REMOTE MANAGEMENT AND ARTIFICIAL INTELLIGENCE: MITIGATION OF TRANSACTION COSTS AND OPPORTUNISM IN CONSTRUCTION WORKS

Construction projects exhibit high transaction costs driven by monitoring needs and opportunism under information asymmetry. Yet intensive face-to-face inspection can itself become a conflict trigger by fostering perceptions of policing and unfairness. We analyze two field cases of AI-enabled remote monitoring (Optikon) as a depersonalized governance mechanism that shifts enforcement from interpersonal confrontation to auditable digital evidence. Using six months of productivity and financial data (>170 samples) and over 13,000 behavioral records, we document reduced conflict latency and improved compliance outcomes following implementation. In a mining contract, helmet compliance increased from 9.54% to 73.60% within one week, consistent with an “awareness trigger” followed by evidence-based managerial intervention. In a dam project monitored fully remotely, man-hour turnover reached USD 54.75/HH, exceeding national benchmarks. We discuss boundary conditions related to contestability, privacy safeguards, and algorithmic control.

1. Introduction

The management of large engineering projects faces the ongoing challenge of balancing production costs with the costs of ensuring that the contract is fulfilled. Inefficiency in this balance often results in disputes, contractual amendments, and lost productivity. To understand how technology can mitigate these problems, it is first necessary to dissect the economic nature of these costs. This study contributes to conflict management by exploring how depersonalized monitoring can mitigate opportunism while potentially reducing the friction typical of human enforcement.

1.1. Definition of Transaction Costs

The total cost of any economic activity is not limited to the costs of transformation (inputs, labor and equipment). It also includes Transaction Costs (TC), a concept introduced by Coase (1937) and expanded by the New Institutional Economics. TCs represent the resources consumed to plan, adapt, and monitor the execution of tasks under varying governance structures.

According to Williamson (1985), these costs arise due to the interaction of three behavioral and environmental factors:

1. Bounded Rationality: The inability of agents to predict all future contingencies in a complex contract.
2. Uncertainty: The variability inherent in the business environment.
3. Opportunism: The tendency of agents to act for their own benefit, often shrewdly, when information asymmetry allows.

Therefore, the greater the uncertainty and the risk of opportunism, the greater the costs incurred to monitor and ensure compliance with the agreement

1.2. Transaction Costs in Engineering

In the context of civil engineering and industrial assembly, Transaction Costs manifest themselves acutely. The technical complexity and variability of the construction site create the perfect environment for

conflicts to arise. According to the Standish Group (2001), 45% of projects exceed the budget and 63% the contractual term, a direct reflection of the high governance costs required to correct deviations during execution.

Traditionally, the sector's response to this risk of opportunism (such as low productivity or non-compliance with safety standards) is the intensive allocation of "inspectors": field engineers, safety technicians, and pointers. However, this governance structure based on direct human supervision is, paradoxically, a source of conflict. Constant face-to-face inspection creates interpersonal friction, perception of "policing," and resistance on the part of the workforce, which drives up organizational friction costs.

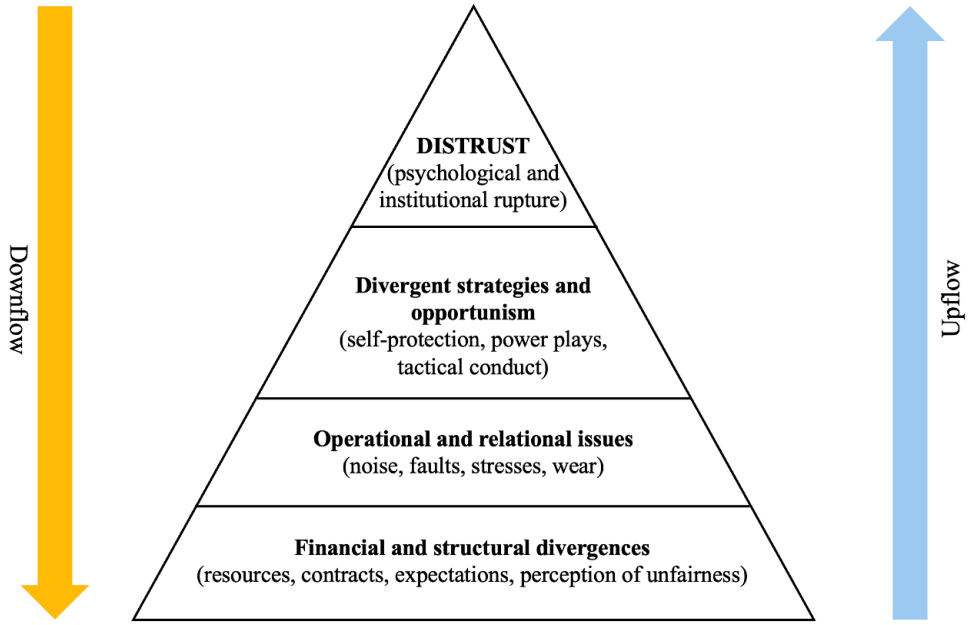
This article proposes that the reduction of the face-to-face inspection framework (reduction of people), replaced by remote monitoring systems via Artificial and Human Intelligence, acts as a superior governance mechanism. The technology depersonalizes control, reducing interpersonal conflict and information asymmetry, resulting in the effective decrease of the project's total Transaction Costs.

