Detection of Sub Assets and Verification of Industrial Vehicles by Registered License Plate Using OpenCV

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Abstract - **This paper presents an automated system for the refueling of industrial vehicles, emphasizing the detection of sub-assets (industrial vehicles), recording their time of arrival, and verifying the vehicle type using license plate information. The system incorporates OpenCV for real-time vehicle detection, Optical Character Recognition (OCR) to extract license plate details, and a cross-referencing mechanism with a pre-registered database to ensure precise vehicle type verification. By automating the vehicle identification and verification process, this system streamlines the refueling workflow, eliminating the need for manual data entry, reducing human errors, and significantly improving operational efficiency in industrial settings. Experiments performed on a diverse sample of industrial vehicles demonstrate high detection accuracy, robust OCR performance, and a high success rate in vehicle verification, highlighting the potential of the system for large-scale industrial applications.**

Keywords-Automated vehicle detection, industrial vehicles, license plate recognition, Optical Character Recognition (OCR), OpenCV, real-time detection, vehicle type verification, database cross-referencing, operational efficiency, industrial automation.

I. INTRODUCTION

The automated detection and verification of vehicles based on their license plates has become an indispensable component of modern industrial and commercial operations, including transportation, parking management, and law enforcement. As cities and industries expand, the need for efficient, accurate, and scalable vehicle identification systems has intensified. Traditional methods, which often rely on manual inspection, have significant limitations. These methods are not only labor-intensive and time-consuming but are also prone to errors due to human fatigue or oversight, making them inadequate for handling the growing complexity and volume of vehicle traffic in today's environments.

Automation of vehicle detection and verification has seen significant progress. These technologies enable the development of systems that can recognize and classify vehicles in real-time with far greater accuracy and efficiency than manual methods. In this context, automated systems can handle large-scale vehicle monitoring tasks with minimal human intervention, improving not only the speed but also the reliability of the process. Such systems offer substantial benefits, including reduced labor costs, enhanced accuracy, and the ability to operate continuously in diverse environmental conditions, such as varying light or weather scenarios, where human inspection would be less reliable.

This paper presents an automated system designed using OpenCV (Open Source Computer Vision Library) for real-time detection of vehicles, referred to as sub-assets in this context. The system focuses on detecting vehicles as they enter a specific area, recording their time of arrival, and verifying their type through the identification of license plates. To accomplish this, the system integrates Optical Character Recognition (OCR) to read license plate information and cross-references the extracted data with a pre-existing database to confirm the vehicle's type, ensuring accuracy and reducing the possibility of error.

The primary objective of this system is to create a reliable, high-performance solution for vehicle detection and verification that can be deployed across various industrial applications. For instance, in automated toll booths, the system can identify and classify vehicles automatically, streamlining toll collection and reducing traffic congestion. Similarly, in parking systems, it can monitor vehicle entry and exit, providing a seamless experience while ensuring that the correct vehicles are accessing designated areas. In law enforcement, this technology can aid in tracking vehicles involved in traffic violations or criminal activities, improving public safety.

By automating these processes, the system enhances operational efficiency and accuracy while reducing the dependency on human labor. This is particularly valuable in high-volume, high-speed environments, such as highways, industrial complexes, or large parking lots, where manual vehicle identification would be too slow or inaccurate to meet operational needs. The system's ability to operate continuously, without fatigue or lapses in attention, further underscores its utility in mission-critical applications.

In the following sections of this paper, we will delve into the architecture of the system, its key components such as OpenCV for vehicle detection and OCR for license plate recognition, and the methodology for verifying vehicle types against a pre-registered database. We will also discuss potential real-world applications, challenges, and future directions for enhancing the system's capabilities. Ultimately, this system represents a significant step toward fully automating vehicle identification and management processes in industrial and commercial settings.

II. Literature Review

The automation of vehicle detection and license plate recognition (LPR) has seen considerable advancements in recent years, driven by the increasing need for efficiency in various applications, including industrial vehicle management. This literature review synthesizes key research contributions in the field, highlighting methods, findings, and implications for automated refueling systems.

