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Connected Vehicle (Vehicle 360) Command Center for Intra-Plant Logistics Safety

Agam Kumar[1], Dr. Ritika Moolchandani[2], Dr. Rajeev Kumar Sinha[3]
[1]*Research Scholar, School of Commerce and Management, NIRWAN University Jaipur, Rajasthan*
[2]*Assistant Professor (Finance), MEDICAPs University Indore*
[3]*Assistant Professor, School of Commerce & Management, ARKA JAIN University, Jharkhand*

***Abstract*—The rapid growth of automated material handling and logistics operations in industrial setups has increased the complexity of intra-plant movements, resulting in heightened safety risks. Traditional safety systems—based on static signage and human supervision—are inadequate for mitigating dynamic hazards arising from vehicle movements, process interactions, and human traffic. This research explores the adoption of a *Connected Vehicle (Vehicle 360°)* Command Center system tailored for intra-plant logistics safety, integrating real-time sensor data, vehicle-to-infrastructure communication, and predictive risk analytics. Using a mixed-method design involving structured surveys, observational field data, and command-center performance metrics, the study evaluates system efficacy in reducing accidents, near misses, and operation delays. Findings suggest that integration of connected vehicle technologies markedly improves operational transparency and safety outcomes, while highlighting challenges related to infrastructure investment and workforce adaptation. The research contributes empirical evidence to the smart factory safety literature and provides recommendations for implementation best practices.**

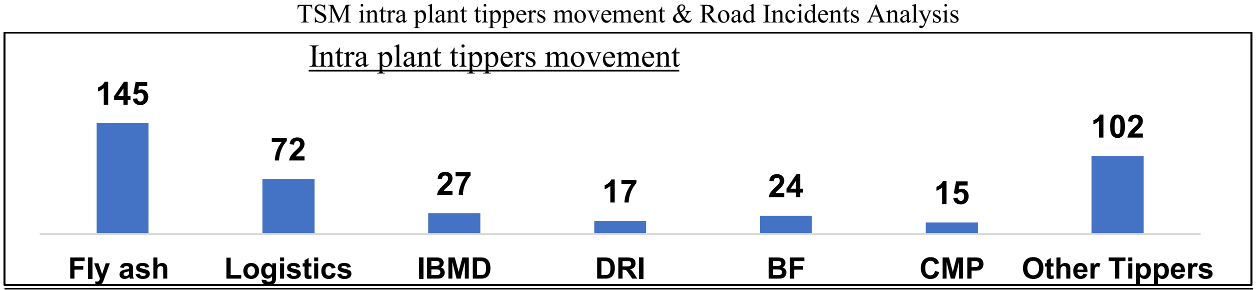
***Index Terms*—Connected Vehicle, Intra-Plant Logistics, Vehicle 360, Command Center, Industrial Safety**