1.3. The Pyramid of Distrust and Organizational Erosion

The efficiency of governance in engineering projects is often compromised by a psychosocial phenomenon described as the Pyramid of Distrust (ALMEIDA JR.; SILVA, 2025).

Figure 1

Representation of the Pyramid Model of Distrust.



Source: Almeida Júnior e Silva (2025).

This model postulates that the rupture of institutional trust is not an isolated event, but a process of structural deterioration where doubt is established as the primary interpretative filter of all operational interactions.

In the work environment, the premise of a priori non-compliance — characteristic of the descending flow of the pyramid — triggers what is defined as "cognitive rumination". This mental state, fueled by ostensible human surveillance, replaces technical cooperation with strategies of self-protection and power games, drastically increasing relational friction. As distrust rises, the organization can reach a stage of "organizational schizophrenia", characterized by parallel narratives and conflicting agendas that inflate the unit cost of each delivery, making the system progressively cumbersome, expensive, and inefficient (FUKUYAMA, 1995; KRAMER, 1999).

The introduction of a digital audit via AI proposes to interrupt this cycle. By depersonalizing control and replacing the subjectivity of the human "mental filter" with objective digital evidence, technology acts at the base of the pyramid, mitigating the perception of injustice and eliminating the need for excessive safeguard

mechanisms. Thus, the compliance and productivity gains analyzed in this article result from the restoration of data-driven governance, which preserves the social capital of the operation by mitigating the erosive effects of distrust.

2. Why is investing in security important?

Every year, millions of workers suffer accidents or develop work-related diseases, generating significant human, social, and economic impacts. Estimates from the International Labor Organization (ILO) indicate the annual occurrence of about 360 million non-fatal accidents and 2.3 million deaths worldwide, with Brazil consistently ranking among the countries with high absolute records due to sectors like civil construction and mining. For project governance, these indicators represent more than operational risks; they are a primary source of Transaction Costs (TC), as accidents generate direct and indirect costs that compromise contracts, reputation, and ESG compliance.

In this context, intelligent monitoring via AI allows for constant and objective auditing, reducing underreporting and providing evidence for intervention before accidents occur. This approach replaces punitive logic with a preventive culture, reducing information asymmetry and expanding control capacity without the friction of constant human surveillance. By depersonalizing enforcement, the technology ensures that safety compliance is based on objective data, preserving the social capital of the operation.

From a financial perspective, in a medium-sized operation with an estimated annual payroll of R$ 30 million, the systematic reduction of incidents allows the optimization of tax components such as the Accident Prevention Factor (FAP) and Occupational Environmental Risk (RAT). The estimated annual savings can reach approximately R$ 700 thousand in these tax components alone. When including avoided costs such as indemnities, operational interruptions, and staff turnover, the consolidated potential gain can exceed R$ 1 million per year, converting compliance into a measurable and sustainable economic advantage.

3. Continuous evolution of intelligent monitoring

The main advantage of using artificial intelligence in security management lies in its ability to continuously evolve. Solutions that were initially limited to detecting the absence of helmets began, in a short

time, to recognize other relevant elements and behaviors, such as the use of gloves and vests, improper use of cell phones, falls, access to restricted areas, and even productivity indicators. This expansion of functionalities significantly increases the range of monitoring and reduces the need for additional manual interventions.

In addition, direct integration with physical devices, such as turnstiles, sirens, and reflectors, enables automatic and immediate responses to critical events. With this, the operation gain's reaction speed, reinforces the security of the enterprise and reduces the dependence on face-to-face inspection as the main control mechanism.

This set of advances sustains a permanent cycle of improvement and contributes to raising occupational safety standards. By expanding the capacity for prevention, standardization and traceability, the technology also helps to reduce the distance that still separates Brazil from the best international indexes.

