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Seeing the Unseen: How AI can Improve Safety in Geopark Drilling Operations in Colombia

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Abstract

The authors present the implementation of artificial intelligence (AI) technologies in the health and safety processes in HSE of the Geopark-Colombia company, with a specific focus on drilling operations in the Llanos basin. The project analyzes major incidents involving personnel injuries, identifying the main causes, particularly limb injuries, through statistical analysis and risk matrix correlation. The application of Intelligent Video Analysis processes allows for monitoring and analyzing critical activities in real-time, identifying potential risk to implement immediate interventions and prevent incidents. The work also describes the calibration process and training of image and video analysis algorithms, aimed at detecting risk patterns and generating early warnings of potential risk that enable timely corrective measures to be taken during drilling operations.

The approach focuses on training the machine learning model based on video analytics, oriented towards the identification of unsafe behaviors and conditions in operational environments (drilling). The system was configured to monitor the correct use of personal protective equipment (PPE), detect the presence of personnel in unauthorized areas, the management and securing of red zones – NO GO ZONE – DROPS, and record unsafe behaviors and practices in real-time. Examples of its implementation in critical areas of the rig and its integration with the company's safety management (HS) programs are illustrated.

The implementation of AI solutions has had a profound impact on reducing he injury frequency rate (IFR) in Geopark drilling operations compared to the last five years.

Introduction

The use of technologies, especially in the oil and gas industry, has strengthened and improved task supervision and control processes in the workplace, helping to reduce the occurrence of workplace accidents affecting people. This tool is a powerful catalyst for organizational learning and strategic alignment, which is being implemented in incident prevention management. In the drilling industry, workplace incidents are a major concern for managers, leaders, and supervisors, since in most cases, events that occur on a drilling rig involving people have the potential to cause serious injuries to workers that can lead to lost time injuries (LTIR), restricted work (TRIR), and events that can even result in fatalities. Organizations have understood

that an efficient operation must ensure that all employees and collaborators return home safely, performing operational correctly.

At Geopark, safety is a priority, its genuine commitment to caring for the health and safety of all its employees and contractors to develop safe and incident-free operations, where safety is one of the pillars and fundamental values of the organization. For this reason, initiatives and projects focused on preventing injuries to people, promoting self-care among workers, and strengthening the HSE culture are part of the strategies developed by the company to fulfill this purpose.

With the development of artificial intelligence (AI), which has been implemented in the industry for 20 years, new applications are being generated that are covering different needs, providing solutions to specific problems that arise mainly from data management and administration, supporting processes in which the solution is focused on administrative, technical, safety, operational, and strategic situations for organizations. and strategic situations for organizations. In general terms, the application of AI has helped to simplify processes, analyze situations, and make decisions based on facts, strengthening strategies and organizational culture.

Seeing the Unseen, how the project begins in operation

At GeoPark Colombia, the drilling department has been working to find initiatives and strategies that allow us to be more efficient every day, taking care of the people who work in our operation. The commitment of leaders and supervisors is to ensure an operation without injury to people, considering that over the last four years there have been eight recordable events with lost time (LTIR) and restricted work (TRIR). In order to analyze and understand the causes of these events, an accident rate assessment was carried out on GeoPark's drilling operations, which identified that 35% of events involving injuries to workers occurred in the Rig Floor, Catwalk, and Land Platform areas. Likewise, the hazardous energies involved as causal agents of the incidents corresponded to kinetic energy (38%), gravity (27%), chemical energy (11%), and mechanical energy (11%). The same analysis identified variables such as the type of operation, activity performed, and accident classification, it was established that of all the incidents that occurred in operations, 28% corresponded to injuries to persons requiring first aid (FAC) and 7% to events with incapacitating injuries and restricted work (LTIR-TRIR), the latter impacting the organization's HSE performance KPIs[1].