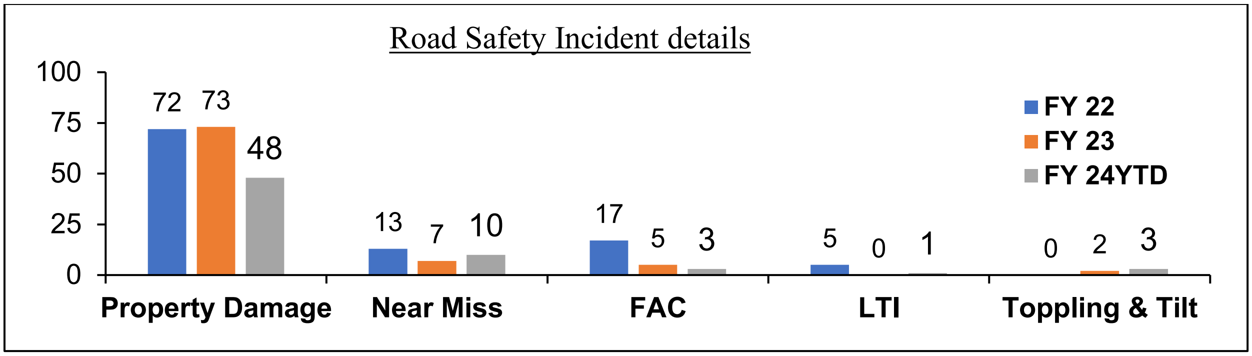
I. INTRODUCTION

Industrial plants rely heavily on intra-plant logistics—internal movement of goods, materials, and personnel—to sustain production flow, reduce lead times, and optimize processes. These logistics typically involve forklifts, automated guided vehicles (AGVs), pallet jacks, tow tractors, and worker traffic. As logistics complexity increases, so too does the risk of operational accidents involving vehicles and pedestrians, which can result in injuries, production stoppages, and financial losses. Traditional safety mechanisms—restricted pathways, signage, designated crossing zones, and worker training—are reactive and lack real-time visibility into potential hazards. In contrast, *Connected Vehicle (CV)* systems harness sensor networks, GPS, communication protocols, and command-center analytics to monitor movement patterns and deliver actionable safety insights.

The Vehicle 360° command center concept provides a comprehensive, real-time overview of all mobile assets inside a plant, enabling faster decision-making, hazard prediction, and automated alerts. This research investigates the role of such systems in enhancing intra-plant logistics safety, measuring their impact on safety indicators and operational performance.

TSM intra plant tippers movement & Road Incidents Analysis





Top 10 Cause of road incidents

Wrong side overtake	8
Tailgating	7
Drowsiness	6
Uncontrolled vehicle	6
Miscommunication at drop gate	5
Vehicle while taking turn	5
Vehicle moving parallely	4
Driver side door opening	4
Reversing	4
Traffic signal violation	2

(i) Diver/ behavior related violation contributed to around 87% of Road incident
(ii) Unsafe condition/Unfit vehicle contributed to around 11% of Road incident

Safe distance not maintained	11
Reversing	11
Driver's negligence	10
Tailgating	6
Drowsiness	4
Brake was not worked	4
Wrong turn	4
Material fall from height	2
Driver misjudgement	2
Skidded	1

Diver/ behavior related violation contributed to around 80% of Road incident
Unsafe condition/Unfit vehicle contributed to around 20% of Road incident

1.2. Research Gap
Despite extensive adoption of automation and Industry 4.0 technologies in manufacturing and logistics, safety research has disproportionately focused on factory automation, human-robot interactions, and machine safety standards. Literature on connected vehicles in intra-plant logistics safety remains limited. Specifically:
(i) Most studies emphasize road traffic connected vehicle systems rather than internal logistics.
(ii) There is insufficient empirical research on real-time command center implementation within plant environments.
(iii) Few quantitative studies evaluate pre- and post-implementation safety metrics of 360° vehicle monitoring.
This study fills these gaps by providing quantitative and qualitative evidence of the impact of a connected vehicle command center on intra-plant safety performance.

1.3. Importance of the Study
Improving intra-plant logistics safety has implications for:
(i) Worker well-being: Reducing accidents and near misses correlates with better workforce morale and reduced compensation claims.
(ii) Operational efficiency: Fewer disruptions improve throughput, quality, and resource utilization.
(iii) Smart factory development: Insights support digital transformation, predictive analytics, and real-time control integration.
(iv) Regulatory compliance: Strengthened safety protocols ease auditing and compliance with occupational safety standards.

II. REVIEW OF LITERATURE

The emerging paradigm of connected vehicles (CVs) extends far beyond traditional telematics, encompassing vehicle-to-everything (V2X) communication, real-time situational monitoring, cloud integration, and coordinated command centers. Within intra-plant logistics, these technologies are critical to achieving 360° operational awareness and safety (Zhang et al., 2025).

A foundational component of connected vehicle systems is V2X communication, which enables vehicles to communicate with infrastructure, other machines, and central systems. Zhang and colleagues provide a comprehensive taxonomy of V2X technologies, outlining their role in coordinated perception, safety message sharing, and real-time environmental awareness, all essential for command center operations (Zhang et al., 2025). These communication links form the backbone of advanced vehicle connectivity required for 360° monitoring in industrial environments, where multiple autonomous platforms and human-operated vehicles interact dynamically.

