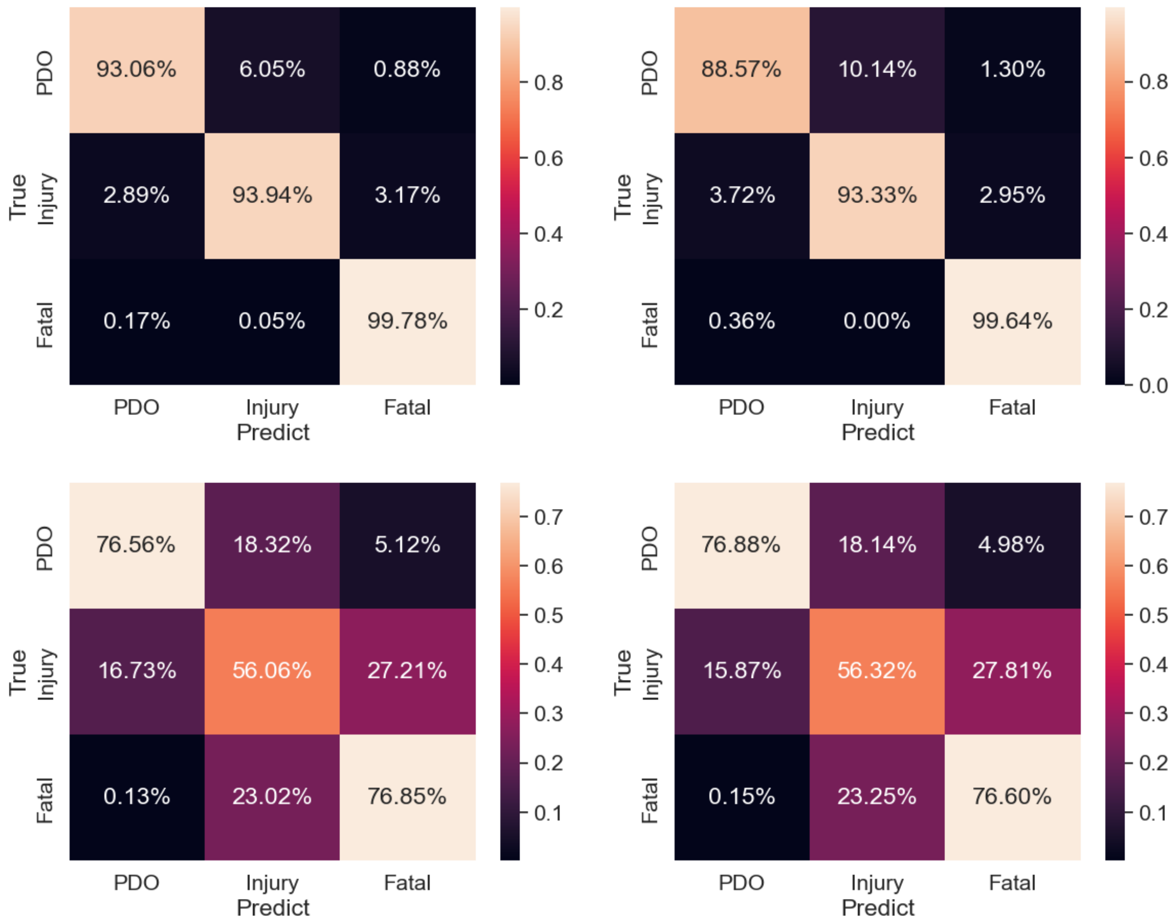
Table 1 Classification report of all five models (XGBoost, RF, SVM, Decision Tree, AdaBoost) for the training and testing dataset)

XGBoost							
Training				Testing			
Crash Type	Precision	Recall	F_1 Score	Crash Type	Precision	Recall	F_1 Score
PDO	0.97	0.93	0.94	PDO	0.96	0.91	0.93
Injury	0.94	0.94	0.94	Injury	0.92	0.91	0.93
Fatal	0.96	0.99	0.98	Fatal	0.96	0.99	0.98
Accuracy	0.96			Accuracy	0.94		
SVM							
Training				Testing			
Crash Type	Precision	Recall	F_1 Score	Crash Type	Precision	Recall	F_1 Score
PDO	0.92	0.82	0.87	PDO	0.92	0.82	0.87
Injury	0.86	0.88	0.87	Injury	0.85	0.89	0.87
Fatal	0.94	0.99	0.97	Fatal	0.94	0.99	0.97
Accuracy	0.90			Accuracy	0.90		
RF							
Training				Testing			

Crash Type	Precision	Recall	F_1 Score	Crash Type	Precision	Recall	F_1 Score
PDO	0.97	0.93	0.95	PDO	0.95	0.91	0.93
Injury	0.94	0.94	0.94	Injury	0.92	0.93	0.92
Fatal	0.96	0.99	0.98	Fatal	0.95	0.99	0.98
Accuracy	0.96			Accuracy	0.94		
Decision Tree							
Training				Testing			
Crash Type	Precision	Recall	F_1 Score	Crash Type	Precision	Recall	F_1 Score
PDO	0.97	0.93	0.95	PDO	0.96	0.89	0.92
Injury	0.94	0.94	0.94	Injury	0.90	0.93	0.92
Fatal	0.96	0.99	0.98	Fatal	0.95	0.99	0.98
Accuracy	0.96			Accuracy	0.94		
AdaBoost							
Training				Testing			
Crash Type	Precision	Recall	F_1 Score	Crash Type	Precision	Recall	F_1 Score
PDO	0.81	0.77	0.79	PDO	0.83	0.77	0.80
Injury	0.57	0.56	0.58	Injury	0.56	0.57	0.56
Fatal	0.71	0.77	0.74	Fatal	0.69	0.77	0.73
Accuracy	0.70			Accuracy	0.70		

Figure 10 presents the confusion matrix derived from the XGBoost, SVM, RF, Decision Tree, and AdaBoost models, offering a comprehensive comparison of true and predicted values across both training and testing datasets. In the training dataset, the XGBoost model exhibits robust performance, accurately predicting 93.04% of PDO, 93.97% of Injury, and an impressive 99.78% for Fatal Injury classifications. The testing dataset results indicate the XGBoost model's ability to predict PDO at 90.68%, Injury at 93.24%, and Fatal Injury at 99.64%. The RF model, while slightly lower in accuracy, still performs well, with 93.01%, 93.98%, and 99.79% accuracy for PDO, Injury, and Fatal Injury in the training dataset, and 90.88%, 93.10%, and 99.62% in the testing dataset, respectively. The confusion matrix provides a detailed insight into the models' predictive capabilities, showcasing their strengths across various severity classifications.





Training Dataset (Top to Bottom: XGBoost, SVM, RF, Decision Tree, AdaBoost)

Testing Dataset (Top to Bottom: XGBoost, SVM, RF, Decision Tree, AdaBoost)

Figure 10 Confusion matrix for XGBoost, SVM, RF, Decision Tree, and AdaBoost models

3.10 Model Interpretation

SHAP (SHapley Additive exPlanations) summary plots play a crucial role in understanding the contribution of each feature to crash severity prediction models. These plots provide insights into the impact of individual features on the model's output, offering a clear depiction of feature importance. The values on the y-axis represent the features, while the x-axis illustrates the Shapley values, indicating the average contribution of each feature to the model's output. The shape value for ‘Crash Type’ and ‘Season’ was the highest mean, which implies that increased feature value contributes significantly to higher crash severity predictions. Sideswipe and rear-end collisions are more likely to result in injuries (Lidbe et al., 2022). Head-on crashes with other buses, trucks, or motorcycles also increase injury risk (Rahman et al., 2011). The shape value for ‘Hazardous Material Involved’ and ‘Cell Phones’ was the least important feature. This is reliable, as other factors like functional class and traffic controls play a vital role in the crash severity for the school bus.