Another relevant benefit is the maximum use of the existing infrastructure. With a single camera, it is possible to simultaneously carry out compliance checks with security standards, time and attendance control, facial recognition and productivity analysis, optimizing the investment already installed in the project.

Finally, the automation of alerts and reports, distributed by dashboard or messaging app of choice, accelerates decision-making, reduces latency in responding to risks, and reduces dependence on manual actions in the management process, making monitoring more consistent and scalable.

4. Methodology

To validate the hypothesis that the technology reduces costs by minimizing direct human intervention, two application scenarios of the Optikon system (Computer Vision and AI) were analyzed:

Study A (Focus on Behavior): Contract for earth movement and infrastructure in a mining plant in Minas Gerais. The dataset of this study was built through the processing of video streams from 5 connected cameras, covering living and production areas (carpentry). In the consolidated reports for the first two weeks of November 2025 alone, more than 13,000 records of interactions, security, and facial microexpressions were processed. All behavioral and biometric data collection followed strict ethical and legal data protection protocols, the compliance details of which are further elaborated in the results section of this study.

Study B (Focus on Productivity): Construction of a dam for agricultural purposes, fully monitored by remote systems, with a focus on physical and financial efficiency. The follow-up took place over six months, before and after the implementation of the remote monitoring system, with financial data collection and productivity analyses based on more than 170 samples.

4.1 Governance Logic and Data Quality

The transition from human to digital oversight in these studies follows a specific logic to ensure legitimacy and reduce friction:

- **Objective Evidence as a Common Ground:** Instead of subjective "policing," the system establishes a shared factual base for managers and workers.
- **Contestability:** AI outputs are treated as contestable evidence rather than absolute truths. This allows managers to use data (like the hourly cell phone logs) to investigate root causes—such as operational bottlenecks—rather than merely enforcing punishment.
- **Ethical Compliance:** All behavioral and biometric collection followed strict protocols and the General Data Protection Law (GDPR). Data was processed in an aggregated manner to preserve worker dignity and mitigate individual exposure.

5. Results: Fewer Intermediates, less opportunism.

The addition of intelligent remote surveillance generated complementary results in both environments, proving the reduction of transaction costs via conflict mitigation.

5.1 The Depersonalization of Enforcement (Study A - Mining)

The classic conflict on site occurs in the direct collection between inspector and worker. By delegating the audit to AI in the mining project, the charge became based on objective data, reducing resistance.

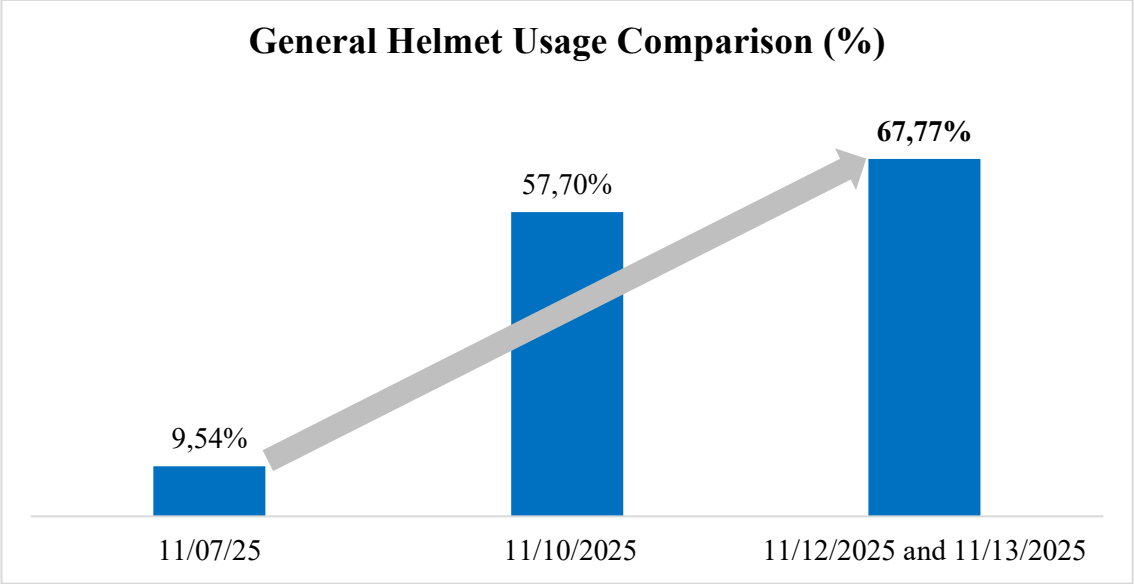
The baseline measurement, carried out on 11/07/2025, revealed a compliance of only 9.54% in the use of helmets in the traffic area. It is essential to highlight that, as this is a transition zone where the use was not

mandatory, this indicator was used to measure the preventive habit instead of mere coercion. The premise is that the commitment to safety must manifest itself intrinsically, and not just under obligation.