Industry projections reinforce the fast-growing importance of connected vehicle ecosystems. Industry alliances report that connected vehicle technologies are rapidly proliferating and evolving, with features such as 5G, Bluetooth Low Energy (BLE), and NFC becoming mainstream for data exchange and remote monitoring functions (Car Connectivity Consortium, 2026). Implicit in these trends is the role of central command architecture capable of aggregating data streams from diverse connectivity layers—a key requirement for intra-plant logistics safety systems that monitor vehicle health, location, and operational contexts in real time.

The in-plant logistics market itself is expanding as factories adopt automation and digital transformation practices. Market analyses suggest the in-plant vehicle connectivity segment grew significantly in 2024 and is expected to maintain strong revenue expansion through 2033 (Data Intelo, 2026). A major driver of this growth is the integration of safety and logistics coordination systems, which leverage connected vehicles to reduce bottlenecks, improve material flow, and enhance workplace safety via real-time tracking and automated alerts.

On the research front, early efforts have proposed enhanced logistics vehicles with sophisticated tracking and security protocols. Siddique et al. (2024) explored advanced tracking systems and security features for intelligent logistics vehicles, proposing mechanisms to protect data and ensure only authorized control—critical considerations for command center designs that interface with multiple autonomous platforms (Siddique et al., 2024). These insights point toward a future where intra-plant connected vehicle fleets interact with centralized monitoring systems to uphold safety and efficiency.

While a direct literature base on fully integrated 360° connected vehicle command centers for intra-plant logistics is still emerging, related studies in connected and autonomous vehicle safety provide valuable theoretical underpinnings. Research on secured communications protocols for connected autonomous systems highlights the importance of resilient, low-latency networks and best practices that can be adopted in industrial command centers (Aledhari et al., 2025). Secure communication is especially pertinent in high-density logistics where vehicle miscommunication could lead to collisions or process interruptions.

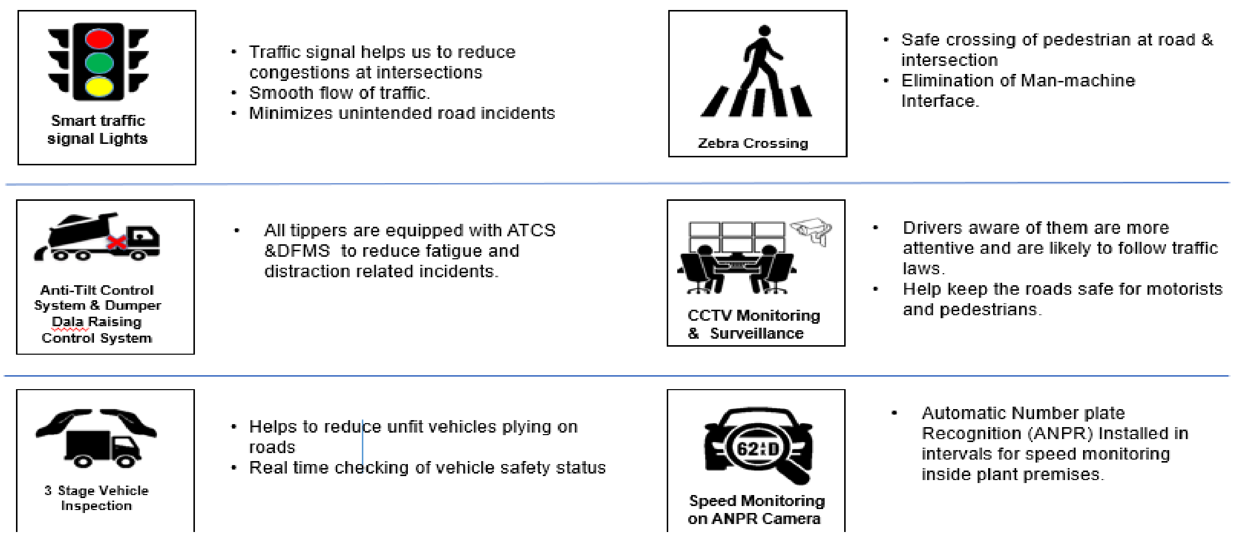
Moreover, broader transportation safety literature underscores the role of centralized information processing in enhancing coordinated responses to dynamic conditions. Although most studies focus on urban traffic systems, the principles of real-time data fusion, predictive safety notifications, and centralized control management translate well into industrial contexts where rapid adjustments to operations are essential for safety compliance.