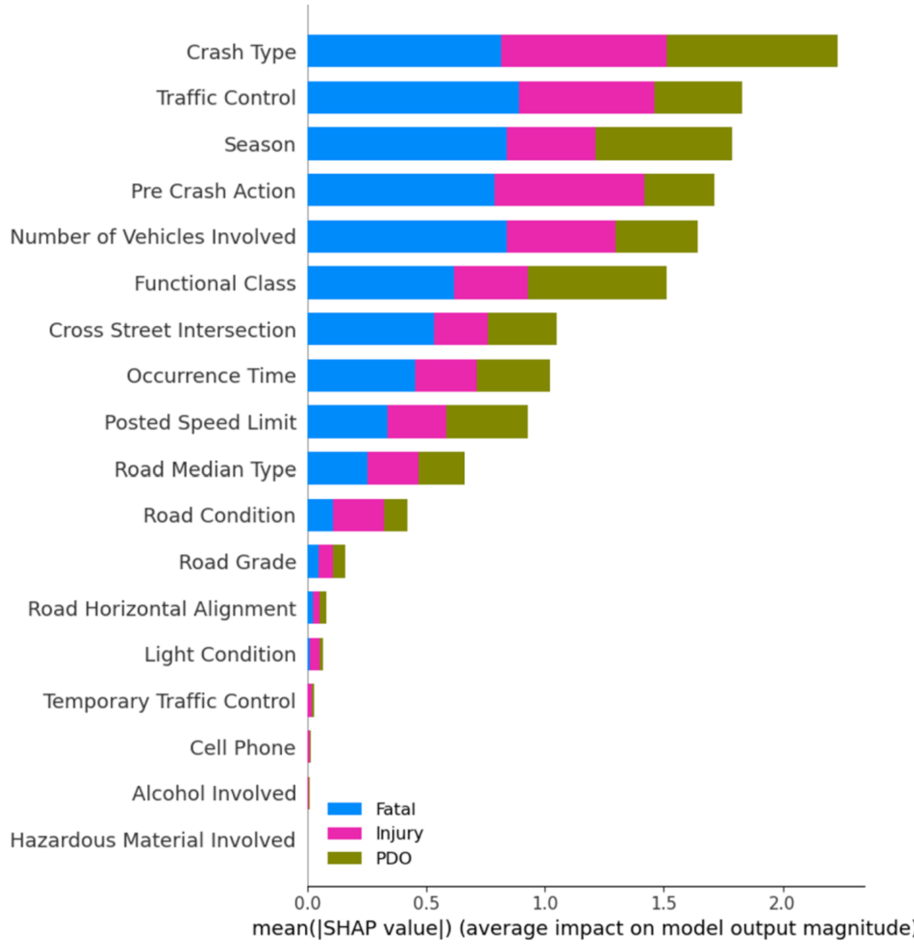


Figure 11 SHAP general summary plot for the variables

The SHAP summary results shed light on the variables that significantly impact the severity of crashes, categorized into Property Damage Only (PDO), injury, and fatal injury outcomes. Analysis of Figure 12 highlights that 'Head On' collisions predominantly result in PDO and injury crashes, whereas fatal crashes often involve ‘collisions with fixed objects’ or ‘rear-end’ impacts. Head-on collisions with school buses generally result in PDO or injury crashes due to the protective design and larger mass of buses, which absorb much of the impact. In contrast, crashes involving fixed objects or rear-end impacts are more likely to be fatal, as these scenarios often involve sudden deceleration or force concentration on specific vehicle parts, leading to severe outcomes (Mayrhofer et al., 2003). Seasonal variations also influence crash outcomes; fatal crashes occur more frequently in winter, while summer sees a higher occurrence of PDO crashes, potentially due to adverse weather conditions that increase such incidents (El-Basyouny et al., 2014) (Hasan, A.S., et. Al., 2023). Also, fatal crashes are more prominent when one vehicle is involved in the crash, whereas injury severities occur when two or more vehicles are involved. Single-vehicle crashes tend to result in more fatal outcomes because the vehicle often encounters a solid, immovable object or rolls over, leading to concentrated impact forces on the occupants (Tay & Rifaat, 2007), (Kakhani A., et. Al., 2024). In contrast, multi-vehicle crashes usually distribute the impact forces across several vehicles, which often reduces the severity of injuries, making fatalities less likely (Elvik, 2010).

Furthermore, the timing of crashes varies with severity; fatal crashes are most likely to occur in the morning, coinciding with school commute hours, thereby increasing their frequency. In contrast, PDO crashes are more common in the evening, influenced by reduced visibility and increased driver distraction (Voas et al., 2009). This temporal pattern underscores the need for targeted interventions during these specific times to mitigate severe and fatal crashes, especially during school operational hours (Adeyemi et al., 2021), (Hasan, A.S. et. Al., 2024)

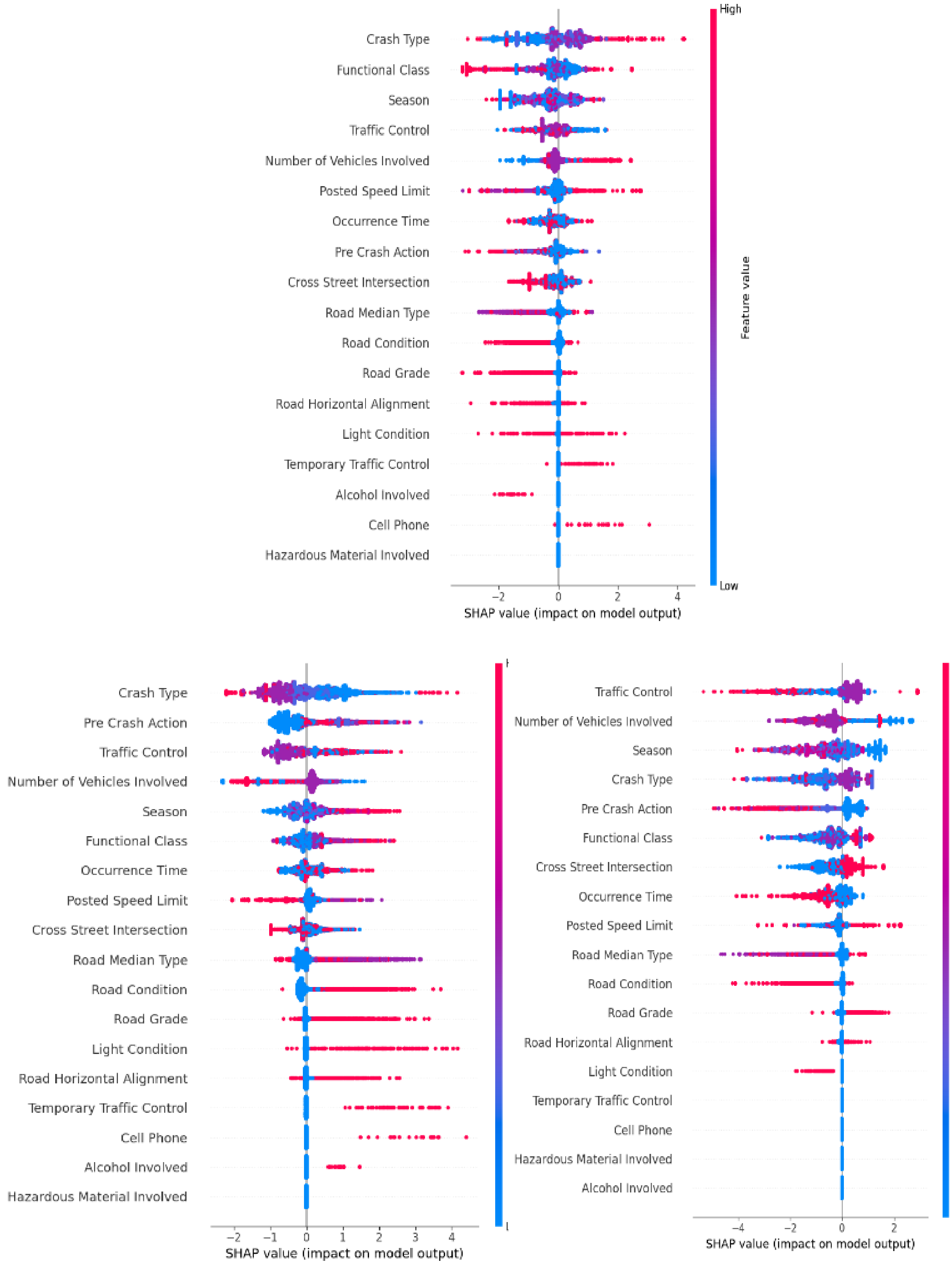


Figure 12 Shape plots for PDO, injury, and fatal crash

3.11 Conclusion

This section helps provide an understanding the severity of crashes involving school buses. To investigate this issue, we utilized advanced machine learning models, XGBoost, SVM, RF, Decision Tree, and AdaBoost, to analyze and predict crash severity in school bus-related incidents. The results indicate that XGBoost was the most effective, particularly for predicting fatal crashes, outperforming Random Forest and Decision Tree. SHAP analysis highlighted crash type and season as significant contributors to crash severity, evidenced by their high SHAP values. Conversely, factors like cell phone use and hazardous material involvement have less impact. The analysis also revealed specific patterns: collisions with fixed objects are more likely to be fatal, while head-on collisions predominantly result in PDO and injury-related crashes. Additionally, fatal crashes are more prevalent in the morning and during winter, whereas most PDO crashes occur in summer and in the evening.

Our findings can help develop targeted strategies to reduce serious crashes by improving visibility and driver alertness, especially during high-risk times such as mornings and winter. Future research could use advanced modeling techniques and real-time data analytics to better predict and prevent crashes. Additionally, our methods of using machine learning to analyze traffic safety can be applied to other road safety studies. However, this study is not without limitations. The dataset used spans only from 2016 to 2024, which may not capture more recent trends or changes in road safety regulations. In addition, the lower count of fatal crashes may affect the prediction and model performance in terms of training.

4. PRACTICAL INSIGHTS

4.1 Introduction

To assess challenges and best practices in school bus safety, researchers conducted surveys and semi-structured interviews with school bus safety personnel, enforcing agencies, and school bus contractors. These efforts provided insights into their expertise, field experience, and contributions to improving school transportation safety. The findings were summarized to identify key lessons learned, challenges faced, and effective strategies for enhancing student safety. This approach allowed for a comprehensive exploration of safety measures, policy implementation, and operational challenges from the perspectives of those directly involved in school bus safety management. The following groups were interviewed during the study period.

1. Subject Matter Expert Interview for School Bus Safety
2. Survey with the Enforcing Agencies Related to School Bus Non-compliance
3. Survey with the School Bus Contractor Companies

4.2 Subject Matter Expert Interview for School Bus Safety

To gain a deeper understanding of school bus safety from experienced professionals, researchers conducted semi-structured interviews with school bus safety personnel. These interviews provided insights into their expertise, field experiences, and contributions to enhancing school transportation safety. The findings were summarized to identify key lessons learned, challenges faced, and best practices in ensuring student safety. This approach allowed for a comprehensive exploration of safety measures, policy implementation, and operational challenges from the perspectives of those directly involved in school bus safety management.