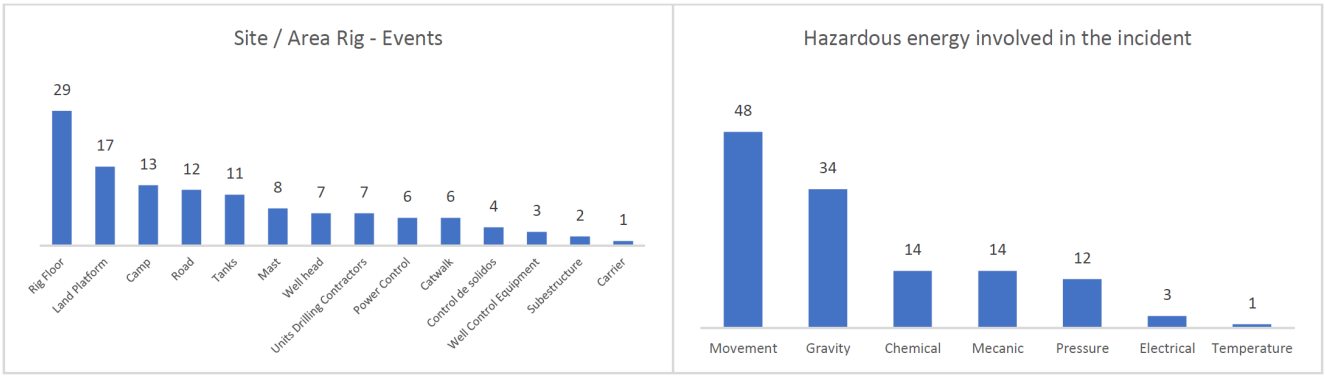

Figure 1—Statistical analysis of Drilling accident rates in GeoPark Colombia.

Based on this analysis, which identified the areas of the drilling operation where accidents occur, the different operational processes that were being carried out, the main hazardous energies associated with these events, the mechanisms that contribute to the occurrence of the event, and the type of injury and impact on the workers involved, a comprehensive assessment (Operations & HSE) is carried out to define and establish mechanisms and tools that help improve and reinforce the operational controls that must be applied to ensure the execution of activities, especially those associated with events involving personal injury.

Another factor that was considered in structuring the model and considering its design was to include the analysis of the causes of investigations into incidents that resulted in personal injury. Factors such as inadequate assessment and analysis of task hazards and risks, improving compliance with standards, procedures, and work guidelines, and lack of supervision were identified as the main causes of accidents. The organization must ensure the application of specific controls that are effective in mitigating the risks associated with the activities carried out in drilling operations.

Finally, one of the management tools used to carry out safety interventions in which workers actively participate is the task observation program. All this information was reviewed and analyzed in an artificial intelligence data management program (ROWS), which was cross-referenced with the information obtained from the statistical analysis carried out, to gain greater clarity and focus on the type of intervention required to implement improvements in controls that would reduce incidents involving personal injury. These task observation reports, which identify unsafe acts and conditions, validated that for certain activities in the operation, personal protective equipment (PPE) is not used correctly, unauthorized personnel are present in restricted areas of the drilling operation (No Go Zone // Red Zone), personnel are exposed to hazards without adequate protective mechanisms, equipment and tools are used unsafely, people are exposed to mechanisms and moving equipment, and ergonomic postures and positions are inadequate. These observation reports were correlated with both the incident analysis and the root cause analysis of incident investigations, finding that there are common and cross-cutting elements on which activity control can be improved through the implementation of the HSE video analytics tool, which allows for early identification of deviations identified in the task observation report, such as non-use of PPE, inadequate exposure to Red ZONE and danger lines, or personnel exposed to moving equipment and mechanisms, and finally, performing manual load handling activities in an inadequate manner.