With the implementation of remote monitoring and the introduction of impersonal feedback — without any addition of human inspectors on site — compliance rose to 57.70% in just three days (11/10/25), stabilizing at 67.77% on 11/13/25.

Figure 2

Helmet Wear Compliance



Source: OPTIKON Weekly Report Case Study A (Exxata, 2025)

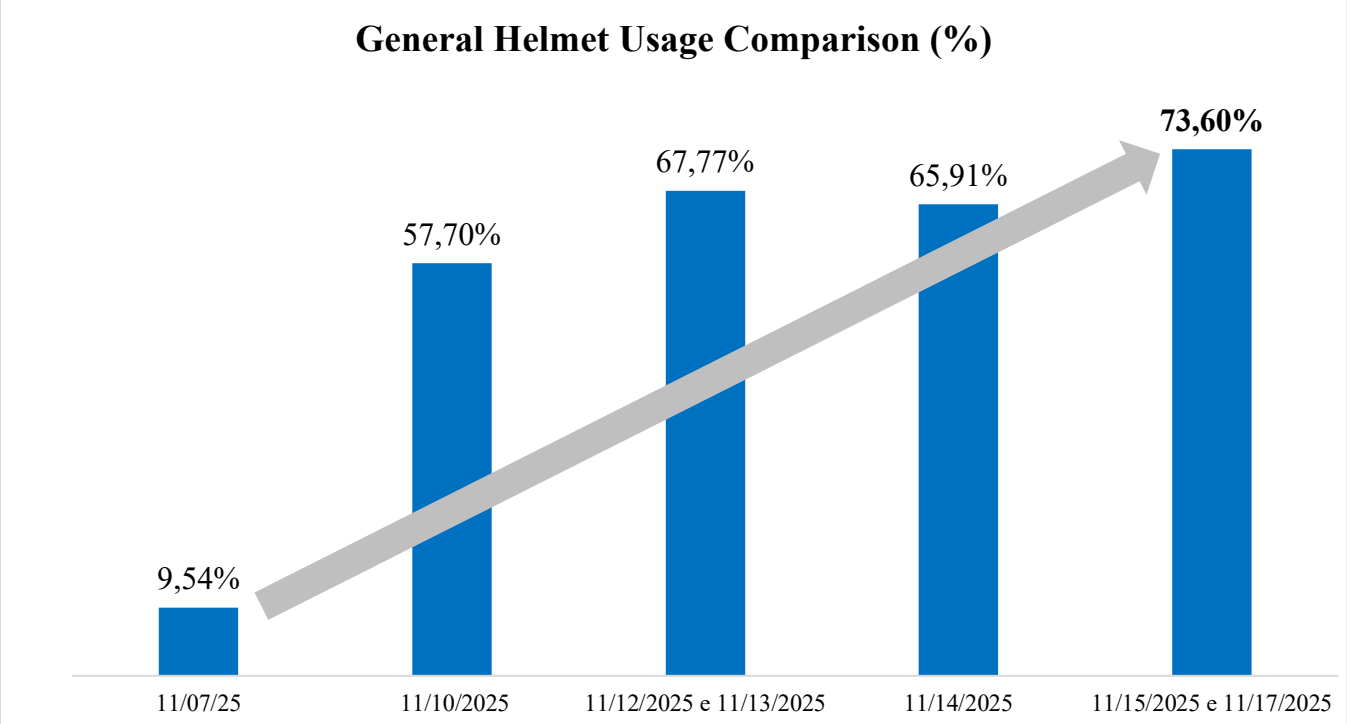
It is imperative to note that the exponential growth in compliance in the first days (from 9.54% to 67.77%) was not only due to direct punitive interventions, but to the annulment of information asymmetry. Upon being formally informed about the implementation of the digital audit, employees internalized the presence of monitoring. Management used this data to reinforce the safety culture, allowing the safety technician and contract manager to replace overt oversight with evidence-based communication. Thus, the simple knowledge of the presence of an objective and irrefutable system induced an immediate behavioral change, where the employee starts to self-regulate, knowing that the 'shadow zone' of human inspection has been eliminated.

This drastic change in behavior in just four indicates that remote digital surveillance works as an initial awareness trigger, proving to be more agile than traditional human surveillance. However, it is important to note that this technology does not operate in isolation; Its value lies in serving as a decision support tool for safety managers and technicians. Although the presence of the system reduces the cost of accidents and the wear and tear of daily confrontation, it represents the beginning of a governance process.