The questions made up the semi-structured interviews; most of them were open-ended, depending on the interviewee's background, while one predetermined question focused on the interviewee's professional function, title, and experience.

The questions were based on the expertise of the interviewees, suggestions, proven strategies for reducing crashes, challenges, countermeasures, and recommendations. Following is the list of agencies with whom the interviews were conducted.

Table 2 List of agencies for the interview conducted

No	Type of Interview	Agency	Years of Experience
1	State Police	NJSP	18
2	Agency	Safe Routes Partnership	9
3	DOT	South Carolina DOT	14
4	DOT	California DOT	15
5	State Police	NJSP	9

The interview design allowed the interviewees to consider the questions and provide details that they would not have otherwise mentioned. Because they were free to stray and ask follow-up questions, participants were able to elaborate on certain unplanned topics and provide examples, which resulted in a clearer and more thorough response. The interviews, which lasted an average of approximately one hour, were done one-on-one using the online platforms Webex and Microsoft Teams. For additional analysis, audio recordings of the conversations were made, and verbatim transcripts were created. The results of this analysis are subsequently presented in the following section.

4.2.1 Expertise of the Interviewees

The structured interviews conducted with public agencies in the Tri-State area involved experts with 14-18 years of experience in school bus-related activities and commercial vehicle enforcement, along with extensive involvement in lobbying for school zone safety regulations. Professionals possess significant expertise in reviewing crashes, monitoring compliance, and advocating for policy changes to enhance school bus and school zone safety. Their work is focused on policy development, safety advocacy, traffic management, and regulatory enforcement, aiming to improve school bus operations and ensure the safety of commercial vehicles in school zones.

4.2.2 Suggestion for Enhancing School Bus Safety

The interview findings suggest a comprehensive approach to enhancing school bus safety by addressing pre-crash, during-crash, and post-crash measures.

- Pre-crash strategies emphasize ensuring driver qualifications and vehicle certification to meet safety standards.
- During crashes, a focus on identifying root causes such as driver error, environmental factors, or mechanical failures is crucial for prevention.
- Post-crash measures prioritize injury prevention through proper safety equipment, efficient crash response protocols, and well-trained emergency responders.

Additionally, broader safety measures include implementing strategies from safe routes to school programs, such as separating transportation modes, marked crosswalks, daylighting corners, and reducing crossing distances while considering kinetic energy transfer in fast-moving vehicles to enhance overall safety.

To further support these efforts and foster community involvement, it is recommended that the NJDOE develop and disseminate a “School Bus Safety” presentation or informational flyer for schools to share with parents and guardians, outlining potential enforcement activities, penalties, and administrative disciplinary actions related to school bus safety violations. This outward messaging will help raise awareness, promote compliance, and strengthen the collective responsibility for ensuring the safety of students during school transportation.

4.2.3 Most Proven Strategies for Reducing Crashes in School Zones

Proven strategies for reducing crashes in school zones emphasize a combination of engineering, enforcement, and data-driven approaches. Key recommendations include implementing marked crosswalks, daylighting corners, and reducing crossing distances to improve pedestrian safety. Data-driven strategies are essential for addressing driver-related crash factors, requiring adjustments to driver training and testing based on school district crash data. Additionally, integrating engineering solutions with effective traffic management and targeted enforcement during critical times is crucial for maximizing safety and reducing crash risks in school zones.

4.2.4 Challenges in Maintaining Safety on School Buses

Maintaining safety in school buses presents several challenges, including ensuring that children wear seatbelts and identifying responsible personnel for monitoring compliance. Limited funding within local sectors and school districts makes it difficult to implement necessary safety measures. Managing the mix of various transportation modes in school zones and ensuring safe separation between them further complicates safety efforts. Additionally, variations in vehicle size and weight, combined with the need to understand children's behavior while boarding or crossing the bus, add further complexity to ensuring school bus safety. The potential countermeasures for these challenges are provided in the following table.

Table 3 Countermeasures for the challenges in maintaining safety in school buses

Challenges	Countermeasures
Monitoring Seatbelt Compliance	Implement regular seatbelt checks and designate responsible staff for compliance.
Funding Limitations	Seek alternative funding sources, such as grants, or prioritize safety measures in the budget.
Managing Mixed Traffic	Create designated zones for different transportation modes (e.g., separate lanes for buses, bikes, and pedestrians) with public engagement through workshops/training.
Vehicle and Child Safety Concerns	Train drivers to understand children's behavior and implement vehicle design changes (e.g., lower bus heights) to ensure safety during boarding.

4.2.5 Interview Perspectives on School Buses

Interviews with stakeholders highlighted the importance of ongoing driver certifications that include medical evaluations, such as reflex assessments, to help ensure driver readiness. Participants emphasized the value of collaboration between the NJDOE and the NJDOT to develop policies that align with local needs and community expectations. Addressing gaps in technology and assessing their effectiveness should be prioritized alongside establishing regulations for their proper use. At the federal level, reinstating safe route-to-school requirements and funding local training can enhance safety, while state investments in proven countermeasures, as demonstrated in Minnesota and Washington, can help reduce fatalities. Locally, coordination between school districts and the DOT is crucial to addressing challenges effectively.

4.2.6 Recommended Emerging Technologies and Challenges for Integrating Technologies

Emerging technologies recommended for improving school bus safety include cameras with vehicle detection systems to monitor illegal passing, both inside and outside the vehicle, for effective crash identification. Automatic braking systems are suggested as a potential measure to prevent collisions, while three-point seatbelts for children are emphasized as crucial for reducing crash severity. However, integrating these technologies poses challenges, particularly due to complications in data collection arising from varying company policies and regulations. Additionally, the effective use of cameras inside and outside school buses requires proper policy implementation to ensure compliance and maximize safety benefits.

4.2.7 Recommended Driver Training for Improving Safety in School Buses

Driver training for improving school bus safety includes recurrent licensing and proficiency-based training to ensure safe vehicle operation. Collaboration between school districts is necessary to identify best practices for driver requirements, training methods, and implementation. Additionally, training should emphasize understanding student behavior during boarding, drop-off, and road crossings to enhance safety measures and minimize risks associated with school bus transportation.

4.2.8 Overall Findings and Discussions

Overall recommendations to improve school bus safety using existing resources include enforcing recurrent licensing and proficiency-based training for drivers and incorporating reflex and medical tests as part of certification. School districts and transportation agencies should collaborate to develop standardized policies tailored to local needs and ensure effective implementation. Enhancing enforcement through cameras with vehicle detection for illegal passing and deploying both interior and exterior surveillance can strengthen monitoring without requiring major infrastructure changes. Implementing marked crosswalks, daylighting corners, and reducing pedestrian crossing distances in school zones are cost-effective engineering solutions that can significantly enhance safety. Additionally, setting clear seatbelt requirements for students and ensuring proper monitoring to enforce their use can improve crash outcomes. Moreover, assessing gaps in current safety technologies and optimizing available resources, such as improving driver training on student behavior and emergency response, can maximize effectiveness while minimizing additional costs.

4.3 Survey with the Enforcing Agencies Related to School Bus Non-compliance

The survey was conducted to assess the policies and regulations related to school bus non-compliance, focusing on enforcement measures, challenges, and potential improvements. The primary goal was to gather insights from law enforcement agencies regarding existing standards, inter-agency collaboration, safety equipment assessments, and strategies for enhancing compliance and public awareness.

A total of nine surveys were conducted with different police departments, targeting agencies directly involved in enforcing school bus safety regulations. The survey covered various critical topics, including policy standards, enforcement challenges, penalties for non-compliance, driver training and monitoring, school bus maintenance, funding availability, public outreach efforts, and specialized coordination programs.

Table 4 List of enforcement agencies for the survey

No	Agency
1	Brooklawn PD
2	Clementon PD
3	Gloucester Township PD
4	Lindenwold PD
5	Magnolia PD
6	Pennsauken PD
7	Voorhees Township
8	Cherry Hill PD
9	Winslow PD

The survey consisted of multiple open-ended questions, allowing respondents to express their opinions and provide detailed feedback on the issues and challenges they encountered. The surveys were conducted via email, enabling participants to share their insights comprehensively.

4.3.1 Enforced Regulation/Policy to Ensure Safety Standards

The findings from the interviews highlight important aspects of school bus safety enforcement. Several police departments lack specific policies related to school bus safety, as they are not directly involved with busing districts. Safety enforcement relies on collaboration between local police, school districts, and educational boards, with police ensuring compliance with New Jersey's Title 39 regulations while school districts are responsible for managing bus inspections and driver qualifications. Additionally, some departments follow federal and state DOT regulations, including bi-annual inspections, regular maintenance, and pre-trip inspections conducted by certified mechanics.

4.3.2 Collaboration in Emergency Preparedness for School Buses

Emergency preparedness for school buses involves varying levels of collaboration and planning. While some areas lack coordinated efforts, others have established emergency response plans that include coordination between law enforcement, school districts, and relevant organizations. Emergency drills, such as bi-annual evacuation exercises, are sometimes conducted, but they typically focus on broader emergency scenarios like active shooter situations rather than specifically addressing school bus-related incidents.

4.3.3 Assessment of Safety Equipment on School Buses

Several police departments do not evaluate the effectiveness of safety equipment on school buses. However, some areas have coordinated efforts, such as the collaboration between local law enforcement and bus supervisors to assess GPS and camera systems, with footage being obtained legally through subpoenas for enforcement purposes. Some departments also report no legal obstacles in accessing data for law enforcement needs. In certain regions, the DOT is responsible for assessing and providing camera footage during investigations without major issues.