Design of the prevention model applying video analytics with AI

Once these elements that are part of the areas for improvement have been identified, if they are correctly controlled and secured, they will have a direct impact on reducing work incidents and, therefore, on reducing injuries and harm to personnel who are exposed to occupational hazards during operations. In the search for solutions, some tools using artificial intelligence (AI) technology were considered, including Video Computer Vision (VCV) processes with the application of Intelligent Video Analysis, which allows critical activities to be monitored in real time, identifying potential risks for immediate intervention and helping to prevent incidents. This model (VCV) is essentially designed in general terms under a structure that consists of a high-resolution camera system installed in the work area in which all activities subject to supervision are monitored and tracked, a connection based on Edge Computing architecture. The system uses video surveillance cameras and an AI Edge Server, all integrated into the Local Area Network (LAN), with remote connectivity provided by a Starlink antenna. The Edge Server processes video streams in real time on site and, upon detecting a preconfigured alert condition, activates two notification channels[2]:

- Local: To a Visual Alert Unit for immediate response, without relying on an internet connection.
- Remote: To external notification services, using connectivity.

During the project planning process, different models and programs offered in the industry for video analytics monitoring with AI cameras were reviewed to evaluate the best option to meet GeoPark's requirements. The focus was on finding an alternative that could build flexible algorithms to generate automated alert and notification processes, cyclical review within the program for validation of alerts, and on-site devices to view alerts in real time. This is based on a prevention model that aims to improve the supervision of on-site tasks and enable effective safety interventions to control risks in critical operations that could lead to incidents with serious and fatal injuries.

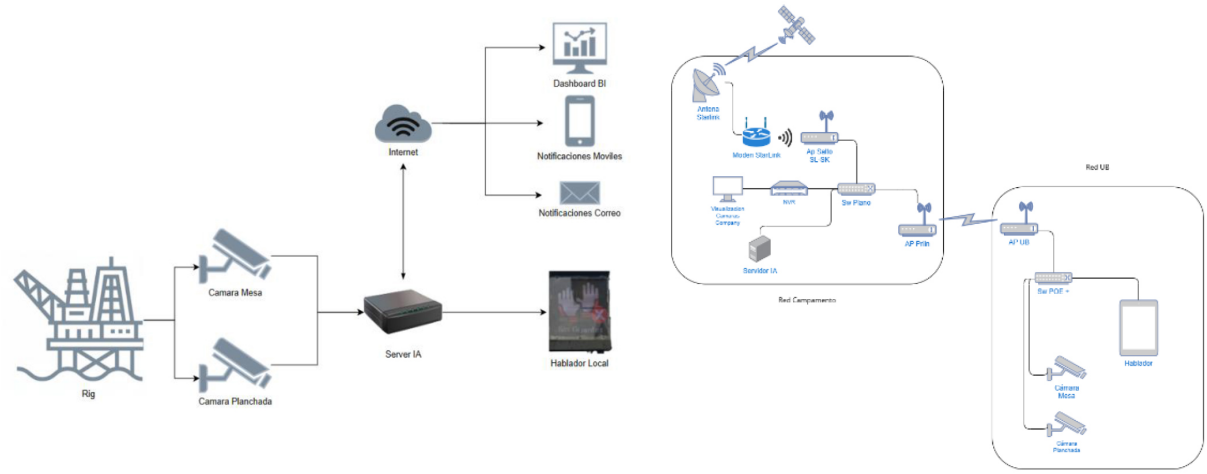

Figure 2—Distribution diagram of the HSE monitoring and video analysis system with AI – Source: ScanHawk contractor.