Sanjana Dutta, Krishna Gabale, Shunbham Gaikwad, Priya Ghegade, P.B Mane, 2021, Number Plate Recognition Using Raspberry Pi, JETIR, Vol.8, Issue 6

Low-cost, portable number plate recognition system with moderate accuracy. Capable of real-time vehicle identification. Integrating cloud processing for improved performance. Enhancing accuracy with advanced image processing techniques. Limited processing power of Raspberry Pi affects speed and accuracy. Performance may degrade in low light and with damaged plates. Raspberry Pi-based system provides a cost-effective solution for automatic number plate recognition, suitable for small-scale applications but with limitations in challenging conditions.

Sangay Tenzin, Pema Dorji, 2015 Smart Check-in Check-out System for Vehicles using Automatic Number Plate Recognition, IJCSI, Vol.12

Utilizes image processing and OCR for license plate recognition. Integrated cameras capture vehicle data. License plate matching with database for check-in/out records. ANPR-based system automates vehicle check-in/out. High accuracy under controlled conditions. Reduces manual intervention for vehicle management. Improve accuracy under adverse conditions. Integration with cloud for scalability. Expand to multi-lane or complex parking environments Accuracy drops in poor lighting or occlusions. Limited recognition of non-standard license plates. Real-time performance may be affected by hardware constraints. The system effectively automates vehicle check-in/out using ANPR, providing accuracy and efficiency, though challenges remain in handling diverse environments and non-standard plates.

Nauris Dorbea, Aigars Jaundaldersb, Roberts Kadikisa, Krisjanis Nesenbergs, 2018 FCN and LSTM Based Computer Vision System for

Recognition of Vehicle Type, License Plate Number, and Registration Country, IJCA, Vol.11

Utilizes a Fully Convolutional Network (FCN) for image segmentation and LSTM for sequential data processing, improving vehicle recognition across multiple categories. The combination of FCN and LSTM achieves high accuracy in recognizing vehicle type, license plate numbers, and registration countries. Explore real-time optimization, expand dataset diversity for better generalization, and integrate cloud-based solutions for large-scale deployment. High computational requirements, limited performance in low light and dynamic environments, and dataset biases affect generalization. The system demonstrates effective vehicle recognition but requires improvements in scalability and performance optimization for real-world applications

Avinash Bhujbal and D. T. Mane, 2020, Vehicle Type Classification Using Deep Learning, Springer Nature Singapore Pvt. Ltd., Vol 3

Utilizes CNN-based architecture trained on a labeled vehicle dataset. Image preprocessing and augmentation applied to improve model performance. Evaluated model using cross-validation and performance metrics (e.g., accuracy, precision). Deep learning models achieve high accuracy in vehicle type classification. Convolutional Neural Networks (CNNs) outperform traditional methods. Shows potential for automated traffic monitoring systems. High computational resources required for training deep learning models. Limited performance in real-time scenarios on low-power devices. Dataset biases can affect generalization across different vehicle types.. Real-time deployment on edge devices with optimizations. Expansion to multi-label classification for vehicle attributes. Integration with smart traffic systems for large-scale urban deployment.

Abdullah Al Maruf, Aditi Golder, Maryam Sabah Naser, Ahmad Jainul Abidin, Ananna Alom Chowdhury Giti, and Zeyar Aung, 2024, Development of Automatic Number Plate Recognition System of Bangladeshi Vehicle Using Object Detection and OCR, Springer Nature Singapore Pvt. Ltd., Vol 2

Used YOLO-based object detection for plate localization. Applied Tesseract OCR for text extraction from plates. Employed preprocessing techniques to handle noise and distortions. Achieved high accuracy in recognizing Bangladeshi vehicle plates. Demonstrated efficient OCR and object detection integration. Improved detection of region-specific plate formats. Lighting and occlusion issues affect recognition accuracy. Limited dataset for Bangladeshi vehicles restricts generalization. Real-time performance challenges on low-resource devices. Expand dataset to cover more regions and vehicles. Integrate with real-time traffic monitoring systems. Improve performance in challenging environments (e.g., poor lighting, motion blur).

