Whitepaper

Multi-level Performance Monitoring of Equipment using just 2 data-points in Industry 4.0

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Executive summary

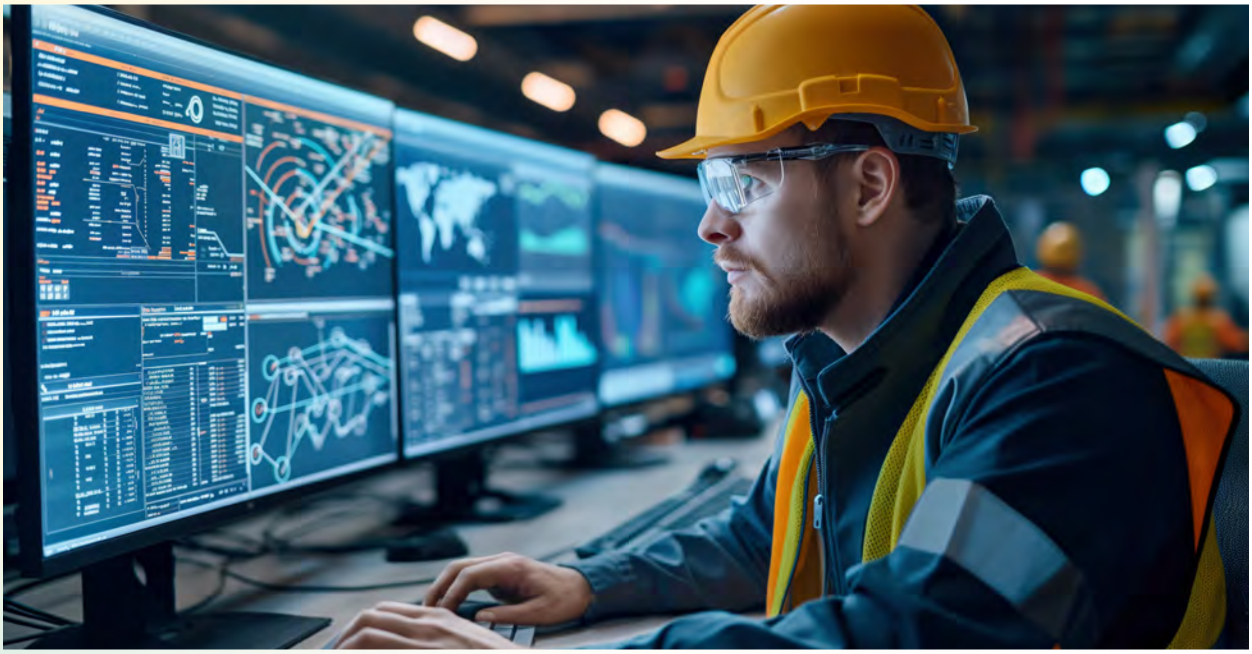
Multi-level Performance Tracking & Monitoring of Equipment which helps and benefits the customer to:

- Get real-time insights
- Efficiency amplification by being able to monitor more than 25 Equipment KPIs using just 2 data points
- Helps to take corrective actions on time
- Significantly reduce manual effort and human error

In today's fast-paced world, businesses are constantly striving to reduce costs, improve operational efficiency, and enhance performance. The first step is to monitor and track the equipment performance, which is crucial in ensuring smooth and efficient operations. This paper discusses the benefits of multi-level performance tracking and monitoring of equipment for customers, focusing on the advantages it offers in terms of real-time insights, efficiency amplification, timely corrective actions, and reduction in manual effort and human error.

By tracking more than 25 equipment KPIs with minimal cost and effort, businesses can identify trends, patterns, and potential areas for improvement. Continuous monitoring and reporting and a proactive approach to maintenance and troubleshooting help businesses prevent equipment failures, minimize downtime, and improve operational efficiency.

Automating the processes mentioned above with minimal investment helps businesses dedicate their time and capacity to innovation rather than spending it on monotonous manual activities.