Training in AI algorithms and adjustment to operational requirements

As part of the process of building the algorithms, which were defined according to the specific needs of the project, a prevention model was designed to identify scenarios in which there is a high probability (greater than 80%) of detecting unsafe behavior that has been parameterized to manage HSE video analytics, i.e., the identification of an on-site activity that requires supervision by key operational personnel. For the effective implementation of the model, different tests were run within a period to validate the different scenarios and, with this, the effectiveness of the identified alerts. In the case of the use of personal protective equipment (PPE), tests were carried out to detect the use of safety harnesses on the rig floor when personnel are required to work at heights (above the 4-foot level of the Rotary Table). Part of the tests for detecting helmet use involved identifying the non-use of this PPE, the presence of safety helmets worn by personnel in training or those with restricted access to the Rig Floor level, and the non-use of safety gloves by personnel in the Rotary Table area. Another test carried out to apply supervision rules (algorithms) was the detection of people on the Rotary Table. For this scenario, it was considered that the system would detect a minimum and maximum number of personnel in this area, as well as their length of stay. With these variables, controls were sought in the No GO Zone // Red Zone to minimize the number of people exposed to falling objects DROPS (Dropped Objects Prevention Scheme), in which specific controls are strengthened and applied to the Red ZONE and the management of this risk, which continues to be one of the most important mitigation measures for controlling human exposure, implemented in numerous drilling rigs and drilling contractors for both onshore and offshore operations. One of the algorithms designed to detect human exposure to mechanisms, moving equipment, and improper ergonomic postures and positions required a series of simulations comparing ergonomically correct positions with positions for the task in activities involving the use and handling of equipment and tools, developing a program with the support and advice of a specialist in manual load handling, which generated an alert when it identified a deviation from the correct way of handling equipment and tools or when personnel moved their limbs with mechanisms that were in motion and that were in accordance with the parameters established in the prevention model that was designed. This process was not easy to build and required time to review and refine the model to ensure that reliable data was available, with a sensitivity that maintained a very acceptable margin of certainty, to ensure that the false positive rate decreased and to quantify alerts with a margin of certainty and accuracy greater than 90% that took into account true positive values.

Application as a tool to support on-site supervision

To ensure that identified events were communicated in real time to operations, a threshold was established for the system response time and the means of receiving alerts, to guarantee that notifications were reported and visible at the work site. To this end, a visual and audible system was installed in the work areas (Rig Floor and Catwalk) to notify personnel in the work area of alerts related to identified unsafe behavior or warnings for on-site personnel due to the detection of people in the Red Zone or Line of Fire. This alert is notified to the operation and HSE supervision personnel via the web so that they can analyze it and take the appropriate action and control measures, always seeking to focus on reviewing what is happening in the operation, supported by on-site supervision through cameras, to adopt preventive and awareness-raising measures for personnel that improve behavior, strengthening the commitment to self-care and the execution of safe operations through the promotion and application of Geopark's health and safety management tools.

The system was configured so that the algorithm recognizes an event and generates an alert when the probability of the identified parameter is above 80% probability of occurrence, to perform quality control of the information reported by the system. On site, key HSE personnel have access to the alert notification database, where all incoming notifications are continuously reviewed and evaluated to determine whether the alerts correspond to false notifications or to real events that have been identified are in line with the defined algorithm rules. During the test when the system was carried out, it was found that 40% of the notifications did not meet the parameters defined in the algorithm and corresponded to false alerts or events with no correlation with the situation detected. This led to a review and debugging mode process to improve the training of the algorithms and create secondary rules to improve the efficiency of the analysis process, which included instructions in the software to recognize variations and changes in some operations. For example, specific programming was carried out to avoid sending multiple alerts for a single event identified during a continuous operation.