4.3.4 Agency Guidelines and Outreach for Transporting School Students

The interview revealed that some police departments do not provide specific school bus safety guidelines for parents or individuals outside of school personnel. In contrast, other areas use social media and community outreach to share school bus safety guidelines, receiving positive feedback from parents. Some departments send letters with safety information and codes of conduct, but they may not engage in further outreach. Additionally, certain areas have conducted past safety studies and continue to use social media reminders to educate the community about school bus safety and laws.

4.3.5 School Bus Driver Training and Credentialing Policies

Most police departments do not have specific policies on this matter, as training and credentialing are generally managed by school districts or the Department of Transportation. Some areas provide annual training during driver orientation, focusing on bus and traffic safety to ensure compliance with laws. Additionally, drivers are required to pass written and behind-the-wheel tests, maintain a clean driving record, and complete biennial training as part of state-regulated training. In certain cases, police departments rely on the Department of Transportation for driver training and credential oversight.

4.3.6 Enforcement of CDL, Medical Cards, and Driver Complaints

Some police departments primarily address safety issues during crashes or infractions, but do not actively track complaints. While one department does not enforce CDL or medical requirements, it tracks and investigates complaints related to school buses, as these responsibilities fall under the jurisdiction of the school districts. In contrast, another department monitors critical documents such as medical cards, background checks, and CDL expirations, with expired documents leading to the removal of drivers from their routes. Additionally, some departments implement comprehensive tracking systems, which include monitoring CDL, medical cards, and service hours and investigating complaints through interviews, camera footage, and driver observations.

4.3.7 Penalties and Enforcement for School Bus Violations

In response to the interview, several police departments have minimal involvement with school buses but will issue citations for Title 39 violations if encountered. When it comes to safety concerns, certain departments direct these issues to the school district or bus company unless they are related to crash incidents. Responsibility for seatbelt violations generally lies with the bus driver or school district, with warnings or citations typically issued to the driver. Enforcement against students or parents for seatbelt violations is rare, though it may occur in cases of repeated offenses. For multiple infractions, students may face detention or suspension, and parents are notified. In some instances, police departments may issue summonses to parents for repeated violations.

4.3.8 Challenges in Enforcing School Bus Safety Regulations

The findings highlight several issues faced by different police departments. One department encounters a challenge with misinformation spread on social media during emergencies, which impacts public communication and confidence. To combat this, they focus on using official channels for accurate information. Another department struggles with student non-compliance, particularly when students ignore safety protocols like standing up or not wearing seatbelts. Addressing this issue is time-consuming and often requires written reports and video reviews. In contrast, some police departments report minimal challenges in enforcing safety regulations, with no significant issues regarding compliance.

4.3.9 School Bus Maintenance Checks and Tracking

Some police departments implement specific measures to ensure safety. For example, one department uses checklists for driver pre-trip inspections and state inspections to maintain proper documentation and track maintenance issues. In contrast, another department indicated that maintenance checks are overseen by the Department of Transportation, but no further details were provided regarding the process.

4.3.10 Proactive Aggressive Driver Campaigns Near School Buses

Various efforts have been made by police departments to improve safety around school zones. Some departments conduct proactive patrols near school bus zones, focusing on aggressive driving, often supported by grant funding. A comprehensive approach is adopted by another department, running campaigns that combine traffic enforcement, education, and the review of signage for compliance with safety standards such as the MUTCD. School Resource Officers are also involved in monitoring bus safety. Additionally, enforcement is emphasized at the start of the school year to address traffic issues and educate the public. Some departments engage in direct patrols within school zones as part of regular efforts to enhance safety for pedestrians, motorists, and school buses.

4.3.11 Investigation and Reporting of School Bus Crashes

The findings on the investigation and reporting of school bus crashes reveal varied approaches. All departments investigate school bus crashes and document them using NJTR-1 forms, tracking these incidents in their Police Records Management System, though not specifically for school buses. Other departments track school bus crashes within the same records system, but do not separate them from other types of crashes. Some also maintain a separate administrative file for monitoring school bus crashes to ensure focused analysis. However, a few departments do not track school bus crashes separately, reporting them as regular motor vehicle crashes instead.

4.3.12 Key Takeaways from School Bus-Related Incidents

The key takeaways from school bus-related incidents highlight several important aspects of emergency response and safety. Some departments have not dealt with specific school bus emergencies, as they primarily focus on broader safety issues. However, key lessons from motor vehicle crashes emphasize the importance of immediate police and medical responses, effective communication, and maintaining calm while sharing findings with relevant staff. In minor crashes, tracking passenger locations during emergencies was a crucial takeaway. After serious crashes, a study of bus routes was conducted to identify safety issues, leading to adjustments in pickup and drop-off locations.

4.3.13 Challenges in Implementing School Bus Safety Protocols

The use of safety protocols shows a range of experiences across different departments. Some departments have not encountered specific challenges when implementing safety protocols during school bus emergencies. A significant challenge, however, is the spread of false information on social media, which can cause confusion and panic. To counter this, some departments focus on providing accurate updates through official channels to maintain public confidence. In some cases, school districts manage bus operations without direct involvement from the police in handling emergency protocols. Additionally, some departments report minimal issues when enforcing safety regulations.

4.3.14 Specialized Enforcement and Coordination for School Bus Safety

Specialized enforcement and coordination for school bus safety shows a range of practices across different departments. Some police departments do not conduct specialized enforcement or coordination for school bus safety, with one noting that they are a walking district and do not handle such safety concerns. In contrast, other departments implement targeted enforcement operations to address driver behavior around school buses, enforce relevant laws, and collaborate with school bus personnel on safety issues. Additionally, some departments leave school bus safety enforcement to the school district, as the buses are managed by the schools.

4.3.15 Overall Findings and Discussion

The surveys of enforcement agencies revealed key insights into the enforcement and coordination of school bus safety. Enforcement of seatbelt usage and other safety violations is primarily handled by bus drivers and school districts, with penalties typically issued to drivers for non-compliance. Maintenance checks and inspections are managed by the Department of Transportation, along with school districts, using detailed checklists during pre-trip inspections and state inspections to ensure buses are in safe operating condition. Proactive enforcement campaigns focus on addressing aggressive driving and improving traffic safety in school zones. These campaigns include public education, targeted patrols, and collaboration with law enforcement to reduce violations in these high-risk areas. When it comes to school bus crashes, these are investigated and tracked by law enforcement, with some police departments maintaining dedicated records for school bus-related incidents. However, some police departments report a lack of detailed information regarding specific policies, procedures, or funding related to school bus safety. This highlights potential gaps in data collection, policy enforcement, and overall response to school bus safety concerns.

To improve school bus safety, it is recommended that local police, school districts, and educational boards strengthen collaboration and coordination in enforcing safety regulations, planning emergencies, and sharing resources. Regular emergency drills, involving both school districts and police departments, should be standardized, along with clear communication protocols for faster response times. The use of GPS and camera technology on school buses should be expanded, with streamlined access to footage for law enforcement to identify and prosecute violations, including seatbelt non-compliance. Public outreach campaigns on social media and through community programs should educate parents, students, and drivers on safety practices, emphasizing the importance of wearing seatbelts, with clear penalties for those who fail to comply. An audit of policies, procedures, and funding related to school bus safety should be conducted to address gaps in enforcement and emergency response frameworks. Additionally, specialized enforcement focused on school bus safety should be implemented in all districts, and seatbelt violations should be more rigorously enforced, with penalties for repeated offenses. School bus driver training and certification should be enhanced to cover all safety aspects, and law enforcement should support ongoing training for drivers to ensure they are aware of relevant laws and safety protocols. These actions would lead to a comprehensive and coordinated approach to improving school bus safety for all involved.

4.4 Surveys of School Bus Contractors

This survey was conducted to gather insights from school bus contractors regarding their experiences, challenges, and decision-making factors in school bus operations. The primary goal was to assess key considerations in vehicle procurement, safety feature enhancements, and the adoption of new technologies to improve school bus safety and efficiency.

The survey targeted members of the New Jersey School Bus Contractors Association (NJSBCA), focusing on their perspectives on school bus design, regulatory compliance, and emerging industry trends. A total of four surveys were completed, covering topics such as purchasing decisions, design improvements, challenges in implementing safety technologies, costs associated with new installations, the inclusion of three-point seatbelts, safety testing compliance, and the production of electric school buses.

Table 5 List of companies for the survey

No	Company
1	BR Williams Inc
2	Belair services/transport
3	Villani Bus Company
4	Klarr Transportation

The survey featured multiple open-ended questions, allowing respondents to provide detailed feedback and share their professional insights. It was conducted via email, ensuring participants had the flexibility to respond comprehensively.

4.4.1 Fundamental Considerations in School Bus Design and Manufacturer Preferences

The survey responses indicate that reliability and operating costs are key factors in the design of school buses. Safety is inherently prioritized, with all buses required to meet strict New Jersey and national regulations. In addition to the standard safety features, manufacturers are increasingly focusing on incorporating crash avoidance technology, which, while not yet mandatory, is becoming a standard option. One respondent mentioned a preference for Thomas buses due to a strong working relationship with the supplier. However, they noted that all buses comply with the same state safety requirements, and there are no significant differences in safety features across brands. Additionally, the findings emphasize adherence to strict New Jersey specifications, including seatbelts, fire-resistant materials, and emergency exits, and prioritize the driver area for safe operations, with a preference for the reliable and cleaner diesel engines available today.