Overview of the topic

The mining, construction, and manufacturing industries rely heavily on equipment trips to track operations and performance. Each trip is associated with multiple key performance indicators (KPIs) essential for evaluating efficiency and productivity. This paper aims to demonstrate that by capturing just two data points from all the equipment, each trip can be accurately tracked, and the necessary KPIs can be computed.

Equipment trips are common in these industries, as machinery is constantly moving and performing tasks. Tracking these trips accurately is crucial for monitoring the productivity of the equipment and the overall operations. Additionally, each trip is linked to various KPIs that provide valuable insights into the equipment's performance and the operations' efficiency.

By capturing just two data points from all the equipment, i.e., equipment location and status, it is possible to track each trip accurately. These data points can be used to calculate important KPIs such as trip duration, distance traveled, fuel consumption, and idling. By efficiently capturing and analyzing this data, businesses can identify areas for improvement, optimize equipment usage, and ultimately increase productivity.

The ability to capture and compute essential KPIs with just two data points from all equipment offers a streamlined and efficient approach to tracking equipment trips and evaluating performance. This paper highlights the importance of leveraging data analytics in these industries to improve decision-making, enhance operational efficiency, and drive business success.

The problem statement

The lack of a fully automated systematic method for tracking trips and production levels has been a significant challenge in the mining, construction, and manufacturing industries. Reliance on manual communication with operators has led to inefficiencies and potential inaccuracies in data management and production monitoring. This outdated approach has hindered companies' ability to make informed decisions in real time, as crucial data is only available at the end of the shift.

One of the fundamental issues companies face in these industries is the lack of real-time information during operations. Without access to up-to-date data on trip tracking and production levels, companies cannot optimize their processes and maximize efficiency. Manual communication with operators is not only time-consuming but also prone to errors, leading to potential discrepancies in the data being collected.

Furthermore, the reliance on manual methods for data management and production monitoring can result in missed opportunities for improvement and cost savings. With an automated system, companies can streamline operations, reduce downtime, and make data-driven decisions to enhance overall performance.

By implementing a fully automated systematic method for tracking trips and production levels, companies in the mining, construction, and manufacturing industries can improve their operational efficiency and competitiveness. Real-time access to KPIs will enable companies to identify bottlenecks, optimize workflows, and make proactive decisions to drive success.

The current situation in these industries highlights the urgent need for a low-cost, end-to-end solution to track and monitor essential key performance indicators (KPIs). Without a reliable and efficient system, companies risk falling behind their competitors, who have embraced automation and digitalization in their operations. Investing in a low-cost, end-to-end solution can help companies overcome these challenges and position themselves for success in an increasingly competitive market.

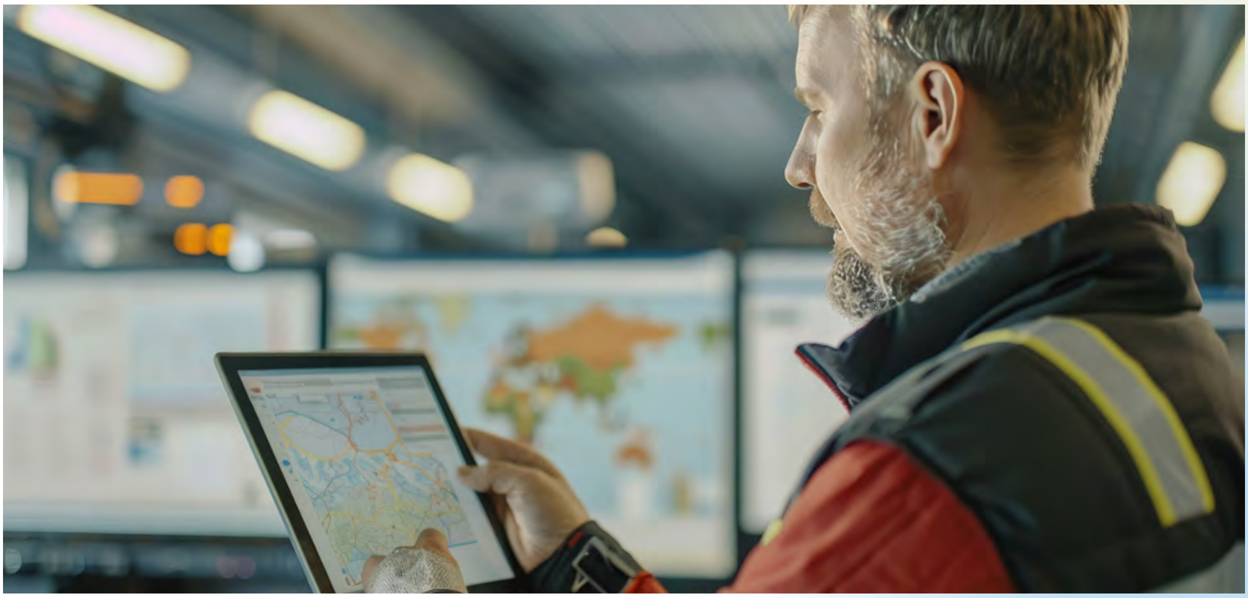
What is the solution?