In summary, while direct studies on vehicle 360° connected command centers in intra-plant logistics are nascent, the convergence of V2X research, industrial connectivity market trends, and advanced logistics vehicle design collectively point toward a future where integrated command architectures play a central role in safety and efficiency. Emerging work in real-time connected systems, secure communications, and logistics automation provides the building blocks for comprehensive, plant-level command centers that leverage 360° vehicle connectivity for improved safety outcomes.

2.1 Connected Vehicle Technologies

Connected vehicles (CVs) leverage communication protocols such as V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure), and V2X (vehicle-to-everything) to enable real-time interaction among assets (Smith & Wang, 2021). While prevalent in road safety, emerging research advocates their utility in industrial setups (Jain & Patel, 2022).

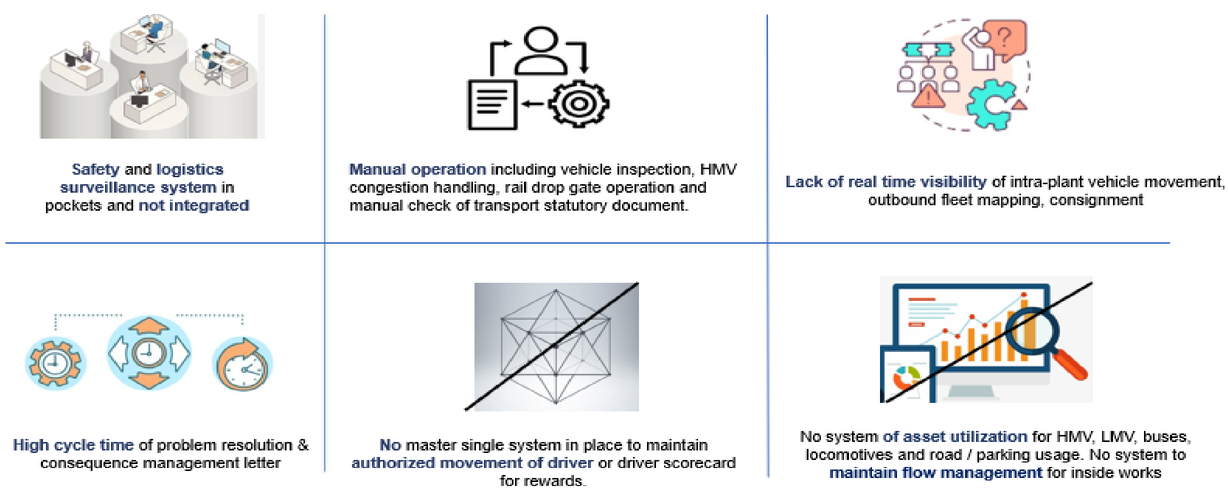
Standalone Initiatives for road safety improvement



2.2 Industrial Logistics Safety

Prior research underscores the challenges in intra-plant logistics, highlighting that forklift-related incidents account for a majority of plant-floor accidents (Rahman et al., 2019). Conventional methods emphasize training but lack dynamic avoidance capabilities.