4.4.2 Design Improvements for School Bus Occupant Safety During Emergencies

The survey responses indicate that while companies do not incorporate additional design improvements specifically aimed at assisting occupants during emergency situations, they prioritize the driver area, driver comfort, and convenience. One respondent emphasized that well-trained, competent, and diligent drivers, rather than solely relying on technology, play an unmatched role in ensuring safety.

4.4.3 Equipment and Technology for Supporting School Bus Emergency Responses

From the result, it was indicated that buses are equipped with GPS, which is checked daily for functionality, and two-way radio communication between drivers and dispatch, with routine inspections and testing. Also, live cameras with AI technology are used to help keep drivers awake, alert, and focused on the road, with audible prompts for driver distraction. While some buses have radios that connect directly to the County's Original Equipment Manufacturer (OEM) for emergency use, maintaining these radios has become challenging due to parts and service shortages. For buses without radios, drivers use their cell phones for communication, which has become the standard due to the comfort and ease of use. Additionally, 90% of the fleet is equipped with cameras, although ensuring their functionality remains a constant challenge.

4.4.4 Challenges in Integrating New Safety Technologies into School Buses

Responses highlight that the main challenges in integrating new safety technologies into school buses are cost related. Adding additional features increases both the purchase cost and the level of maintenance required, which can significantly raise operational costs. A thorough quarterly inspection already takes several hours, and adding more features would further extend these costs. Additionally, the financial constraints imposed by the low-bid procurement system in New Jersey make it difficult for contractors to afford improvements beyond the minimum specifications. While safety is ultimately dependent on the driver's training and performance, these financial and operational challenges present significant barriers to integrating advanced safety technologies.

4.4.5 Estimated Costs of Integrating Safety Technology into School Buses

All the responses indicate that providing an estimate for the costs associated with integrating safety technology into school buses is challenging due to the wide variety of technologies available. As a result, no specific cost estimate can be provided at this time. However, according to the other findings, it requires an initial investment of approximately $1000 per vehicle, with a monthly cost of $50, along with additional maintenance and labor costs to keep the system running smoothly.

4.4.6 Impact of Three-Point Seatbelts on School Bus Seating Capacity and Costs

The survey responses indicate that all school buses purchased in New Jersey in 2019 and later are required by law to be equipped with three-point seat belts. This requirement did not affect the seating capacity of the bus, which remains at 54 passengers, considered small compared to other states where buses can hold over 60 or even up to 72 passengers. The addition of three-point seatbelts increased the cost of the bus by approximately $7,000.

4.4.7 Safety Tests and Inspections for School Buses

School buses undergo multiple safety inspections throughout their life cycle. The NJMVC inspects all new buses before they are put into service and conducts biannual inspections for the life of the vehicle. Additionally, the company has an in-house repair shop that performs quarterly inspections and maintenance every three months. Aftermarket safety items are inspected weekly, and drivers are responsible for conducting pre-trip inspections four times a day. Any issues identified during the pre-trip inspections are addressed within 24 hours. These safety tests involve both internal (company repair shop and drivers) and external (NJMVC) parties.

4.4.8 Maintenance Procedures for School Buses

The companies follow specific procedures for the maintenance checks of school buses, as required by New Jersey law. Drivers are required to perform a pre-trip inspection every day before operating their buses, using an app on their phones that guides them through a step-by-step process to ensure completion of the inspection. Additionally, the fleet team inspects all school vehicles every 3,000 miles or every 3 months, as mandated by law. These inspections are thoroughly documented to maintain proper records. The responses also highlighted that no technology or equipment can replace the importance of well-trained, experienced drivers in emergencies, despite meeting or exceeding all State and Federal maintenance requirements.

4.4.9 Ensuring Compliance with Safety Regulations and Standards

The companies ensure compliance with safety regulations and standards set by federal and state authorities through an internal review process and regular inspections by the NJMVC, which reviews their records every six months. Additionally, the companies leverage their experience and a strong commitment to maintaining the safest fleet in New Jersey as part of their dedication to safety. Moreover, the survey responses indicate that maintaining safety and compliance requires significant investment in staff, equipment, and wages, but contractors struggle to remain competitive due to routes being awarded solely on the lowest bid rather than on safety.

4.4.10 Involvement in the Production and Use of Electric School Buses

The survey indicates that companies currently operate seven electric Thomas 54-passenger school buses but are still in the early stages of using electric vehicles (EVs) and continue to learn and document their performance. However, the company does not engage in the production of electric school buses. No specific advantages or disadvantages regarding safety in emergencies were detailed in the response.

4.4.11 Collaboration with Law Enforcement and DMV for School Bus Safety and Inspections

Respondents collaborate weekly with multiple New Jersey DMV inspection teams. Under a maintenance contract, they are also responsible for maintaining and inspecting the school bus fleets of other school districts. The response did not mention any full-scale exercises or specific training involving law enforcement or the DMV.

4.4.12 Additional Resources for Enhancing Emergency Preparedness

The survey responses emphasize the need for more accountability in the school bus industry, including school bus certification with annual reviews and better follow-up with contractors, especially those without secure facilities or compliance records. The lack of oversight, particularly for smaller contractors, raises concerns about safety risks, such as untrained drivers or compromised equipment. The company also stresses the importance of human factors in improving emergency preparedness and safety, advocating for annual disaster training programs for first responders and focusing on personnel over equipment. They highlight a new training program launched last July, which reduced incidents by 25%, and underscore the need for a culture of safety, responsibility, and accountability to combat unsafe practices, particularly from "rogue contractors" that harm the industry's reputation.

4.4.13 Overall Findings and Discussions

The overall findings from the survey responses highlight a strong focus on safety, reliability, and cost-effectiveness in school bus operations. Manufacturers and companies prioritize meeting strict safety regulations, with an emphasis on routine inspections and the use of technology such as GPS, communication devices, and cameras to enhance emergency preparedness. However, challenges arise due to financial constraints, which limit the ability to incorporate advanced safety technologies beyond the basic regulatory requirements. While human error remains a significant concern, companies are investing in driver training programs to reduce incidents and improve safety outcomes. Additionally, collaboration with external agencies such as the NJMVC and local law enforcement plays a critical role in maintaining compliance and ensuring safety standards are met. Despite these efforts, the industry faces challenges with rogue contractors, which undermine safety efforts and highlight the importance of maintaining strong oversight and regulations.

To enhance school bus safety and operations, it is recommended that companies continue to prioritize regular driver training programs focused on improving judgment and adherence to safety protocols, as human error remains a key factor in incidents. Additionally, increased collaboration with local first responders and the NJMVC for ongoing disaster training and inspections could further strengthen emergency preparedness. Financial constraints should be addressed by exploring funding opportunities or partnerships that enable the integration of advanced safety technologies, such as crash avoidance systems, without compromising budgetary limits. Furthermore, strict enforcement against rogue contractors is essential to maintain industry standards and ensure safe operations, as these entities undermine the efforts of legitimate contractors. Establishing earlier annual certification deadlines, implementing automated compliance alerts, and maintaining up-to-date contractor lists will help ensure that only qualified and compliant operators are providing student transportation. Incentivizing early compliance and enforcing penalties, including public disclosure for persistent violations, will further strengthen oversight and promote a consistent safety culture across the industry. Strengthening oversight and developing a consistent safety culture across the industry will be key to sustaining improvements in safety and reliability.

5. CONCLUSION AND RECOMMENDATIONS

Recommendations for improving school bus safety were developed based on crash statistics, crash analysis, literature review, and interview findings.

5.1 Inclusion of Lap-Shoulder (Three-Point) Seatbelts and Enforcement

New Jersey law now requires all school buses manufactured on or after 180 days following the enactment of P.L. 2018, c.118 to be equipped with lap-shoulder (three-point) seatbelts. Although this requirement applies to newly manufactured buses, many older buses remain in service without these enhanced restraints, continuing to pose a safety risk for students.

The financial cost of retrofitting each bus with lap-shoulder belts is approximately $7,000 per bus. With an estimated 17,000 buses in New Jersey still lacking this technology, the total cost would be about $120 million and could be implemented over a number of years to align with fleet replacement cycles and budget constraints.

Enforcing mandatory seatbelt use for students is crucial to enhancing safety inside school buses, as improper restraint usage can significantly impact injury severity during crashes. In New Jersey, seatbelts are required on all school buses, but compliance enforcement is inconsistent, similar to other states where mandates exist but are weakly enforced (California Department of Transportation, 2021; Safe Ride 4 Kids, 2024).

NJMVC could mandate compliance checks during inspections, require district reports, certify trained enforcement staff, and coordinate with law enforcement on surveillance-based violations. To mitigate injury risks, LPS, offered by manufacturers, provide enhanced protection by restraining both the lap and torso, reducing serious injuries in crashes; their effectiveness depends on proper enforcement, student education, and integration into broader safety strategies.

To ensure consistent and effective seatbelt compliance in school buses, New Jersey should implement a clearly defined enforcement policy, assign responsibility, and introduce appropriate penalties for non-compliance. According to policies from other states and findings in the literature, bus drivers and aides should be tasked with monitoring seatbelt use both before departure and during rides. In the event of repeated violations, parents of the child should be notified, reinforcing accountability and ensuring that compliance is maintained through a shared responsibility between school staff and families. The state can adopt a model where accountability is clearly established, and penalties serve as effective deterrents. Additionally, the installation of onboard surveillance cameras could be mandated to monitor seatbelt usage and provide verifiable evidence to support enforcement actions and disciplinary measures. A comprehensive approach, including enforcement, penalties, education, and infrastructure investment, is necessary to improve school bus safety.