The full effectiveness of the solution is observed in the following days, when the direct interventions of decision makers, now based on accurate data, boost compliance rates to even higher levels, reaching 73.60% of average usage compliance on November 15 and 17, transforming transparency into a sustainable operational culture.

Figure 3

Helmet Wear Compliance



Source: OPTIKON Weekly Report Case Study A (Exxata, 2025)

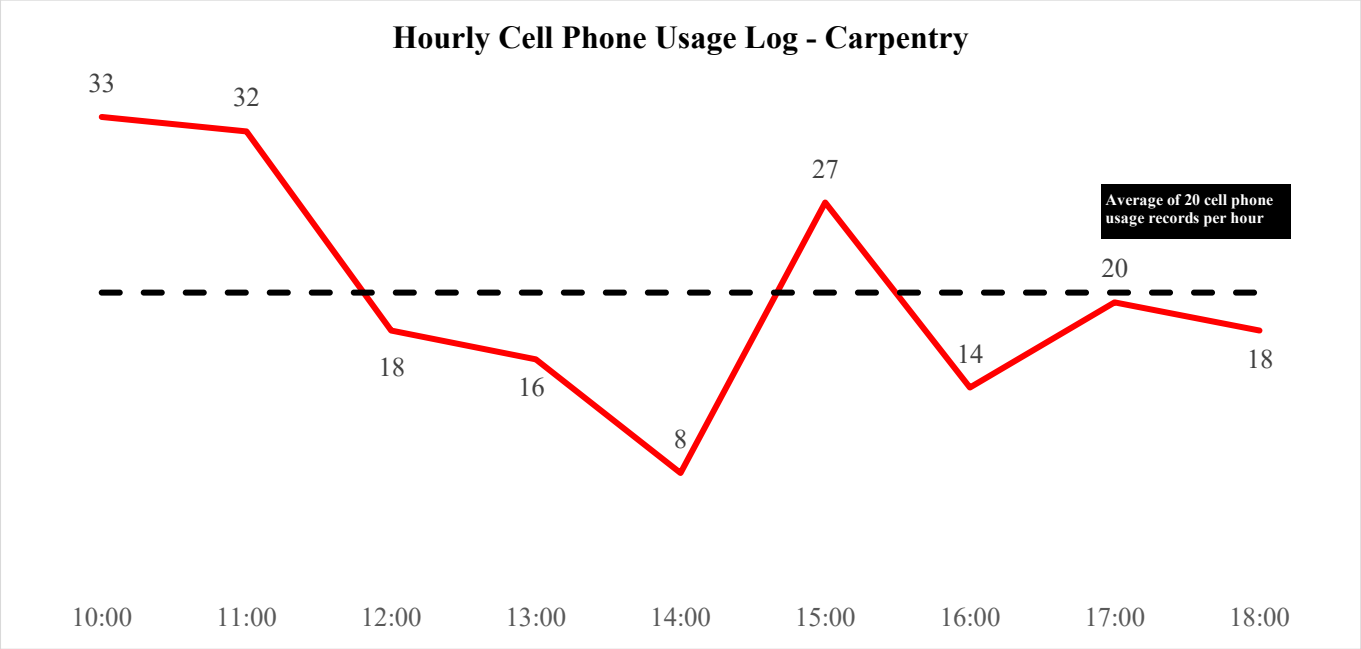
5.2 Objectivity in the Operational Discipline (Study A - Mining)

Disputes over productivity are common sources of cost, often derived from time spent in negotiations based on subjective perceptions. AI removes this ambiguity by providing context and hard data for operational diagnostics. On 11/14, the system identified that the use of cell phones in the production area (Carpentry) was 30.46%, while in the living area it was 15.50%.

From the hourly records, the manager can identify peaks in utilization and act surgically. As observed in safety compliance, this detailed mapping serves as a basis for future interventions, allowing management to act preventively on productivity deviations before they turn into interpersonal conflicts or consolidated financial losses.

Figure 4

Record of Cell Phone Usage by Hour – Carpentry Area



Source: OPTIKON Weekly Report Case Study A (Exxata, 2025)

The analysis of Figure 3 reveals peaks of utilization at 10:00 a.m. and 11:00 a.m., reaching 33 and 32 records, respectively. Having this visibility allows the manager to investigate whether these peaks coincide with operational bottlenecks or periods of forced idleness, transforming what would be a subjective discussion into a root cause analysis.