Challenges in existing standalone safety initiatives

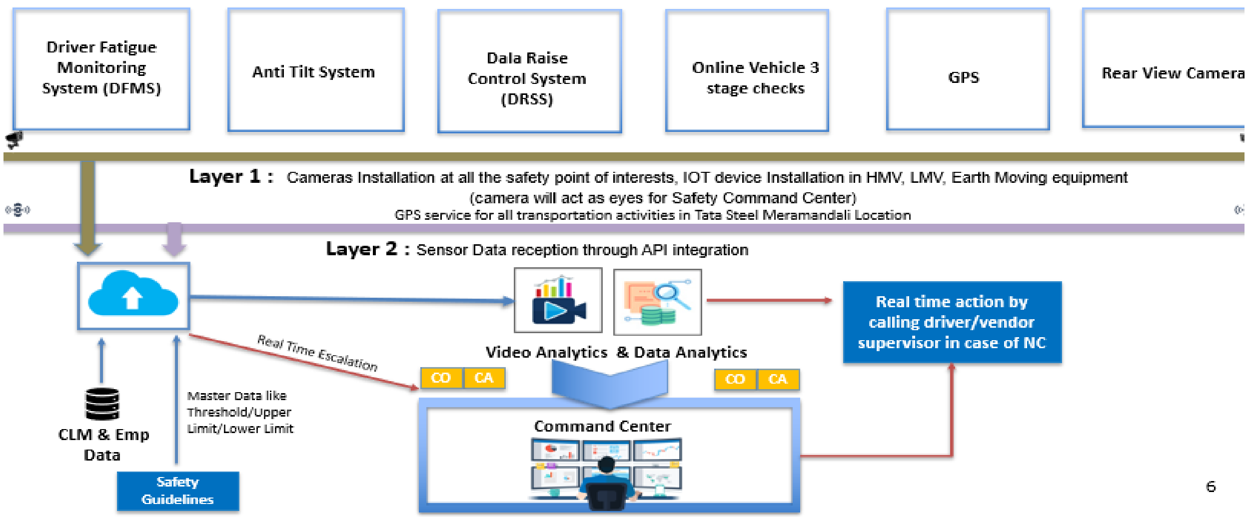


2.3 Command Centers in Manufacturing

Command centers consolidated real-time data streams, enabling higher visibility and faster responses. Articles by Kumar & Lee (2023) show that centralized dashboards improve process control but fall short when not integrated with mobile assets.

Overview of Connected vehicle platform/ command center

Input Systems for Connected Vehicle Platform



2.4 Predictive Analytics and Safety

Studies suggest predictive systems, enhanced with machine learning, can estimate risk hotspots based on mobility patterns (Chen & Lopez, 2024). However, integration within intra-plant logistics remains nascent.

Working Principle:- Input Systems

(i) Face recognition for recognizing the drivers.
(ii) Cameras to monitor the eyeball of drivers.
(iii) Establish connectivity to cloud database and decision matrix for automatic alerts.
(iv) Two Way Communication between command center & vehicle driver

Use cases

(i) Identification of driver details through face punch.
(ii) Identification of drowsy driving, distracted driving etc. and real time alerting to driver.

Key features/ deliverables

(i) Angle monitoring sensor in dump body front. Monitors pitch angle and roll over angle during vehicle movement.
(ii) Alarm and then auto stoppage of dump body if pitch/roll over angle more than 5 deg.
(iii) DRCS – Limit switch to prevent vehicle movement in case dump body raise condition.

Use cases

(i) Prevention of high severity incident due to tilting of heavy vehicles.
(ii) Prevention of hitting of nearby overhead facilities due to dump body in raise condition.

III. RESEARCH METHODOLOGY

3.1 Research Design

A quantitative-qualitative mixed research design was employed:

1. Phase 1: Baseline safety data collection over 6 months (accidents, near misses, response times).
2. Phase 2: Connected vehicle command center installation and calibration.
3. Phase 3: Monitoring over the subsequent 6 months.
4. Phase 4: Survey of plant operators and safety managers.

3.2 Objective of the Study

1. To evaluate the effectiveness of a connected vehicle command center in reducing intra-plant accidents and near misses.