5.2 Policy and Regulation Improvements

A standardized enforcement framework across school districts is essential to ensure consistency in school bus safety regulations, as enforcement practices currently vary. Law enforcement agencies report gaps in data collection and policy enforcement, with some departments lacking detailed records of school bus-related incidents. Research suggests that strengthening regulatory frameworks through standardized enforcement and institutional planning can significantly enhance school safety (Kang, 2023). This framework should also include monitoring LPS conditions through common performance indicators, with manufacturers offering FMVSS-compliant systems that can significantly reduce crash severity when properly used, documented, and enforced.

Expanding enforcement campaigns focused on school zone safety and aggressive driving prevention are also crucial, as such initiatives have proven effective in reducing violations. Interview findings indicate that inconsistent enforcement leads to lapses in school bus safety, reinforcing the need for stricter sanctions against non-compliance with safety education and operational guidelines. Additionally, structured funding strategies must be developed to support school bus safety initiatives and prevent resource constraints from undermining policy effectiveness. Research highlights that robust institutional plans, including dedicated funding for enforcement and safety programs, can improve overall compliance and protection for students (Kang, 2023). Implementing these measures would address existing regulatory shortcomings and create a more effective and uniform approach to school bus safety enforcement.

5.3 Collaboration Between Agencies

Strengthening collaboration between school districts, enforcement agencies, and the DOT is essential for ensuring effective school bus safety measures. Law enforcement officials indicate that proactive campaigns, such as targeted patrols and public awareness initiatives, help reduce traffic violations in school zones. Additionally, coordination between the NJMVC, law enforcement, and school bus contractors is necessary to maintain compliance with existing regulations. Improved communication between these entities will facilitate better enforcement, ensure timely policy updates, and streamline safety inspections.

5.4 Technology Implementation for Safety and Monitoring

Utilizing technology is an effective way to enhance school bus safety, particularly in monitoring violations and improving emergency preparedness. Contractors report successful integration of GPS tracking, vehicle communication devices, and onboard cameras in many school bus fleets, yet financial constraints limit widespread adoption. In the U.S., stop-arm cameras have proven effective in penalizing illegal school bus passers, with at least 30 states enacting laws permitting their use (National Conference of State Legislatures, 2025).

To improve safety, school districts should consider the installation of onboard and stop-arm cameras while establishing clear policies on data collection, storage, and usage to address privacy concerns. Enforcement agencies would also need to receive sufficient resources to process violations efficiently and ensure compliance. Given the success of state-level camera programs in reducing violations, prioritizing cost-effective, widely adopted safety technologies can significantly improve student safety and strengthen school bus enforcement. Onboard surveillance cameras play a critical role in monitoring student behavior, ensuring seatbelt usage, and preventing bullying, assault, or other disruptive incidents. These systems provide visual verification for drivers and administrators and can serve as evidence in case of emergencies or investigations.

5.5 Driver Training and Certification Requirements

Enhancing driver training and certification requirements is crucial in reducing human error, a significant factor in school bus incidents. Contractor surveys indicate that while companies invest in training programs, financial constraints limit their scope. In New Jersey, regulations require background checks at hiring and renewal, along with frequent medical examinations for older drivers—annual exams for those aged 70-74 and biannual for those 75 and older (NJMVC, 2023).

To improve safety, recurrent licensing and proficiency-based training should be mandated, including medical and reflex tests as part of certification. NJMVC should collaborate with school districts to develop standardized training programs focusing on student behavior management, emergency response, and safety protocol adherence. Stricter competency assessments, similar to New Jersey's medical exam requirements for older drivers, should be enforced to ensure school bus operators remain physically and mentally fit for duty (NJMVC, 2023). By implementing uniform and recurrent training, school bus operators will be better prepared for real-world challenges, ultimately improving safety and reducing human error.

Additionally, it is recommended that New Jersey establish a comprehensive, standardized school bus driver training program that goes beyond basic certifications with a specific focus on preparing drivers to effectively handle emergency situations.

Despite their technical qualifications, drivers may lack the practical skills and situational awareness needed to respond effectively during high-stress emergencies, such as vehicle fires, crash events, medical emergencies, student altercations, or evacuation scenarios. This gap significantly increases the risk to student safety during unforeseen incidents, as drivers often must make split-second decisions under pressure without prior hands-on experience or structured training in managing such events.

To address this critical safety concern, it is recommended that the state implement a dual-mode training approach:

- V*irtual Reality (VR) Simulation Training:* Incorporating VR technology into driver training can provide immersive, realistic scenarios that allow drivers to practice responding to various emergencies in a controlled environment. For instance, the Texas Department of Transportation funded a school bus driver simulator that uses computer-generated imagery to prepare drivers for hazardous driving conditions and unexpected obstacles (Gray, 2020).

Similarly, Dean Transportation in Michigan has experimented with VR scenarios to help drivers fine-tune their responses to real-life situations.

- *In-person Emergency Response Drill:* Complementing VR training with regular, hands-on emergency drills ensures that drivers can apply their skills in real-world settings. These drills should cover scenarios such as evacuations, fire response, medical emergencies, and coordination with emergency services.

5.6 Enhanced Student Safety Training

New Jersey has implemented key safety programs to enhance school bus safety, including mandatory emergency evacuation drills, comprehensive driver and aide training, and the use of student information cards for students with disabilities. Schools are required to conduct two evacuation drills per year, while drivers and aides receive regular training on safe driving, emergency procedures, and special needs care. Additionally, student information cards provide bus staff with critical information to ensure appropriate support during transportation.

Evacuation drills may not adequately prepare students to respond calmly and effectively in real emergencies. Additionally, there is no standardized system to ensure student information cards are consistently updated and effectively used during critical situations. To address these gaps, it is recommended that New Jersey enhances current safety programs by incorporating more realistic and frequent safety drills and improving the management and utilization of student safety information. Specifically, the number of student school bus evacuation drills should be increased from the current two per year to at least three, aligning with Ohio's statewide standard and exceeding the "once-per-semester" guidance supported by the National Congress on School Transportation (NCST) and the NHTSA (School Bus Fleet, 2019), (Ohio Law, 2025). Conducting three drills ensures that students receive regular reinforcement of safe evacuation procedures across the school year, improves retention of safety practices, and provides opportunities to vary drill conditions (e.g., blocked exits, inclement weather) so that students are better prepared to respond calmly and effectively during real emergencies.

Additionally, the management and use of student safety information cards should be strengthened. While New Jersey already requires cards for students with disabilities, they are not always updated or consistently utilized. Other states provide strong models: in Georgia, every school bus carries an emergency medical record with critical details such as allergies, health conditions, and parent contacts, ensuring staff have immediate access to vital information. In Texas, school districts often require parents of students with special needs to complete a transportation information sheet as part of the IEP process, keeping staff informed about health or support changes (Texas Department of Public Safety, 2010). Similarly, New Jersey should transition to a digital format for information cards, require parents to review and update them twice per year, and provide drivers and aides with concise emergency summaries for each student. These cards should also be incorporated into safety drills so staff practice how to access and use them under real conditions.

5.7 School Bus Maintenance Policies and Requirements

Ensuring school buses are in safe operating condition requires a robust maintenance policy backed by coordinated inspections between the DOT, school districts, NJMVC, and contractors. While manufacturers and operators prioritize routine inspections, contractor surveys indicate that financial constraints limit investment in additional safety measures. Enforcement agencies confirm that maintenance checks follow pre-trip and state inspection checklists, yet inconsistencies in compliance persist. Regulations such as N.J.A.C. § 13:20-30.3 mandate systematic inspections and maintenance, requiring operators to maintain detailed repair logs, lubrication records, and daily condition reports, which may be reviewed by the inspectors (Law and Public Safety, 2012). However, law enforcement survey findings highlight gaps in enforcement, with some contractors failing to adhere to these requirements, increasing safety risks. NJMVC can help address these issues by conducting targeted compliance audits.

It is recommended that New Jersey enhance enforcement mechanisms for school bus maintenance to ensure that all vehicles remain in safe operating condition throughout their service life. This should include a combination of stricter compliance monitoring, regular unannounced inspections, and penalties for non-compliance with state maintenance regulations. The current enforcement framework under N.J.A.C. 13:20-30.3, which mandates systematic inspections, maintenance logs, lubrication records, and daily condition reports, should be strengthened through coordinated oversight by NJMVC, with inspection authority also shared by NJSP under N.J.A.C. 13:20-30.5(a). While NJSP does not serve as the primary regulator, its statutory authority to conduct inspections and its role in regulating school bus driver misconduct under N.J.S.A. 39:3B-2.1 reinforce its importance as an enforcement partner alongside NJMVC. In addition to scheduled state inspections, it is recommended that New Jersey adopt a monthly maintenance inspection requirement by local systems and state-approved inspectors to ensure higher safety compliance. Furthermore, daily pre-trip inspections by drivers should be strictly enforced and documented using standardized checklists, as successfully practiced by several police departments and required in states like Florida.

While increased enforcement may require additional state funding for inspection staff and technological resources, the investment will help avoid the higher costs associated with crash investigations, vehicle downtime, legal liabilities, and, most importantly, the risk of student injuries. A centralized maintenance tracking system will streamline compliance monitoring and reduce administrative overhead in the long term.

5.8 Reducing Bus Driver and Aide Distractions, Improve Transparency

To further enhance school bus safety, additional policies should be enacted to strengthen driver accountability, emergency response, and vehicle identification. While New Jersey law already prohibits drivers from using cell phones or similar devices while operating a bus except in emergencies, consistent policies should extend this restriction to aides, limiting non-work-related device use to situations involving EMS or dispatch assistance. In cases of trauma or medical emergencies, 911 and EMS should be contacted immediately to prevent delays in emergency response.