The proposed solution entails implementing a basic edge gateway equipped with a GPS sensor. This setup will allow for the real-time capture of location coordinates, which will be streamed to the cloud in conjunction with the equipment engine's status (on/off). Focusing on these two specific data points, the solution aims to calculate the number of direct and derived KPIs while keeping hardware and software costs minimal and data packet sizes small.

The decision to prioritize the capture of real-time location coordinates and engine status is strategic. Real-time coordinates provide crucial location data, enabling precise tracking and monitoring of moving equipment. This information is essential for various applications, such as fleet management, asset tracking, and route optimization. Meanwhile, monitoring the engine status offers insights into the performance and health of the machinery. By combining these two data points, the solution can deliver comprehensive insights into the system's operations and performance.

The solution's efficiency lies in its ability to compute key KPIs in real time using the data collected from the GPS sensor and engine status. Real-time data analysis allows for immediate insights and actionable information, which is invaluable for making informed decisions, optimizing processes, and enhancing overall performance.

The solution offers a low-cost, streamlined, and effective data capture, analysis, and reporting approach. By focusing on real-time coordinates and engine status, it maximizes KPI reporting while maintaining cost-effectiveness and efficiency. This end-to-end solution provides the necessary tools to monitor, analyze, and optimize operations in real time, ultimately driving improved performance and decision-making.



Effective equipment management solution in detail

The solution for achieving the desired results involves collecting two key data points using an edge gateway installed on the equipment.

- The first data point is the location of the equipment, specified by its latitude and longitude coordinates.
- The second data point is the engine status of the equipment, which can be either Engine ON or Engine OFF.

Once these data points are collected at the edge gateway, they are streamed to the Data Lake at a defined frequency. With this raw data, key performance indicators (KPIs) are computed to analyze and evaluate the equipment's performance and status.

Collecting information on the equipment's location and engine status can give organizations valuable insights into its operations. This data can help monitor the equipment's usage patterns, identify anomalies or inefficiencies, and make informed decisions for optimization.

Overall, the process of collecting and analyzing these data points is crucial for improving the equipment's performance, ensuring its reliability, and maximizing its efficiency. By leveraging the power of data analytics, organizations can unlock the full potential of their equipment and drive continuous improvement in their operations.

The following section explains the derivations of the KPIs using the available raw data points:

Equipment engine status KPI derivation

The equipment status-related KPI derivations are explained below,

S.No.	Status	Logic
1	Running	Engine ON and Speed > 0
2	Engine OFF	Engine OFF
3	Idling	Engine ON and Speed = 0

Table 1: Engine Status Derivation

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Equipment activity derivation

The equipment in the field makes repeated trips, each involving a series of sequential activities. In general, loading equipment (e.g., excavator, loader) and transport equipment (e.g., dumper, tipper) work together to move various materials from a source to a destination. All such equipment activities are listed below, and the methodology used to identify each activity and its related KPI derivations is explained below.