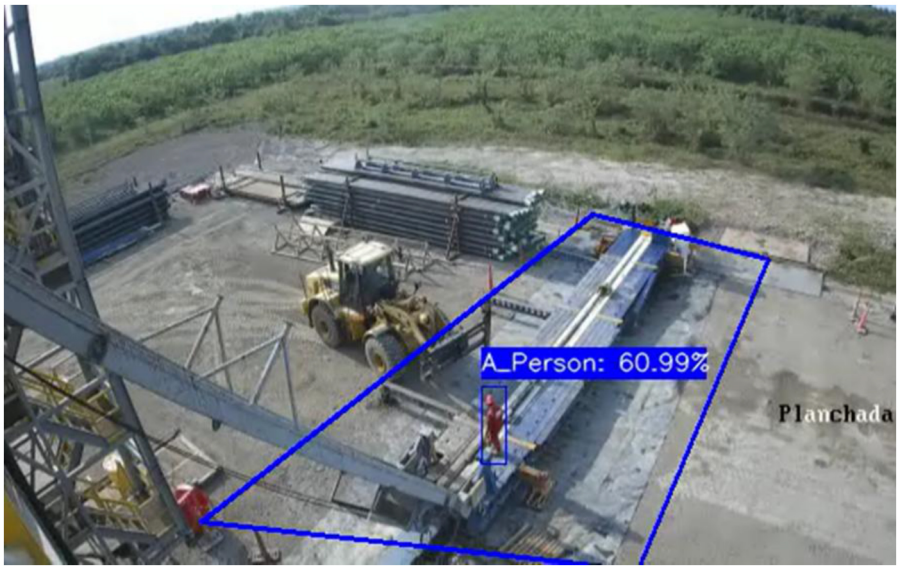

Figure 3—Worker exposed to moving mechanisms - Image of video analytics model for detection people, captured by the system.

Figure 4—Inappropriate position for the task – risk of falling - Image of video analytics model for detection people, captured by the system.

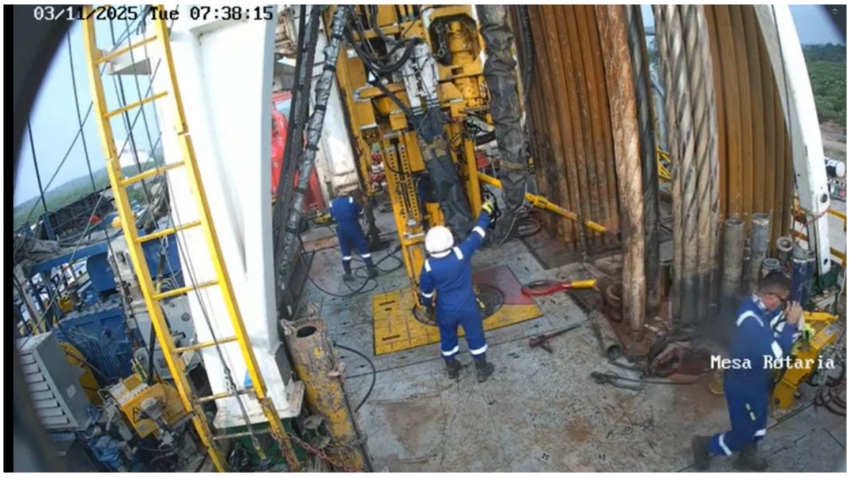

Figure 5—Staff not wearing helmets - Image of video analytics model for detection people, captured by the system.

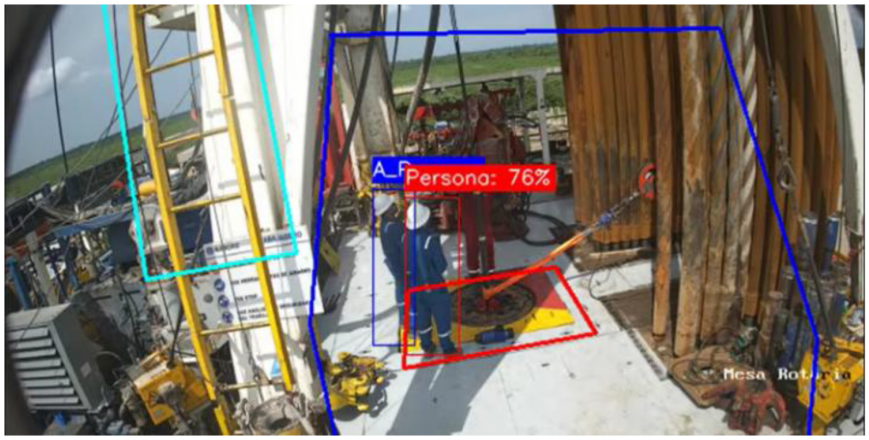

Figure 6—Workers exposed on the Line of fire (Sling under tension) - Image of video analytics model for detection people, captured by the system.