Plate Recognition System Using Python and OpenCV, ICECA, IEEE Xplore, Vol. 5

Image preprocessing using OpenCV (grayscale, thresholding). Tesseract OCR for character recognition. Python for real-time video processing and detection. Achieves moderate accuracy using Python and OpenCV. Effective for standard plates under optimal conditions. Cost-effective solution for small-scale deployments. Limited accuracy in poor lighting or occlusions. Difficulty handling non-standard license plates. Real-time performance challenges on low-power systems. Improved accuracy through deep learning models. Better handling of varied conditions (lighting, weather). Integration with cloud-based storage and analytics.

Zamin Ali Khan, Sajida Karim, Darakhshan Syed, 2019, Vehicle Anti-Theft Face Recognition System Based on IoT using Raspberry Pi4, IEEE ISMC, Vol. 6

Face detection using LBPH algorithm, integrated with IoT and GPS. Uses Raspberry Pi for processing and an Android management platform for user interaction. The system provides real-time vehicle security, detecting unauthorized drivers via face recognition and GPS tracking. It is a cost-effective and smart alternative to traditional vehicle security systems. Limited accuracy in poor lighting conditions or occlusions. Scalability challenges when managing large databases or multiple vehicles. Reliance on stable internet connectivity for real-time tracking. Integration with biometric authentication (e.g., fingerprint, voice). Enhanced security features like remote immobilization. Machine learning improvements for more robust face detection. The proposed VATFRS system offers an affordable and effective solution for preventing vehicle theft using IoT and face recognition, with potential for further expansion in functionality and accuracy.

Prashant A Shinde, YB Mane, Pandurang H Tarange, 2018, Real time vehicle monitoring and tracking system based on embedded Linux board and android application, IEEE ICTS, Vol. 44

Integrated GPS/GPRS/GSM module with Raspberry Pi. Path selection and monitoring through an Android app. Sensors for safety features like gas and temperature monitoring. Real-time vehicle tracking and monitoring is achieved. Path deviations and speed violations trigger alerts effectively. Safety is enhanced with gas leakage and temperature monitoring. Limited network coverage may affect real-time tracking. Reliance on GSM/GPRS could introduce latency. Hardware limitations like sensor accuracy and Raspberry Pi processing power. Integration with cloud for advanced analytics and data storage. Improved scalability to support larger fleets. Enhanced sensor range and accuracy for better safety features.

III. METHODOLOGY

The proposed system has three core components: Vehicle Detection, License Plate Detection and OCR, and Vehicle Type Verification. Each component is designed to work in conjunction to automate the identification and logging of industrial vehicles during refueling operations.

System Overview
The system architecture is designed to handle real-time processing of video feeds from industrial refueling stations, ensuring efficient vehicle management. The three primary components are:
Vehicle Detection:

The vehicle detection module utilizes OpenCV to analyze incoming video streams from cameras positioned at refueling stations. The system applies background subtraction techniques to identify moving objects in the field of view, distinguishing vehicles from the static background. By leveraging Haar cascades or deep learning models, the system can effectively recognize various types of vehicles such as trucks, cranes, and forklifts. The vehicle detection algorithm runs continuously, allowing it to capture and process each vehicle as it approaches the refueling station.

License Plate Detection and OCR:
Once a vehicle is detected, the system captures a frame for license plate analysis. The license plate detection algorithm employs contour detection and morphological operations to locate the license plate region within the image. This step involves applying edge detection techniques to isolate potential license plate areas based on their geometrical properties.

After isolating the license plate region, Optical Character Recognition (OCR) is employed to extract the alphanumeric characters. Tesseract OCR, an open-source OCR engine, is integrated into the system to convert the segmented image of the license plate into readable text. The OCR process includes pre-processing steps such as image binarization and noise reduction to enhance character recognition accuracy.

