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Mobile App and AI-Based Monitoring for Tanker Truck Shipments

Michele Celebre\*, Valentina Stillo, Andrea Venuto, Alessandra Saraceno, Francesca D’Amico, Fortunato Laganà

Raffineria di Milazzo SCPA, C.da Mangiavacca Milazzo (Italy)

[michele.celebre@ram.it](mailto:michele.celebre@ram.it)

The Milazzo Refinery has launched a project aimed at optimizing tanker truck shipments, through the adoption of both organizational and technological solutions. A cross-functional working group has identified two priority tools: a Progressive Web Application (PWA) for tanker truck drivers and a monitoring system for tanker truck waiting area based on Artificial Intelligence (AI) algorithms.

The PWA, easily installable on any smartphone, provides an intuitive platform for managing scheduled deliveries, allowing drivers to change schedules and exchange operational communications. Simultaneously, the AI-powered monitoring system, equipped with six cameras in the external parking area, accurately identifies trucks entering and exiting, associates them with their respective bookings, and detects any behavioral anomalies. The objectives of the project is to prevent overcrowding in the external area, improving safety and reducing waiting times. The result shows a significant decrease in the number of trucks parked and waiting times, with positive effects both in terms of safety and driver satisfaction. Additionally, more precise scheduling has enabled the possibility of organizing multiple deliveries for the same truck and driver within a single day, contributing to a reduction in overall operating costs.

* 1. Introduction

Logistics optimization is a strategic lever to increase safety, improving operational efficiency, and reducing cost in the oil & gas sector and beyond. Although over 90% of the Milazzo Refinery’s products are shipped by sea, more than 100 tanker trucks are loaded daily on average. Given that the external waiting yard accomodates just over twenty trucks, effective planning and management of loading operations is essential to minimize risks and waiting times.

AI-based methods have been successfully adopted in various areas in Oil & Gas Downstream (Olaizola et al, 2022). In particular, machine learning and computer vision techniques have been successfully applied to address issues such as classification of cars and trucks, determining the occupancy status of parking spaces (Won, 2022).

With progressive web apps (PWA) is possible get the benefits of the web as well as those of native applications. PWA, like native language apps, allow the user to work offline, receive push notifications, access the smartphone's GPS coordinates and offer the possibility of installing the application directly on the home screen (Kothapalli, 2021).

In this context, the Milazzo Refinery launched a project to improve the scheduling of tanker truck shipments, enhance communication by sharing information in real time with all users involved, and optimize the use of the external truck parking area. Specifically, the project integrates traditional shipment management systems with a Progressive Web Application (PWA) and a video surveillance platform powered by artificial intelligence.

The objectives are:

* Reducing Waiting Times: By improving transparency of scheduling and communication, thus minimizing idle times and truck parking congestion.
* Improving Safety: By reducing overcrowding and monitoring potentially unsafe parking or behaviors in the waiting area.
* Enhancing Operational Efficiency: By facilitating the scheduling of multiple loads for the same truck within a single day, thus streamlining operations and reducing costs.

This paper presents the complete framework of the project, from its industrial case study context to the system architecture and technical methodology employed. It also provides an in depth analysis of the results and discusses the potential applicability of the approach to other logistical systems.

* 1. Case Study: The Milazzo Refinery Approach

The Milazzo Refinery, an industrial plant located in Sicily, ships petroleum products through multiple logistics channels. Tanker truck shipments are part of the daily operations, involving about one hundred trucks and drivers each day. Scheduling for tanker truck is typically conducted the day before by the logistics departments of the depositing companies.

Before the implementation of the current project, truck drivers often arrived at the site simultaneously or without an established schedule. This lack of coordination resulted in excessive waiting times, frequent congestion, and inefficient loading operations.

To address these challenges, the Refinery established a cross-functional team.

The key elements of the approach were:

• Organizational coordination: Operational constraints and procedures for tanker truck loading were jointly defined with the logistics departments of the depositing companies.

• New digital tools: the software for managing product delivery orders, loading operations and producing the related tax documentation was enhanced with:

- a scheduler for optimizing tanker truck loading times;

- a PWA (Progressive Web Application) to enable real-time information sharing among all stakeholders;;

- an AI-powered camera system to monitor the external truck waiting area.

* 1. Methodology
     1. Scheduler:

A program has been created that, the day before loading, based on the loading requests entered by the depositing companies, optimizes the order and time of loading in compliance with the agreed priorities and constraints.