Evaluation of model information and process management

The administration of all information generated by the system is consolidated in a database that collects all data and classifies it by alert type, identified work site, and work shift during which the event occurs. This allows the different variables are evaluated, their features, and trends to be monitored by a dashboard. their behavior and trends, to have a management tool that allows visualization of the different alerts recorded, which ones are most frequently repeated and have an impact on the operation, and the times at which each of these alerts is recorded. This allows statistical analysis to be performed to generate complementary action plans to reinforce prevention activities in the workplace.

One of the highlights video aspects of this prevention model, which has been part of the success of this prevention strategy, relates to the interventions carried out with personnel after alerts are reported for unsafe behaviors or situations detected. The philosophy defined for addressing personnel and generating awareness processes that impact the development and strengthening of an HSE culture of prevention it's not to generate "punishment" or reproval for the unsafe behaviors that were. The objective of carrying out interventions through the information that HSE video analytics provided to the operational process was focused on reviewing occupational health and safety programs, reinforcing concepts, improving the ability to identify hazards in the workplace, better analyzing the risks of these activities, reviewing the controls needed to perform an activity safely, verifying the correct application of rules of life at work, which for GeoPark are the SOS (Standard Operational Safety) guidelines for the task observed by the cameras, and obtaining feedback from personnel on how to improve and ensure an activity that, if not ensured and controlled, could result in injury to people.

The system generates information through the dashboard, where data is classified to identify the different alerts recorded, the number of events detected, and trends by events, visualizing those that have had the greatest impact in the video analytics. This allows for statistical analysis of this information to review the effectiveness of controls, establish alternatives for adjusting intervention activities, and prioritize prevention activities.

Figure 7—Dashboard used for system monitoring by Axure Technologies - GeoPark Contractor.

Through the implementation of monitoring by cameras with artificial intelligence (AI), GeoPark, in two drilling rigs and one workover rig, has been able to identify around 6,064 effective alerts generated by the HSE video analytics system, of which 395 events in which corrective actions were implemented in real time to ensure the activity, 306 alerts in which unauthorized personnel were detected in restricted areas, where immediate controls were implemented, 5,400 alerts detecting people in the ZONE - No GO Zone, and

19 alerts with potential risk of injury to people, where the Authority to Stop Activity (ADA) was applied. These actions prompted the implementation of proactive measures, with 587 prevention workshops held to reinforce safe habits and behaviors among[3] all direct and indirect employees who perform tasks in our drilling operations that are normally imperceptible to the human eye.

Impact of the project on KPIs – HSE performance

The implementation of AI solutions has impacted on the reduction of the injury frequency rate (IFI) in GeoPark's drilling operations compared to the last five years, where this indicator has been reduced by 25% compared to the previous year. This same situation is reflected in the recordable incident rate, where a 50% reduction in restricted work incidents (TRIR) was observed for the 2025 period compared to the previous year. In terms of the variations in behavior observed in the last quarter of 2025[4], during the 24-hour workday, there was a 16% decrease in alerts during the morning shift. and similarly, this decrease was reflected in the afternoon work shift by 12%, showing an improvement in staff behavior due to the impact of task supervision through AI camera monitoring, which reflects positive aspects in strengthening the HSE culture where staff are adjusting their work practices to the standards and guidelines established to perform work safely.

Conclusions and forward plan

Health and safety are fundamental and strategic values for efficient operations in the oil and gas industry. It is a priority to apply good practices at work that contribute to maintaining safe environments for workers. Effectively implementing occupational health and safety management systems allows for a preventive approach, promoting self-care among workers and contributing to the implementation of safe practices that strengthen the culture of safety in operations. Preventing incidents at work is a constant for all organizations, and maintaining good HSE performance is one of the industry's challenges. Given the incidence of workplace accidents and the likelihood of their occurrence in drilling and workover operations, successful organizations are not measured by the value of their sales and assets. They are evaluated holistically, considering their long-term sustainability indicators, where safety has a special value at the core of the business plan.