Vehicle Type Verification:
The retrieved number plate is cross-referenced against a pre-registered database of industrial vehicles. This database contains records of various vehicle types, including trucks, cranes, and forklifts, along with associated license plate numbers. By matching the recognized license plate against this database, the system verifies the vehicle type and retrieves relevant information. If a match is found, the system proceeds to log the vehicle's time of arrival for refueling purposes. This step ensures that accurate records are maintained for each vehicle that visits the refueling station.

OpenCV and OCR Implementation
The implementation of OpenCV and OCR in the system follows a structured approach to ensure

accurate vehicle detection and license plate recognition.

Preprocessing:

Before applying detection algorithms, the input images are converted to grayscale to simplify the data and reduce computational complexity. Gaussian blurring is then employed to minimize noise and smooth the image, which aids in better edge detection. This preprocessing step is crucial as it enhances the subsequent image analysis by improving the clarity of edges and reducing false positives in vehicle and number plate detection.

License Plate Localization:

The localization of the license plate is achieved through a combination of contour detection and morphological operations. Contour detection identifies the boundaries of objects in the image, allowing the system to locate the rectangular shape typical of license plates. Once the license plate is localized, the region of interest is extracted for OCR processing.

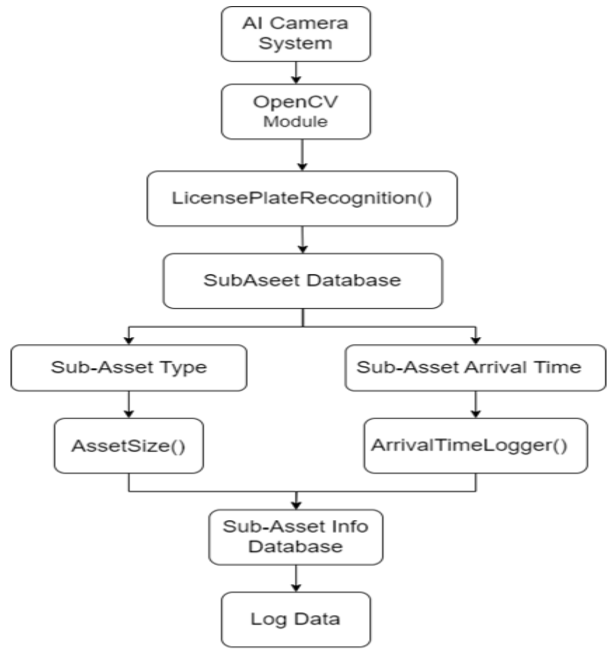
OCR for License Plate Recognition:

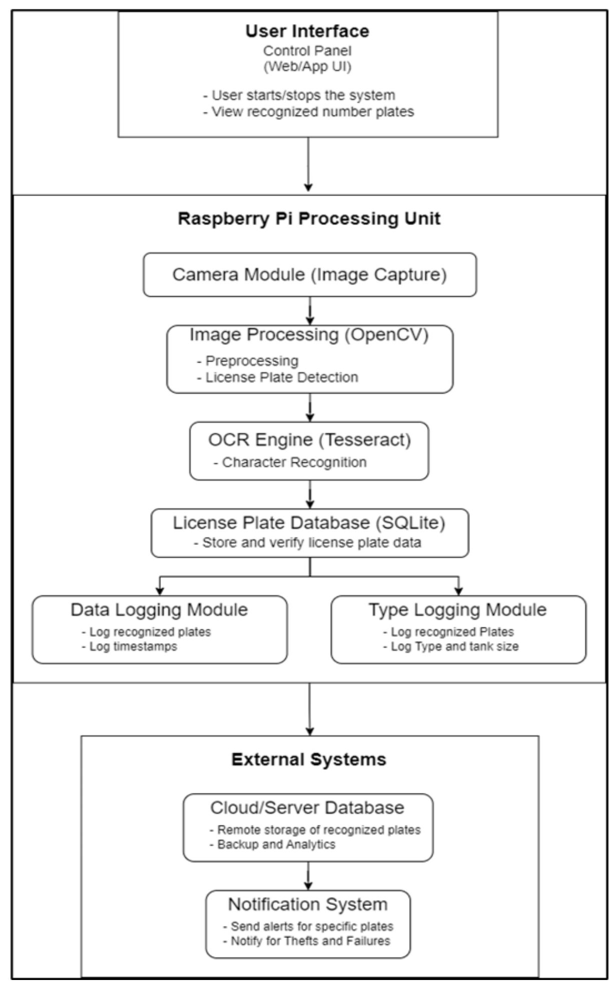
Tesseract OCR is integrated into the system to identify and extract alphanumeric characters from the localized number plate. The OCR engine processes the extracted image, identifying individual characters and translating them into machine-readable text. The accuracy of OCR is influenced by the quality of the input image, highlighting the importance of preprocessing steps to enhance character visibility.