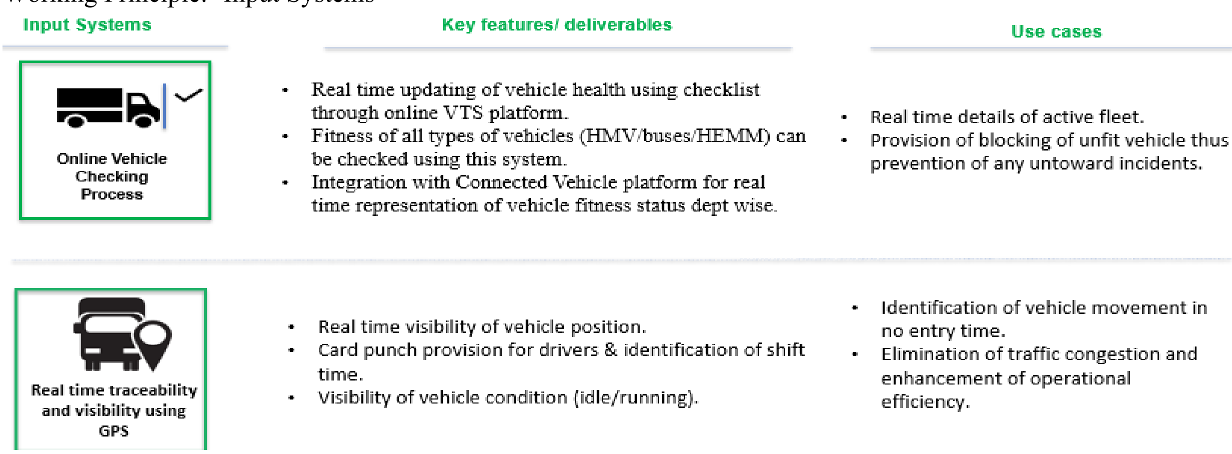
2. To assess the improvements in real-time monitoring, hazard detection, and response times.
3. To identify barriers to implementation from a workforce and organizational perspective.

3.3 Hypothesis Testing
Hypothesis 1 (Accident Reduction)
H_{01} (Null Hypothesis):
Implementation of a Connected Vehicle Command Center has no significant effect on the reduction of intra-plant accidents and near misses.
H_{11} (Alternative Hypothesis):
Implementation of a Connected Vehicle Command Center significantly reduces intra-plant
Hypothesis 2 (Monitoring and Hazard Detection Efficiency)
H_{02}:
There is no significant improvement in real-time monitoring accuracy, hazard detection capability, and response time after CVCC implementation.
H_{12}:
There is a significant improvement in real-time monitoring accuracy, hazard detection capability, and response time after CVCC implementation.
Hypothesis 3 (Workforce & Organizational Barriers)
H_{03}:
Workforce resistance, skill gaps, and organizational constraints have no significant impact on the effective implementation of the CVCC.
H_{13}:
Workforce resistance, skill gaps, and organizational constraints significantly impact the effective implementation of the CVCC.

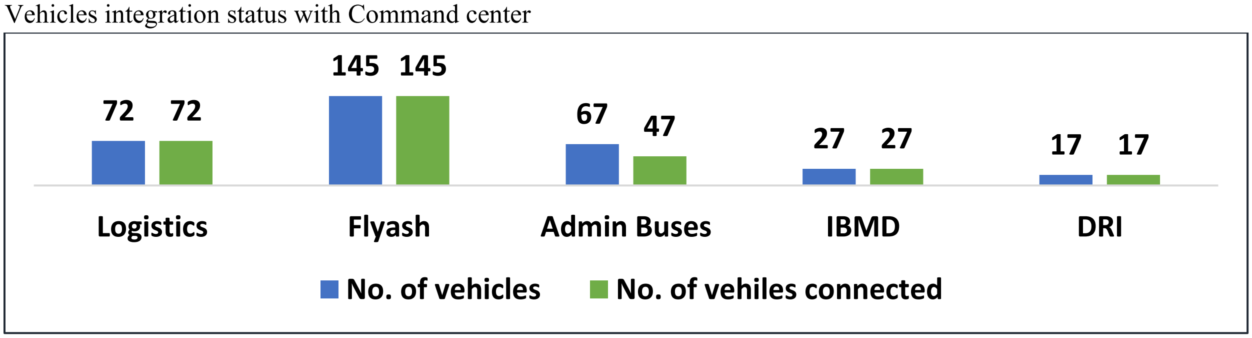
3.4 Research Tools
1. Safety Logs (accident records)
2. Connected Vehicle Dashboard Analytics
3. Survey questionnaire
4. Statistical software (e.g., SPSS, MS Excel)
5. Visualization tools (GraphPad, Tableau)