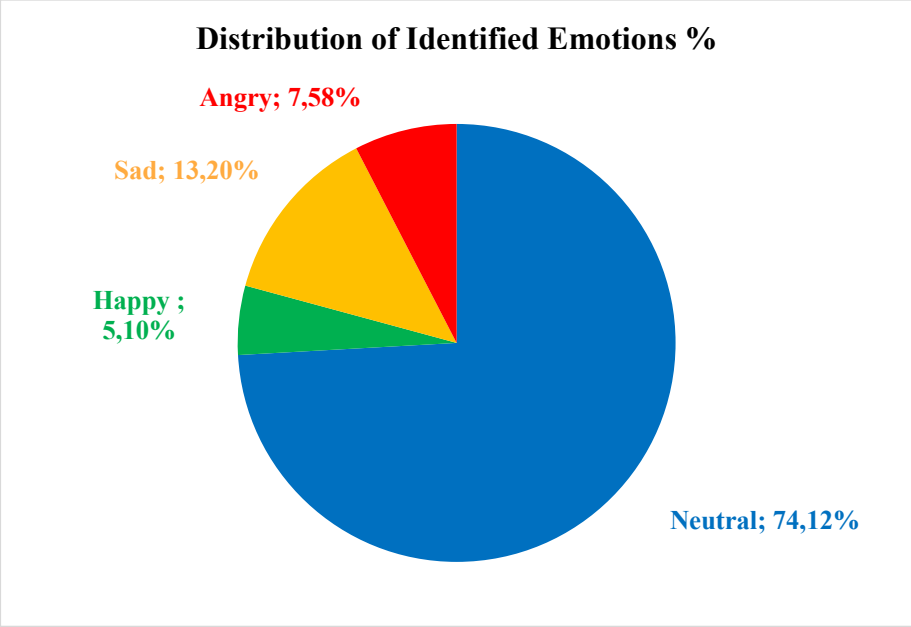
5.3 Non-Invasive Climate Monitoring (Study A - Mining)

The presence of external agents to assess the organizational climate can generate distrust among employees. In this study, the reading was performed from camera records, and the emotions were inferred by the AI model according to the methodology described in the reports.

On 11/18, the report points to a predominance of neutral ratings (74.12%), with "Sadness" varying between 12.60% and 14.20% over the period analyzed.

Figure 5

Emotions Identified in Employees

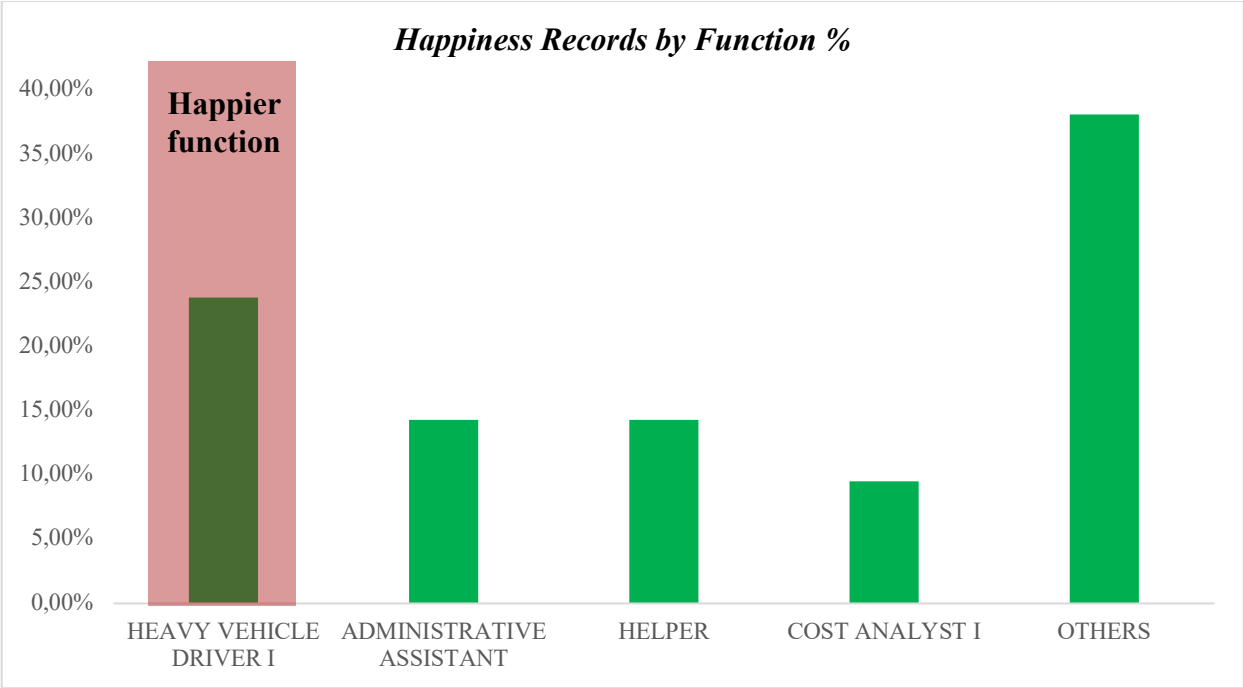


Source: OPTIKON Weekly Report Case Study A (Exxata, 2025)