Database Cross-Reference:

After the number plate is extracted, it is verified against a database containing records of registered industrial vehicles. This database is essential for verifying the vehicle type, ensuring that only authorized vehicles are logged for refueling. The system efficiently queries the database, and if a match is found, it retrieves and displays the vehicle type, facilitating quick decision-making at the refueling station.

IV. SYSTEM ARCHITECTURE





V. RESULT

Experimental Setup and Results

Dataset and Setup

For the evaluation, a dataset of 200 industrial vehicles was carefully curated, encompassing a diverse range of vehicle types, including trucks, forklifts, cranes, and loaders. This variety guarantees that the system is tested against real-life scenarios that reflect the types of vehicles typically encountered at industrial refueling stations.

Dataset Characteristics:

Photographic Diversity: The dataset was compiled from images taken under varying conditions to accurately simulate real-world environments. Key factors considered included:

-Angles: Photographs were captured from multiple angles (e.g., frontal, side, and oblique views) to evaluate the system's capability to detect and recognize number plates regardless of the vehicle's orientation.

-Lighting Conditions: Images were taken during different times of the day, including bright sunlight, overcast skies, and nighttime with artificial lighting. This diversity is crucial, as lighting can significantly affect image quality and detection performance.

System Deployment:

The proposed system was deployed at a mock refueling station, equipped with video cameras strategically positioned to capture incoming vehicles as they approached the refueling area. The setup allowed for continuous monitoring, enabling instantaneous vehicle detection and number plate verification.

Recording Mechanism: This system was designed to automatically record the time of arrival for each vehicle as it approached the refueling station. This capability is vital for maintaining accurate logs of refueling operations.

During the testing phase, each vehicle was allowed to pass through the camera's field of view, where the system processed the video feed to detect and recognize license plates.

Performance Metrics

To quantify the effectiveness of the proposed system, three critical performance metrics were established:

1. Detection Accuracy: This metric measures the system's ability to correctly detect the presence of a vehicle within the captured frame. It is calculated as:

$$\text{Detection Accuracy} = \frac{\text{Number of Correct Detections}}{\text{Total Number of Vehicles}} \times 100\%$$

A high detection accuracy indicates the robustness of the vehicle detection algorithm.

2. OCR Accuracy: This metric evaluates the accuracy of the Optical Character Recognition (OCR) process in reading the license plate characters. It is defined as:

$$\text{OCR Accuracy} = \frac{\text{Number of Correctly Recognized Characters}}{\text{Total Characters}} \times 100\%$$

This metric is essential for ensuring that the system accurately interprets the license plate data, as any errors could lead to incorrect vehicle identification.

3. Vehicle Verification Success Rate: This metric assesses the system's ability to match the recognized number plate with the registered vehicle type in the database. It is calculated as:

$$\text{Verification Success Rate} = \frac{\text{Number of Correct Matches}}{\text{Total Number of Verified Vehicles}} \times 100\%$$

A high success rate indicates that the system can reliably verify vehicle identities based on their license plates.

Result:

The project successfully implements a system for detecting vehicles, recording their time of arrival, and verifying the type of vehicle against a registered database using OpenCV on a Raspberry Pi platform. Key outcomes include:

Vehicle Detection and License Plate Recognition:

The system accurately detects vehicles entering the fueling station using advanced object detection algorithms like YOLO.