As with all processes and activities in general, the development of technologies leads to new risks that must be constantly identified and evaluated by organizations to ensure that their impacts are under control. This adds new challenges to organizations in terms of the operational, safety, and environmental aspects in which the industry's activities are carried out. However, considering that the rise of technologies such as artificial intelligence is being used to improve and reinforce processes in which positive results can be effectively obtained in the execution of activities, providing support and solutions to specific needs, with a significant impact on the comprehensive management of organizations.

One of the main challenges for organizations currently is to strengthen the safety culture in their operations. Although this can be perceived by the way workers perform their jobs following standards and procedures for the execution of activities and the work environment present in their workplace, in general terms, the evaluation of culture is associated in some cases with the performance of lagging indicators defined by the organization. However, it cannot be concluded that the company's LTIR or TRIR performance indicates the degree of safety culture within a company. What can be associated with cultural issues, based on the premise that workers have a clear commitment to performing their activities safely, is the involvement of all levels of the organization in safety issues, adopting all initiatives and strategies that lead to improving and strengthening safety conditions in the environments where operations are carried out, the ability of everyone to communicate aspects that need improvement at work, as well as the application of observations and opportunities for improvement at different levels that derive from the application of safety management tools.

When looking for information on safety performance statistics for the industry, a reliable source such as the IOGP (International Oil and Gas Producers Association) in its IOGP safety performance indicators – 2024 data, has figures that reflect incident indicators and their impact on oil and gas operations. Among these, it is worth mentioning that of the 4.159 billion man-hours worked, the fatal accident rate (FAR) was 0.77, with a 20% increase in fatal events compared to the previous period. In this regard, it is important to note that 31% of fatal events occurred in operations involving being struck by, falling from height, being caught between, or dropped objects, which are part of the risks associated with drilling and workover operations and are linked to the management of the ZONE // No Go Zone // Line of Fire network. In terms of lost time incidents, the IOGP report shows that the LTIR (Lost Time Injury Rate) indicator was 0.81, with the following data of interest extracted from the safety performance indicators[5]:

- Caught in, under, or between (excluding dropped objects) accounted for 189 cases, 20% of the total (145 cases, 19% of the total in 2023).
- Struck by (not dropped object)' accounted for 148 cases, 16% of the total (126 cases, 17% of the total in 2023).

When reviewing these figures, it is important to consider the impact these events have on operations, where the severity of injuries to people is high and the probability of occurrence is very significant, considering the results of the lagging indicators illustrated (FAT, LTIR, and TRIR). This summary shows that events such as Caught in, under, or between, and Struck by, which are associated with Red ZONE // No Go Zone // Line of Fire have been incorporated into the HSE video analytics variables and aims to improve controls for these specific activities in order to establish mechanisms to ensure these operations are supported by the monitoring and supervision of activities through AI cameras, which for our operation is effectively mitigating these risks by applying real-time interventions and reinforcing good practices among the work team, support in the supervision of the operation, all of which contribute to the assurance of activities.

The study highlights that the use of video analysis tools on drilling operations for detecting alerts for lack of Personal Protective Equipment (PPE) and Red Zone violations, Inadequate operational controls and unsafe actions are situations that must be addressed immediately to prevent the risk from occurring.

The implementation of AI solutions has had a profound impact on reducing the injury frequency rate (IFI) in GeoPark's drilling operations compared to the last five years, where this indicator has been reduced by 25% compared to the previous year. This same situation is reflected in the recordable incident rate, where a 50% reduction in restricted work incidents (TRIR) was observed for the 2025 period compared to the previous year. In terms of the variations in behavior observed in the last quarter of 2025, during the 24-hour workday, there was a 16% decrease in alerts during the morning shift. and similarly, this decrease was reflected in the afternoon work shift by 12%, showing an improvement in staff behavior due to the impact of task supervision through AI camera monitoring, which reflects positive aspects in strengthening the HSE culture where staff are adjusting their work practices to the standards and guidelines established to perform work safely.

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