It was also observed that the function of "Heavy Vehicle Driver" consistently presented the highest records classified as happiness

Figure 6

Distribution of happiness records by function



Source: Monthly Monitoring Report of Case Study A (EXXATA, 2025).

These results can be used as screening indicators to direct leadership/HSE attention and prioritize preventive actions on more sensitive fronts and functions. However, such inferences do not constitute an individual diagnosis, nor do they guarantee, by themselves, the occurrence of conflicts or stoppages; They serve as an early signal that must be interpreted in conjunction with the operational context (working hours, productivity, incidents, absenteeism, turnover) and validation with stakeholders.

It is important to note that the collection and processing of biometric and behavioral data were conducted in strict compliance with the General Data Protection Law (GDPR). All employees involved were previously informed about the monitoring for safety and productivity purposes, formalizing their consent through consent forms and contractual clauses for the assignment of use of image and voice.

In addition, sentiment analysis was treated in an aggregated manner by functions, aiming at improving the work environment and mitigating conflicts, ensuring that technology acted as an impersonal governance tool, and not as an instrument of individual exposure, thus preserving the dignity and privacy of workers in the work environment.

6. Discussion: Efficiency as proof of cost reduction

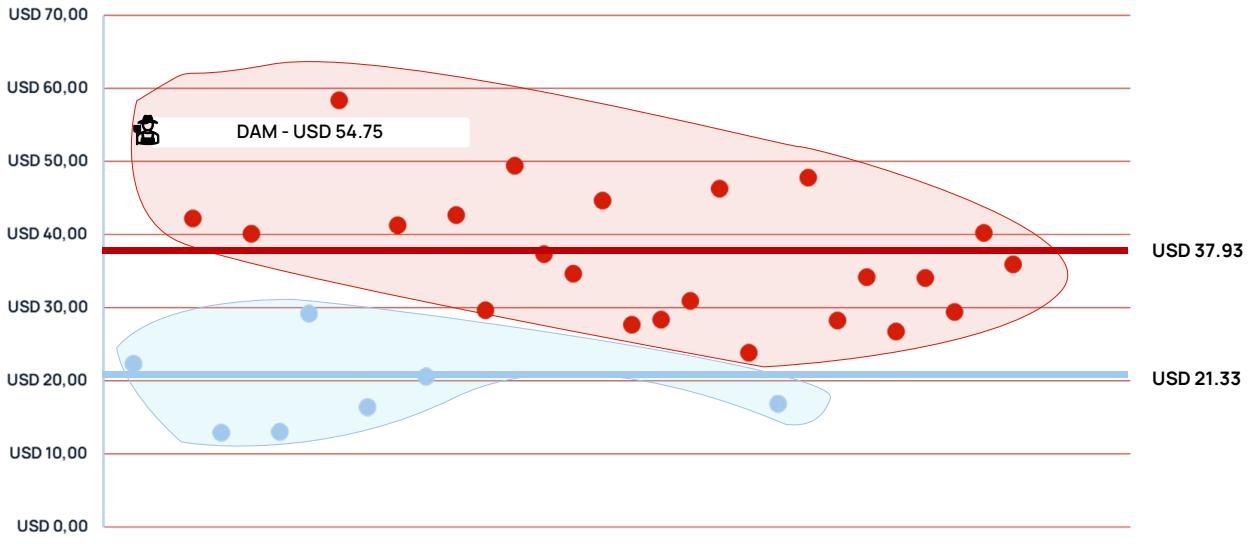
The joint analysis of the two scenarios highlights the versatility of the solution in different engineering contexts. While Study A focuses on transforming the safety culture, Study B (Dam) validates the feasibility of disruptive management models. This project stands out for being the first dam work monitored 100% remotely, operating with zero engineers permanently allocated to the site.

The replacement of the heavy structure of face-to-face inspection with digital audit systems allowed the technology, already in the first month of operation, to ensure a man-hour (HH) turnover of USD 54.75/HH. This value is significantly higher than the market parameters:

- 44% higher than the national average of USD 37.93.
- More than double the average productivity of the sector (USD 21.33) measured by CBIC and IBGE.