To improve transparency and accountability, driver license information, excluding personal details like date of birth and address, should be visibly displayed to passengers, similar to taxi driver licenses, which is especially relevant for smaller schools. Ensuring these measures are enforced will enhance school bus safety, improve emergency preparedness, and create a more accountable and secure student transportation system.

Conclusion

Enhancing school bus safety requires a multifaceted approach that combines enforcement, technology, policy reforms, training, and maintenance oversight. Strengthening seatbelt enforcement through regular monitoring, stricter penalties, and standardized compliance policies will help ensure that students are properly restrained, reducing injury severity in crashes. Establishing a centralized system for tracking school bus incidents and enforcing stricter regulatory measures will improve data-driven decision-making and create more consistent policies across school districts. Expanding the use of advanced technologies, such as onboard cameras and stop-arm enforcement systems, has proven effective in reducing violations and enhancing student safety, but financial support and clear data usage policies are necessary for widespread adoption.

Driver training and certification requirements must be standardized nationwide, incorporating recurrent licensing, medical evaluations, and specialized training in student behavior management and emergency response to address inconsistencies in qualification standards. Additionally, ensuring that school buses undergo regular maintenance inspections with strict oversight of contractor compliance is critical in preventing mechanical failures and ensuring operational safety. While funding limitations remain a challenge, maximizing existing resources through targeted enforcement, inter-agency collaboration, and data-driven safety strategies can significantly enhance school bus safety. By implementing these measures, policymakers, school districts, and transportation agencies can work together to create a safer school transportation system that prioritizes student protection and regulatory compliance.

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APPENDIX A: INTERVIEW QUESTIONNAIRE FOR AGENCIES

Section 1: General Information

1. What is your name?
2. What is your job title?
3. Briefly describe your responsibilities in the position.
4. How long have you been working in this capacity?
5. What is your experience with safety in school zones?

Section 2: Suggestions for Improving Safety

1. What suggestions do you have for enhancing safety in school zones?
1. Have you worked on any initiatives or projects aimed at improving safety in school zones? If so, could you share some details about these efforts?
2. What strategies have proven most effective in reducing crashes and ensuring safety for school children?
3. What are your most prominent safety challenges regarding school buses?
4. What countermeasures do you use to address those challenges?
5. What are the primary challenges you face when implementing safety countermeasures in school zones/school buses?
6. How do you prioritize which safety measures to implement given these challenges?
7. What policy changes would you recommend to improve the overall safety of school zones?
8. Are there any regulatory gaps that need to be addressed to ensure better safety outcomes?
9. Can you describe any specific recommendations you have for improving safety in school zones?

Section 3: Emerging Technology

1. Are there any new technologies on the horizon that you believe will significantly impact school bus safety?
2. Is your agency using any emerging technologies for the safety of school bus-related crashes?
3. What challenges have you encountered when integrating new safety technologies into school buses?

4. How do you address issues related to the maintenance and operation of these technologies?
5. Do you have any recommendations for manufacturers or policymakers regarding the adoption of new safety technologies?

Section 4: Bus Driver Provisions and Training

1. Are you aware of any current provisions and requirements for school bus drivers in terms of age, physical fitness, and experience?
2. Are there any specific programs or incentives in place to enhance the training and qualifications of school bus drivers? If yes, how effective are the current training programs for school bus drivers?
3. In your suggestion, what improvements or additional training do you think are necessary to better prepare school bus drivers?

Section 5: Case Studies and Examples

1. Can you share any case studies or examples where specific safety measures have significantly improved safety in school zones?
2. How do you measure the success of safety initiatives in school zones?
3. What lessons were learned from these examples, and how can they be applied to other areas?

Conclusion:

Is there anything else you would like to share before we conclude the interview?

APPENDIX B: SURVEY QUESTIONNAIRE FOR ENFORCING AGENCIES

1. What specific regulations or policies does your agency enforce to ensure that school buses comply with safety standards?
2. How does your agency collaborate with federal, state, and local law enforcement or other jurisdictions or agencies in emergency preparedness and response efforts related to school buses? If so, explain how.
3. How does your agency assess the effectiveness of safety equipment installed on school buses, such as cameras and GPS tracking systems, driver assistance systems, etc.? What are the procedures for checking those systems? Are there legal hurdles for accessing information, and if so, explain how this impacts your agency's ability to enforce school bus safety measures.
4. Are there any guidelines provided by your agency for parents or individuals outside of school personnel regarding the transportation of school children? Does your agency conduct any outreach activities that support school bus safety?
5. Does your agency have specific policies in place for school bus driver training and/or the credentialing of school bus drivers?
6. If your agency enforces driver's CDL requirements, medical cards, and hours of service, how are those enforced? Does your agency track school bus driver complaints, and how are those followed up on?

1. 7. What penalties are imposed for non-compliance with motor vehicle regulations specific to school buses? For enforcement of seatbelt usage, when a student is not wearing a seatbelt, which entity is primarily responsible for enforcing these penalties, and who receives the warning/citation? Was the driver or a non-compliant student (parent) issued the penalty? Are there reciprocal penalties issued by the school district? At what point are parents required to get involved?

7. What challenges do you encounter when enforcing compliance with safety regulations?
8. Does your agency conduct maintenance checks on school buses? If so, could you provide details about these checks (in terms of frequency, details, etc.)? How are maintenance issues tracked and followed up on?

9. Does your agency receive federal funding to ensure school bus safety? If so, what type, motor vehicle enforcement, inspection, public awareness, etc.? How is that money utilized, and how are the results tracked?
10. Does your agency conduct proactive aggressive driver campaigns near school buses and/or school zones?
11. Does your agency investigate school bus crashes? How is that information reported, and are school bus crashes tracked as a separate subset of crashes?
12. Has your agency dealt with any specific emergencies involving school buses in the past? If so, what were the key takeaways from those incidents? How were these key takeaways disseminated to key staff, like drivers and bus maintainers?
13. What challenges does your agency face in implementing safety protocols for school buses during emergencies?
14. Are there any additional resources or support, in terms of policy or regulation, that you believe would enhance your agency's emergency preparedness for school bus incidents?

APPENDIX C: SURVEY QUESTIONNAIRE FOR COMPANIES

1. What fundamental considerations do you prioritize in the design of school buses? What are some mandatory requirements/details at the top of the list?
2. Does your company incorporate any design improvements specifically aimed at assisting occupants during emergency situations?
3. What equipment or technology do you install in your buses to support emergency responses (e.g., GPS tracking, communication devices, cameras, driver assistance systems)?
4. What challenges do you face in integrating new safety technologies into your school buses?
5. Can you provide an estimate of the costs associated with integrating safety technology into school buses?
6. Does your company equip its buses with three-point seatbelts? If so, how does this affect the seating capacity of the bus, and what additional costs are associated with implementing these seatbelts?
7. What safety tests does your company conduct for school buses? How many individuals/groups sign off on these safety tests prior to vehicle approval?
8. Does your company follow any specific procedures for the maintenance checks of school buses? If so, could you detail these procedures and advise if they are conducted daily, weekly, monthly, or yearly?
9. How do you ensure compliance with safety regulations and standards set by federal and state authorities?
10. Is your company involved in the production of electric school buses? If so, could you share the advantages and disadvantages of electric school buses concerning safety in emergency situations?
11. Do you collaborate with Law Enforcement and/or DMV to assist with School Bus Safety and Maintenance Inspections? What is the frequency of this collaboration?
12. Are there any additional resources or support that you believe would enhance your company's emergency preparedness?

APPENDIX D: LAWS FOR WEARING SEATBELTS IN DIFFERENT STATES

State	Seatbelt Requirement	Seatbelt Mandatory (Yes/No)	Regulation of Wearing Seatbelts
Arkansas	Required for new buses since 2018, contingent on funding	No	Not mandated unless the state provides funding
California	Three-point seatbelts are required on all new buses	No	Not always legally required; most districts have policies
Florida	Required for buses purchased after 2000	Yes	Students must wear seatbelts as per state rules
Louisiana	Required new buses if funded by the state	No	No rule mandates students to wear seatbelts
New Jersey	Required on all buses (lap belts by default)	Yes	Students must wear seatbelts, typically lap belts
New York	Required on all buses	Yes	Enforced by districts, varying degrees of compliance
Nevada	Three-point seatbelts have been required on new buses (since 2019)	Yes	Students must wear seatbelts by law
Texas	Three-point seatbelts are required if funded by the state (since 2018)	No	No specific mandate for wearing if installed
Iowa	Required on all buses per state rule	Yes	Students must wear seatbelts as per state rules