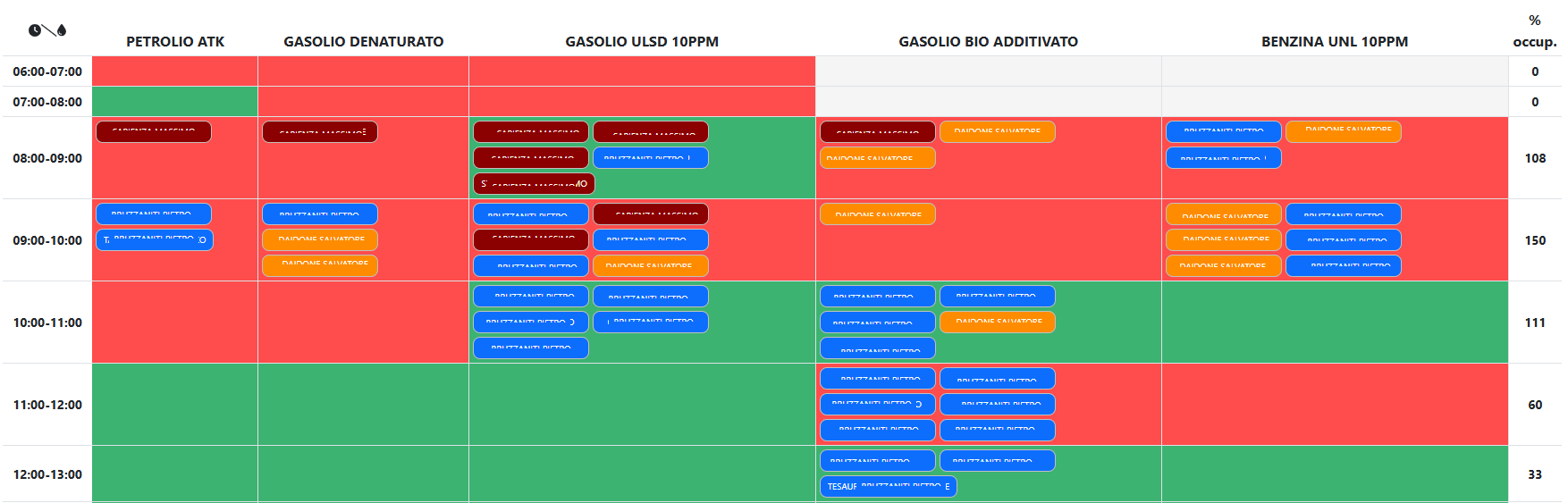
Depositing companies can modify their loading requests based on priorities and availability of refinery loading terminal.

Figure 1: Program, used by depository companies, to view and modify the loading plan

* + 1. Progressive Web Application Development:

The PWA has been designed to be accessible on all smartphones, ensuring immediate and intuitive usability. The main features include:

* Viewing scheduled deliveries (trip): Tanker drivers are able to view their scheduled trips from the day before loading, and, when unallocated slots are available, they can modify their loading schedule;
* Two-way communication**:** The tool allows the exchange of information and notifications between the refinery and tanker truck drivers (e.g., urgent changes, safety alerts);
* Readiness for loading: A feature that allows tanker truck drivers to confirm their presence for loading;
* Control of authorization expirations: the system warns in case of imminent expiration of authorizations, for example quarterly safety courses

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| Immagine che contiene testo, schermata, Carattere, numero  Descrizione generata automaticamente | Immagine che contiene testo, schermata, Carattere  Descrizione generata automaticamente | Immagine che contiene testo, schermata, Carattere, numero  Descrizione generata automaticamente |
| Figure 2a: View scheduled trips | Figure 2b: View trip details | Figure 2c: Change trip time |

* + 1. Waiting Area Monitoring System

The monitoring system uses a network of six cameras installed in the waiting parking lot, integrated with AI algorithms for:

* Truck identification: Automatic recognition of license plates and association with the related scheduled trip;
* Anomaly detection: Monitoring of behaviors deviating from operating procedures and safety regulations. For example:
  + stationary vehicle that occupies multiple parking spaces at the same time;
  + non Tanker Truck vehicle stopped for more than an hour;
  + vehicle stopped on the access or exit ramps;
  + Entering the parking lot of a tanker that has no scheduled trips;
* Real-time control: Visualization of the status of the area for operators, drivers and forwarders, with the aim of avoiding overcrowding and optimizing flows.

In case of anomalies the system can send emails, SMS or push notifications to configured users.

In compliance with privacy regulations, the video surveillance system automatically blurs the image of people present in the waiting area.

* + 1. System Integration

The synergy between the PWA and the monitoring system allows for integrated management of operations. For example, in case of full parking, the PWA immediately informs tanker truck drivers, suggesting alternative areas for waiting and preventing congestion that could compromise safety and operational efficiency.



*Figure 3: Integrated system flowchart*

* 1. Results and discussion

Before the introduction of the new integrated system, waiting times could exceed two hours during peak periods, creating both safety hazards (due to overcrowding) and inefficiencies.

The first periods of use have shown significant improvements:

* Waiting time reduction: The average waiting time dropped by 65% (Figure 4). This improvement not only raises driver satisfaction, but also contributing to a smoother and safer flow;
* Parking optimization: The reduction in the number of parked trucks has made the area less congested, improving operational safety. Furthermore, the detection of unauthorized or improperly parked vehicles by the AI system enables surveillance personnel to promptly address any potentially risky situations (Figure 5).
* Increased productivity: More efficient planning has allowed multiple trips to be scheduled for the same truck and driver, reducing operating costs.