Figure 7

Construction Productivity in Brazil x Case Study



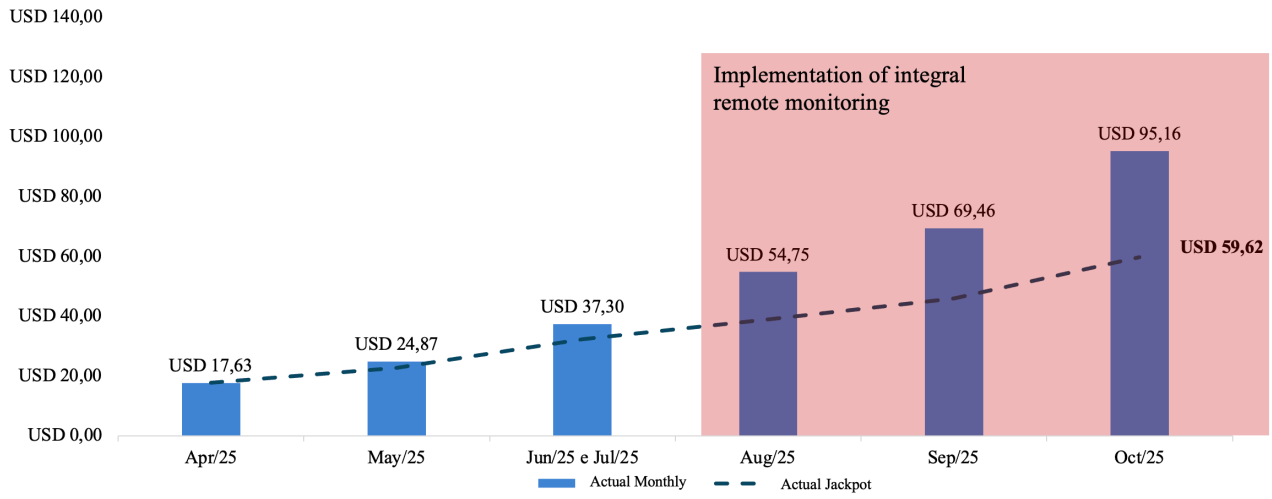
Source: Monthly Monitoring Report of Case Study B EXXATA, 2025 and CBIC and IBGE (2024).

The continuous growth in productivity, observed especially after the implementation of integral remote monitoring in August 2025, demonstrates that the elimination of the fixed costs of face-to-face governance has been converted into direct production. By removing the need for engineers in the field, the project not

only reduced transaction costs and organizational friction but demonstrated that the transparency of remote data is sufficient to ensure physical-financial execution with excellence.

Figure 8

HH Billing Case Study A



Source: Monthly Follow-up Report of Case Study B (EXXATA, 2025).

Taken together, the cases demonstrate that the replacement of face-to-face auditing with objective digital mechanisms meets multiple strategic objectives: from the consolidation of the safety culture via behavioral compliance to the achievement of maximum physical and financial efficiency.

7. Study Limitations

The results presented in this study derive from the analysis of two specific case studies, which limits the direct generalization of the findings to other contexts of the construction industry. In addition, the application of the analyzed technology depends on minimum infrastructure conditions, such as power availability, network connectivity, and proper camera placement, factors that can vary significantly between construction sites.

Any connection instabilities and temporary interruptions in data transmission may impact the continuity of monitoring, although they have not compromised the identification of the trends analyzed. Finally, the observed effects refer to delimited periods after the implementation of the system.

8. Conclusion

This article demonstrates that the application of remote monitoring systems based on Artificial Intelligence contributes to the reduction of Transaction Costs in construction sites by introducing objective governance mechanisms, mitigating opportunistic behaviors without compromising production efficiency.

Despite the positive results observed, it is important to highlight that the analyzed technology is still a recent solution in the context of heavy engineering. Although it presents clear signs of growing acceptance in the market, its adoption occurs progressively and remains conditioned by institutional factors, such as the need for contractual adequacy, organizational maturity, available technological infrastructure, and cultural and regulatory aspects of the work environment.

The joint analysis of the case studies shows that the reduction of the dependence on face-to-face inspection – reaching the total absence of resident engineers in the case of the dam – did not result in a loss of governance, but in greater accountability. A sustained increase in security compliance and significant gains in financial efficiency were observed. By increasing transparency and reducing information asymmetry, the OPTIKON system allowed transactions to take place with lower friction costs. This reinforces the understanding that the future of complex contract management lies in replacing face-to-face auditing with objective digital mechanisms, where the tool acts as the initial compliance trigger and the manager assumes a strategic leadership role guided by data and free of interpersonal bias.

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