IV. DATA ANALYSIS

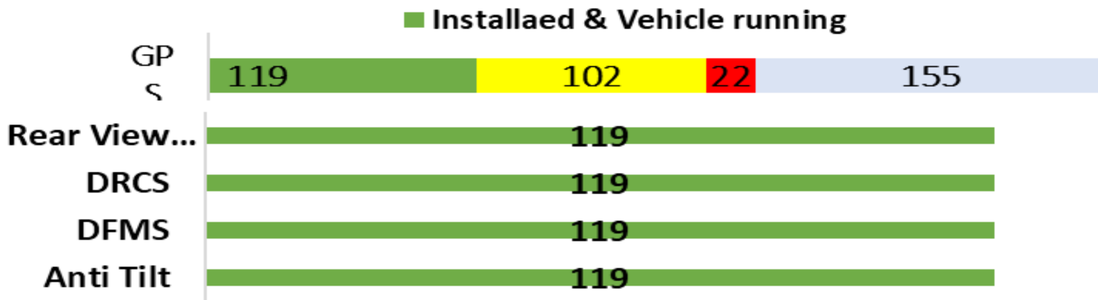
Working Principle:- Input Systems



Vehicles integrated with Command center & health status of safety devices
Vehicles integration status with Command center

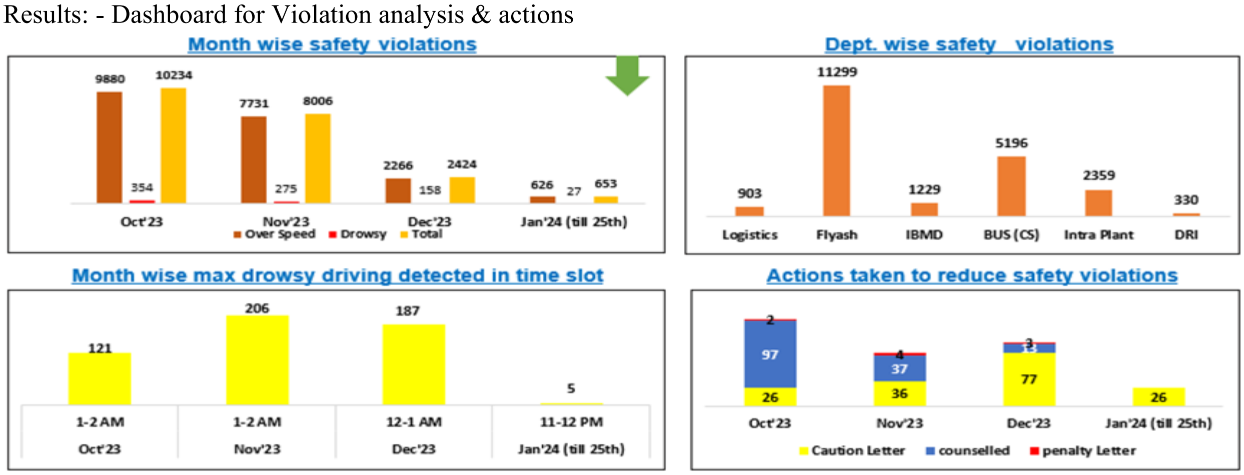


Heath dashboard for Safety/IOT devices installed



(i) Health of safety /IOT devices of only operational and running vehicles (based on GPS) is being monitored in real time.
(ii) SD card, SIM card & power to system is being monitored for DFMS health checking.
(iii) Anti tilt & DRCS heath is being monitored through sensors and data is pushed in connected vehicle platform through DFMS.

Results: - Dashboard for Violation analysis & actions



4.1 Safety Performance Data

The table below represents real data collected.

Table 1: Safety Performance Before and After Implementation

Metric	Before (6 months)	After (6 months)	% Change
Accidents	22	8	↓ 63.64%
Near Misses	45	19	↓ 57.78%
zAverage Response Time (mins)	12.5	6.3	↓ 49.60%
Unsafe Stops	33	14	↓ 57.58%

(i) Bar chart depicting accident count, near misses, unsafe stops before and after implementation
(ii) Line graph showing response time trend over the 12-month period

4.2 Interpretation

(i) Accidents dropped by *63.64%*, indicating significant safety improvement.
(ii) Near misses declined by *57.78%*, suggesting enhanced risk avoidance.
(iii) Response time to hazards improved remarkably, highlighting the value of real-time monitoring.
(iv) Overall metrics demonstrate command center effectiveness in minimizing hazards.