Other qualitative and theoretical remarks

* Real-time data and improved communication: Real-time data sharing between on-site operators, drivers and back-office staff simplifies decision-making.

In the future, tanker truck loading planning could be further refined using acquired historical data and machine learning approaches;

* Safety and Regulatory Compliance: With reduced congestion, there is a lower chance of accidents in the waiting area. Additionally, real-time alerts ensure that drivers comply with mandatory safety authorizations before entering the plant.

Immagine che contiene testo, diagramma, Carattere, linea

Descrizione generata automaticamente

Figure 4: In orange is the average minutes of waiting of tankers in the yard before the PWA and the video surveillance system are put into operation. In blue, the average minutes, after the change.

The drastic reduction in waiting times is evident, in fact, in three weeks we have gone from an average of 114 minutes of waiting to just 40 minutes, with a reduction of 65%.

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| **Immagine che contiene aria aperta, terreno, albero, natura  Descrizione generata automaticamente** | | **Immagine che contiene schermata, testo, Software multimediale, software  Descrizione generata automaticamente** | |
| Figure 5a: The image shows the loading yard with four parking spaces occupied by non-tanker trucks | | Figure 5b: The application of video surveillance system, displaying free spaces (in green), occupied spaces (in blue) and anomalies (in red). | |
| Immagine che contiene ruota, veicolo, Veicolo terrestre, aria aperta  Descrizione generata automaticamente  Figure 6a: Non Tanker Truck vehicle stopped for more than an hour;. | Immagine che contiene testo, veicolo, ruota, Veicolo terrestre  Descrizione generata automaticamente  Figure 6b: Non Tanker Truck vehicle stopped for more than an hour. outside the spaces | |
| Immagine che contiene testo, veicolo, schermata, automobile  Descrizione generata automaticamente | *Immagine che contiene aria aperta, strada, albero, veicolo  Descrizione generata automaticamente* | |
| Figure 7a: an example of how the video surveillance system automatically blurs the image of people | Figure 7b: To read the license plates of vehicles entering and exiting the parking lot, a camera was placed at the entrance to the parking lot and one at the exit. | |
| Immagine che contiene testo, veicolo, aria aperta, ruota  Descrizione generata automaticamente |  | |
| Figure 8: In the case of tanker truck vehicles parked outside the spaces, the system signals the anomaly, indicating the parking area where the vehicle was parked. | | |

Furthermore, an application has been developed (figure 5b), integrated with the video surveillance system, which allows the refinery's tanker shipping department to monitor the waiting area, displaying free spaces, occupied spaces and any anomalies detected.

To ensure compliance with European privacy regulations, as shown in figure 7a, the video surveillance system automatically recognizes and blurs the people filmed by the cameras.

As shown in Figure 6a, 6b and 8, the video surveillance system is able to recognize vehicles other than tankers or parked tanks without a tractor, Figure 5a.

To achieve high efficiency of the video surveillance system, it was necessary to repeat the training phases to improve vehicle recognition when brightness and weather conditions vary.

Retraining the neural network was also necessary due to the great variability in the type of vehicles that are normally present in the truck waiting area.

To accelerate the learning phase of neural networks and "satisfy" the "hunger for data" typical of machine learning-based approaches, a consolidated method was adopted such as using realistic but synthetic data automatically labeled (Quattrocchi, 2023).

* 1. Conclusions

The project carried out at the Milazzo Refinery, demonstrates how the adoption and integration of multiple digital technologies, such as the creation of a scheduler, the distribution of a Progressive Web Application for tanker drivers and the development of a video surveillance system of the external waiting area based on Artificial Intelligence, can lead to significant improvements in logistics and safety management.

The 65% reduction in waiting times has led to a reduction in crowding, contributing not only to improving the safety of operators and tanker drivers, but also to the reduction of operating costs.

The highly integrated approach implemented by the Milazzo Refinery, while adaptable to site-specific requirements, provides a replicable model for similar scenarios. These may include container transport in seaports, distribution centers for consumer and retail goods, and other industrial logistics operations.

The integration of additional features, such as predictive modeling of arrival times, automatic suggestion of alternative parking for the truck in case of congestion in the external waiting area, or advanced anomaly detection (e.g. unsafe behavior, environmental threats, theft attempts), could further expand the potential of this technology.

As AI techniques advance, the integration of predictive analytics may allow for even more proactive and dynamic load scheduling

For instance, real-time rerouting of tanker trucks based on current traffic conditions could push logistics digitalization to new levels of efficiency and safety.

Finally, the rapid development of generative artificial intelligence (Yafei, 2024) could make it possible to introduce a chatbot within the PWA, enabling drivers to ask questions in natural language—regardless of their native tongue—about refinery safety procedures or delivery destination details.

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