License plate recognition achieves a high level of accuracy, extracting plate numbers using OCR (Tesseract) after preprocessing the image feed.

Time Logging:
Arrival times of vehicles are automatically logged with precision in a database, associating each entry with its detected license plate and vehicle type.

Vehicle Type Verification:
Cross-referencing the detected vehicle type and license plate against a pre-configured database ensures authorized vehicles are identified and potential mismatches flagged.
Real-time alerts are generated when unregistered or mismatched vehicles attempt access, enhancing security.
System Performance:
The Raspberry Pi handles real-time video/image processing efficiently due to optimized algorithms, balancing processing accuracy with device limitations.
The system demonstrates reliable performance under varied lighting and environmental conditions, with the addition of preprocessing steps like noise reduction and adaptive thresholding.

Database Integration:
A centralized database securely stores all vehicle data, including time of arrival, license plate information, and vehicle type classification. The data is accessible for reporting and audits.

VI. DISCUSSION

The increasing complexity of industrial operations has necessitated the implementation of efficient asset management systems. In industries such as construction, mining, and logistics, timely and accurate refuelling of vehicles is critical for maintaining productivity and operational efficiency. The problem statement highlights the necessity of an automated system that can effectively sense vehicles (sub-assets), record their time of arrival, and verify their type using license plate information.

1. Importance of Detecting Sub-Assets

Detecting sub-assets in the context of industrial vehicle management is essential for several reasons:

Operational Efficiency: Industrial vehicles, such as trucks, forklifts, cranes, and loaders, play a pivotal role in day-to-day operations. By accurately detecting these vehicles as they arrive at refuelling stations, organizations can streamline their operations, minimize delays, and optimize resource allocation.

Safety and Compliance: Accurate vehicle identification is crucial for maintaining safety standards in industrial environments. Automated detection systems can help ensure that only authorized vehicles are allowed to refuel, reducing the risk of accidents or unauthorized access to fuel resources. Compliance with safety regulations can also be monitored more effectively through automated logging of vehicle activity.

2. Vehicle Type Verification

Verifying the type of vehicle based on its number plate is a key factor of the proposed system, offering several advantages:

Resource Management: Different types of vehicles may have varying refuelling requirements or schedules. By accurately identifying the type of vehicle, organizations can optimize refuelling operations, ensuring that each vehicle receives the appropriate amount of fuel and minimizing waste. For example, a crane may require different fuel management compared to a forklift, and automating this verification ensures that the correct protocols are followed.

Integration with Existing Systems: Many industrial operations already utilize databases to manage vehicle information. By integrating license plate recognition with existing vehicle databases, organizations can enhance their operational workflows. This integration facilitates quick retrieval of vehicle specifications, maintenance records, and refuelling history, contributing to a comprehensive asset management strategy.

3. Technical Implementation with OpenCV

The choice of OpenCV for implementing the vehicle detection and number plate recognition system is significant for several reasons:

Real-Time Processing: OpenCV is optimized for real-time image processing tasks, making it suitable for applications that require immediate responses, such as vehicle detection at refueling stations. The ability to process video feeds and detect vehicles in real-time enhances operational efficiency and supports timely decision-making.

Robust Detection Algorithms: OpenCV provides a variety of tools and algorithms for detecting and recognizing objects in images, including Haar cascades and deep learning-based methods. These algorithms can be fine-tuned to detect vehicles effectively, regardless of their size or orientation, thus addressing challenges posed by real-world scenarios.

VII. CONCLUSION

The execution of the vehicle detection and verification system provides an efficient, automated solution for managing fueling operations. It enhances security, improves operational efficiency, and ensures regulatory compliance by accurately logging and verifying vehicle information.