APPENDIX E: REGULATIONS AND POLICIES FOR TRANSPORTING STUDENTS OTHER THAN THE SCHOOL BUS FROM DIFFERENT STATES

State	Licensing Requirement	Seating Capacity	Vehicle Requirement	Child Safety
California	Valid driver's license, satisfactory driving record, criminal background check, and no irrational behavior	N/A (Not specified)	Vehicle in safe condition, current registration & insurance, first aid kit & fire extinguisher, maintained like a school bus	Seatbelts or child safety seats for all passengers, written parent permission, and provide parents with the driver's record
New York	Valid driver's license, no school bus driver requirements for parents	Vehicle capacity ≤ 10 adults	Vehicle is not subject to school bus inspections, and the vehicle must be safe.	Children under age 8 and <4'9" must use child safety seat
Florida	Valid driver's license, pass physical exam if required by the State Board of Education	Fewer than 10 students	Vehicle must be a passenger car, multipurpose vehicle, or truck; students must sit in designated positions and use the crash protection system	Children must use federally approved child safety seats or seatbelts
Pennsylvania	No special licensing for parents, but the vehicle must be in a safe condition	Vehicle must not exceed the manufacturer's capacity	Vehicle must be safe; child safety seats required for children under age 8 and <4'9" tall	Children under age 8 and <4'9" must use child safety seat
Texas	Valid driver's license; no CDL required for personal transportation	Less than 15 students in a personal vehicle	Vehicle must be in a safe condition, with proper child safety seats, number of passengers should not exceed the vehicle capacity	Children must be secured by a safety belt
New Jersey	No CDL required, no health examination for parents transporting their own children	Capacity ≤ 8 passengers in a private vehicle	Vehicle must have appropriate insurance and be approved by district policies, and it must comply with district regulations for safe transportation	N/A

APPENDIX F: DIFFERENT REGULATIONS FOR SCHOOL BUSES IN DIFFERENT STATES

State	Inspection Requirement	Driver Training Requirement	Max Age and Seating Capacity
California	Inspect every 3,000 miles or 45 days, whichever occurs first	Entry-level training: A minimum of 20 hours of classroom and 20 hours behind-the-wheel training	No state requirements for maximum vehicle age or seating capacity
Illinois	Inspect every 6 months or 10,000 miles, whichever occurs first	Entry-level training: Training is required, but no set minimum hours	School buses cannot operate with more passengers than the manufacturer-recommended capacity
Nebraska	Inspect before the school year and every 80 days during the school year	Entry-level training: A minimum of 11 hours	No state requirements on maximum vehicle age
New York	Inspect every 6 months	Entry-level training: A minimum of 3 hours of initial instruction	No state requirement on maximum vehicle age
Pennsylvania	Spot checks from October to May of each year	Entry-level training: A minimum of 20 hours, including 14 hours of classroom training and 6 hours of behind-the-wheel training	No state requirements for maximum vehicle age or seating capacity
Virginia	Inspect every 45 days or 5,000 miles	Entry-level training: A minimum of 24 hours of classroom and 24 hours of behind-the-wheel training	No state requirements for maximum vehicle age or seating capacity

State	Inspection Requirement	Driver Training Requirement	Max Age and Seating Capacity
Washington	Unannounced, second inspection of 25% of each operator fleet each year	Entry-level training: Training is required, but no set minimum hours	No state requirements for maximum vehicle age or seating capacity

APPENDIX G: REGULATIONS FOR SCHOOL BUS MAINTENANCE IN DIFFERENT STATES

State	Maintenance Type	Maintenance Frequency	Specifications & Other Details
New York	Vehicle Inspection by NYSDOT	Every 6 months	Inspections based on Sections 720 and 721 of NYS Transportation Regulations. Operators must provide an adequate inspection facility.
Florida	Annual School Bus Inspection & Daily Driver Inspections	Annual inspection & Daily inspection by the driver	Daily inspections by drivers
Texas	No longer requires vehicle safety inspections	N/A	New law eliminates vehicle safety inspections.
Alabama	Local & State Inspections	Monthly local inspections & Annual state inspections	Local systems must inspect buses at least monthly; State inspectors perform annual safety feature checks.
California	CHP Inspection & Vehicle Maintenance	Get a CHP inspection every 13 months & every 3,000 miles or 45 days, whichever comes first	CHP inspects buses for compliance with state laws; Maintenance checks are required every 3,000 miles or 45 days.
Kentucky	Monthly Safety Inspections by State-Approved Inspectors	Monthly inspections during school sessions	Monthly inspections are required by state-approved inspectors for each bus owned or contracted by the board.

State	Maintenance Type	Maintenance Frequency	Specifications & Other Details
Wisconsin	Annual State Patrol Inspections	Annual inspections & presale/spot checks	Annual inspections by the State Patrol, covering brakes, steering, electrical, and safety equipment. Additional presale and spot checks were conducted.

APPENDIX H: ATTRIBUTES TABLE FOR THE DEPENDENT AND INDEPENDENT VARIABLES FOR THE SCHOOL BUS

Variables and Categories		Crash Severity			
		Property Damage Only (PDO)	Injury	Fatal	Total
		Frequency	Frequency	Frequency	Frequency
Dependent Variables					
Severity	PDO	15936			
	Injured	577			
	Fatal	89			
Independent Variables					
Alcohol Involved	No	15854	566	85	16505
	Yes	82	11	4	97
Hazardous Material Involved	No	15934	577	89	16600
	Yes	2	0	0	2
Road Functional Class	Collector	1294	73	9	1376
	Arterial	5416	293	43	5752
	Local	8942	194	36	9172
	Interstate	284	17	1	302
Cell Phone Related	No	15864	571	89	16524
	Yes	72	6	0	78
Traffic Controls Present for Vehicles	Sign and Marking	6248	295	43	6586
	None	5932	117	18	6067
	Signals	3424	152	26	3602
	Engineering (Channelization)	165	6	1	172

Variables and Categories		Crash Severity			
		Property Damage Only (PDO)	Injury	Fatal	Total
		Frequency	Frequency	Frequency	Frequency
	Enforcement (Police, Flagman, Crossing Guard, Watchman)	167	7	1	175
Crash Hour	Morning (6:00-12:00)	7215	262	33	8020
	Evening (12:00-18:00)	7608	267	41	8426
Season	Summer	2122	85	11	2218
	Fall	4607	167	25	4799
	Spring	4475	155	32	4662
	Winter	4732	170	21	4923
Intersection Related	No	11690	321	46	12057
	Yes	4246	256	43	4545
Posted Speed (As reported)	less than 25	936	10	3	949
	25 to 45	13267	447	71	13785
	46 to 65	1732	120	15	1867
	more than 65	1	0	0	1
Median Type	None	12040	413	75	12528
	Physically Present	1587	80	5	1672
	Marked	2298	84	9	2391

Variables and Categories		Crash Severity			
		Property Damage Only (PDO)	Injury	Fatal	Total
		Frequency	Frequency	Frequency	Frequency
Crash Type	Fixed Object	6089	62	12	6163
	Sideswipe	3251	52	5	3308
	Rear End	3689	165	11	3865
	Angle	2214	190	27	2431
	Head On	194	36	6	236
	Other	288	6	2	296
Environmental Condition	Clear	13046	457	74	13577
	Adverse	2890	120	15	3025
Light Condition	Daylight	14776	515	73	15364
	Dark-Light	618	35	8	661
	Dark-No-Light	97	5	4	106
	Dawn/Dusk	445	22	4	471
Pre-Crash Action	Straight Movement	7823	333	57	8213
	Slowing/Stopping	3060	114	6	3180
	Turning	2815	103	23	2941
	Other	1329	17	2	1348
	Lane Change	474	7	0	481
	Parking	308	3	1	312
No. of Vehicle Involved	One	1257	90	31	1378
	Two	13931	370	45	14346

Variables and Categories		Crash Severity			
		Property Damage Only (PDO)	Injury	Fatal	Total
		Frequency	Frequency	Frequency	Frequency
	More than two	748	117	13	878
Horizontal Alignment	Straight	14849	538	84	15471
	Curved	1087	39	5	1131
Road Grade	Graded	1499	56	6	1561
	Level	14437	521	83	15041
Temporary Traffic Control	No	15691	570	89	16350
	Yes	245	7	0	252

APPENDIX I: SUMMARY OF ALL RECOMMENDATIONS

Category	Key Recommendations
Seatbelt Enforcement & Monitoring	- Mandate regular monitoring and enforcement of seatbelt use. - Install surveillance cameras to track compliance. - Standardize enforcement policies across the state. - Implement student education programs on seatbelt use. - Secure funding for lap-shoulder belt upgrades.
Policy & Regulation Improvements	- Establish a standardized enforcement framework for school bus safety. - Develop a centralized system for tracking and investigating school bus crashes. - Expand enforcement campaigns targeting school zone safety and aggressive driving. - Implement structured funding strategies for enforcement and safety programs.
Collaboration Between Agencies	- Strengthen coordination between school districts, law enforcement, and DOT. - Improve inter-agency communication for better policy enforcement. - Conduct joint training programs to enhance policy awareness among agencies. - Expand proactive campaigns, such as targeted patrols and public awareness initiatives.
Technology Implementation for Safety & Monitoring	- Mandate onboard cameras and stop-arm cameras for all school buses. - Establish policies for data collection, storage, and privacy protection. - Allocate resources to enforcement agencies for processing violations.

Category	Key Recommendations
	- Promote cost-effective safety technologies to improve compliance.
Driver Training & Certification Requirements	- Implement standardized and recurrent training for school bus drivers. - Require medical and reflex tests for certification and renewal. - Collaborate with transportation agencies to develop comprehensive training programs. - Enforce stricter competency assessments for school bus operators. -Set earlier certification deadlines with automated alerts and updated contractor lists. - Incentivize early compliance and penalize persistent violators through public disclosure.
School Bus Maintenance Policies & Requirements	- Ensure compliance with mandated routine maintenance and inspections. - Enforce detailed record-keeping of vehicle repairs and inspections. - Strengthen oversight by transportation safety agencies to address non-compliance. - Address funding limitations that prevent investment in maintenance improvements.
Additional Recommendations	- Prohibit drivers and aides from using mobile devices while operating school buses. - Require immediate EMS/911 contact during medical emergencies. - Display driver license information inside school buses for accountability. - Mandate clear 'School Vehicle' signage for smaller student transport vehicles.