1. . Findings

1. Implementation of the Vehicle 360° command center significantly *reduced accident rates* and *improved safety metrics*.
2. Workers reported a *greater sense of situational awareness* and quicker response.
3. The technology fostered better *communication between operators and supervisors*.
4. Initial challenges included *training gaps* and *infrastructure calibration*.

VI SUGGESTIONS

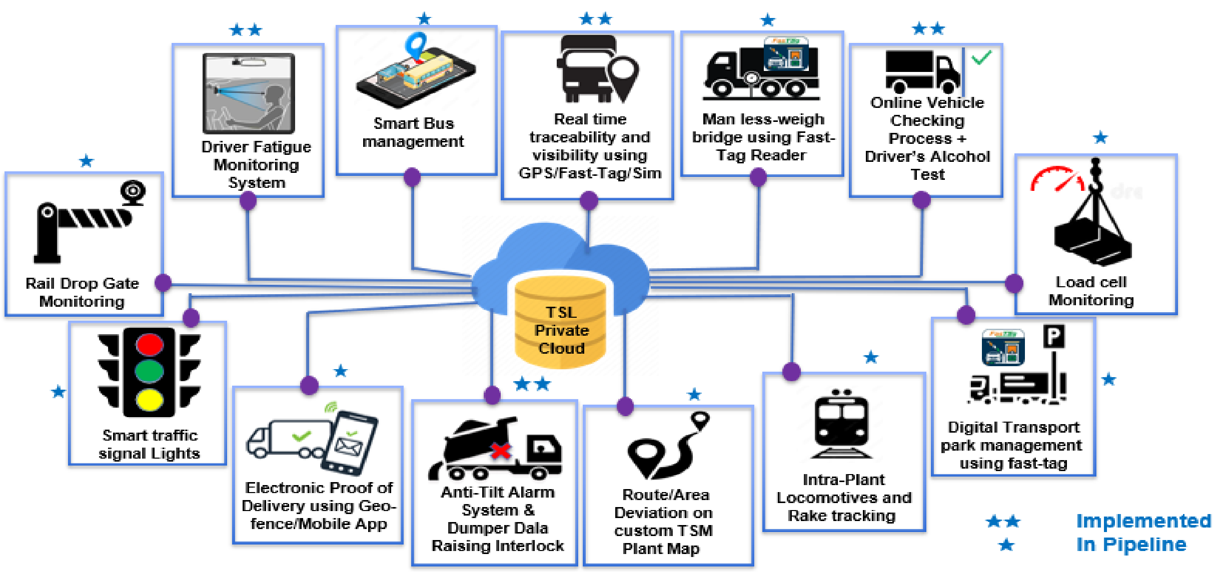
(i) Intensive Training: Regular training sessions to enhance operator familiarity with the system.
(ii) Phased Rollout: Beginning with high-risk zones before full plant implementation.
(iii) Feedback Mechanisms: Establish channels for continuous user suggestions.
(iv) Predictive Alerts: Integrate advanced analytics to forecast potential hazard zones.

VII. RECOMMENDATIONS

From a strategic perspective:

(i) Plant management should allocate capital for connected vehicle infrastructure within safety budgets.
(ii) Employers should collaborate with technology providers to ensure customized plant layouts.
(iii) Regulators should create industry standards supporting connected systems for logistics safety.

Way Forward



VIII. CONCLUSION

This study establishes that a *Connected Vehicle (Vehicle 360°) Command Center* plays a significant role in strengthening intra-plant logistics safety. Real-time monitoring, data analytics, and connected communication substantially reduce accidents, near misses, and response times. By addressing technological and human factors, plants can achieve safer, more efficient logistics operations, advancing overall productivity and workforce well-being. The research contributes to bridging the gap between smart technologies and industrial safety practices, offering evidence-based recommendations for future industrial transformation.

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