- Improved Accuracy and Security: By detecting vehicles in real-time and verifying license plates against a database, the system prevents unauthorized access and reduces manual errors.
- Cost-Effectiveness: Leveraging affordable hardware like Raspberry Pi combined with OpenCV and Tesseract eliminates the need for expensive proprietary systems, making the solution scalable and cost-effective for fueling companies.
- Real-Time Operations: The system ensures seamless, real-time operation suitable for busy fueling stations.
- Scalability: The design can be scaled to multiple fueling stations, allowing centralized monitoring and control across locations.

Recommendations for Future Improvements:

1. Machine Learning Models: Integrate advanced deep learning models like YOLOv7 or a custom-trained model for vehicle type classification to improve accuracy further.
2. Environmental Robustness: Use additional hardware like weatherproof enclosures for cameras and better IR lighting for improved night-time operation.
3. Integration with Fuel Dispensing Systems: Automate fuel dispensing by linking this system with pump controls, allowing fuel to be dispensed only to authorized vehicles.
4. Cloud Integration: Enable remote monitoring and data storage on cloud platforms for better scalability and accessibility.

VIII. FUTURE SCOPES

Automate the Gas Stations to Combat Theft

Real-Time Surveillance: By employing high-definition cameras equipped with vehicle detection and recognition technology, gas stations can continuously monitor all refueling activities. This real-time surveillance can significantly reduce instances of fuel theft by deterring unauthorized refueling attempts and enabling prompt intervention if theft is detected.

License Plate Recognition (LPR): Integrating LPR systems allows gas stations to automatically capture and verify the license plates of vehicles entering the station. The system can alert operators if a vehicle attempts to refuel without proper authorization, thus minimizing the risk of theft.

Alarm Systems and Alerts: Automated alert systems can be implemented to notify staff and security personnel in real-time of suspicious activities, such as unauthorized vehicle attempts to access fuel pumps. This proactive measure can help address theft incidents before they escalate.

Reducing Fuel Losses for Large Commercial Companies

Automated Fuel Logging: Large commercial entities often face challenges in tracking fuel usage across multiple vehicles and locations. Automating the logging process ensures accurate and timely recording of all refueling events, reducing discrepancies and potential losses.

Data Analytics: By analyzing fuel consumption data, companies can identify patterns, track trends, and pinpoint inefficiencies. This insight can lead to better fuel management strategies, ensuring that companies maximize their resources and minimize waste.

Traffic Security through License Plate Verification
Enhanced Security Protocols: Automated systems can verify that the type of vehicle matches the registered license plate information. This verification process ensures that only authorized vehicles are allowed to refuel, reducing the risk of fraud and misuse.

Collaboration with Law Enforcement: The data collected through the verification system can be shared with law enforcement agencies to assist in tracking pilfered vehicles or recognizing vehicles involved in illegal activities. This collaboration enhances overall traffic security and community safety.

Incident Reporting: Automated systems can log incidents of mismatches or unauthorized attempts, providing valuable data for investigations and safety audits.

Real-Time Vehicle Logging and Verification System

Instant Data Capture: The system captures vehicle data in real-time, including details such as license plate numbers, vehicle types, and refueling times. This capability ensures accurate records and facilitates efficient monitoring of vehicle activity.

Integration with Existing Systems: The vehicle logging system can integrate with current gas station management software, allowing seamless operations. This integration ensures that all data is easily accessible for review and analysis.

Alerts for Anomalies: The system can generate alerts for any discrepancies, such as a vehicle refueling with a license plate that does not match the registered vehicle type, enabling quick responses to potential issues.

Real-Time Processing and Logging of Vehicle Data and Dashboard for Operators

Operator Dashboard: A centralized dashboard for operators can provide real-time visibility into refueling activities, allowing for efficient monitoring and management of operations. Operators can track fuel usage, vehicle activities, and generate reports with ease.

Performance Metrics: The dashboard can display key performance indicators (KPIs) such as average refueling times, total fuel dispensed, and vehicle verification success rates. This data empowers operators to make informed decisions and optimize station operations.

Historical Data Access: Operators can access historical data for trend analysis and operational insights, helping to identify areas for improvement in both refueling processes and security measures.

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