S.No.	Activity	Logic
1	Queuing at Loading	• Transport Equipment inside the "Waiting Circle" of the Loading Point • Speed = 0
2	Loading	• Transport Equipment inside the "Loading Circle" of the Loading Point • Speed = 0
3	Loaded Travel	• Previous state is "Loading" • Transport Equipment outside of the "Waiting Circle" of the Loading Point • Speed > 0
4	Queuing at Unloading	• Transport Equipment inside the "Waiting Circle" of the Unloading Point • Speed = 0
5	Unloading	• Transport Equipment inside the "Unloading Circle" of the Unloading Point • Speed = 0
6	Empty Travel	• Previous state is "Unloading" • Transport Equipment outside of the "Waiting Circle" of the Unloading Point • Speed > 0

Table 2: Equipment Activity Derivation

The below illustrations explain the various activities of a trip.

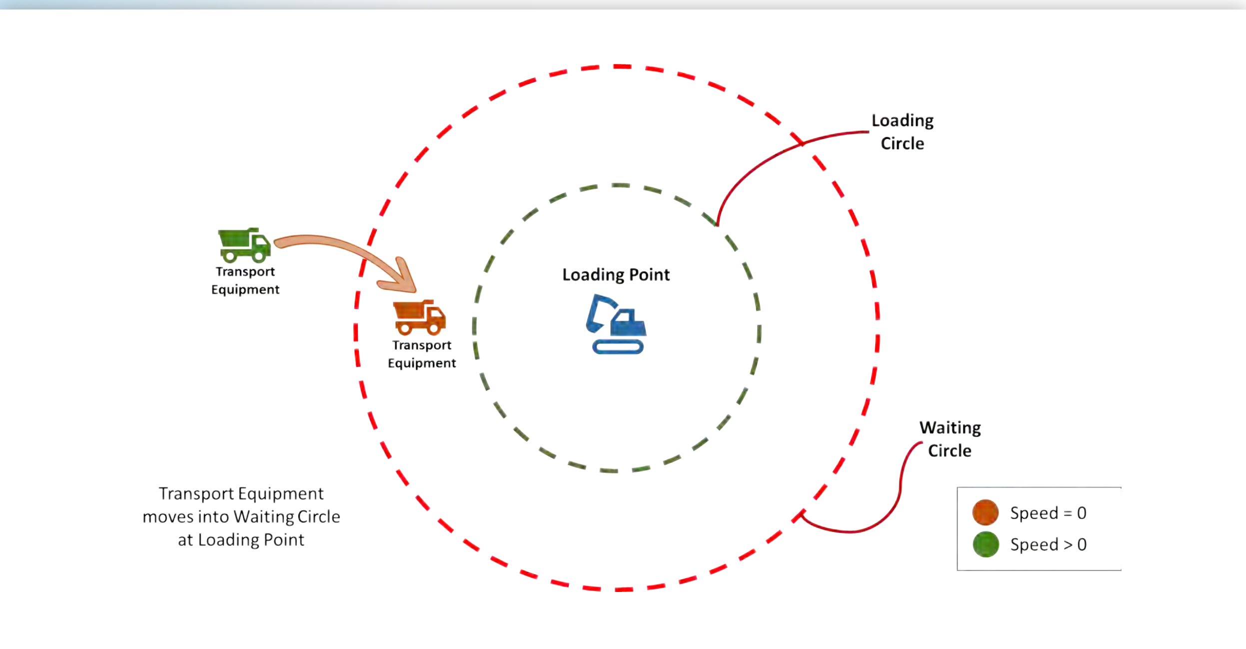

Figure 1: Queuing at Loading

When the transport equipment enters the "waiting circle" and stops (Speed = 0), the system considers the prevailing period as the queueing time until the next activity type is derived.

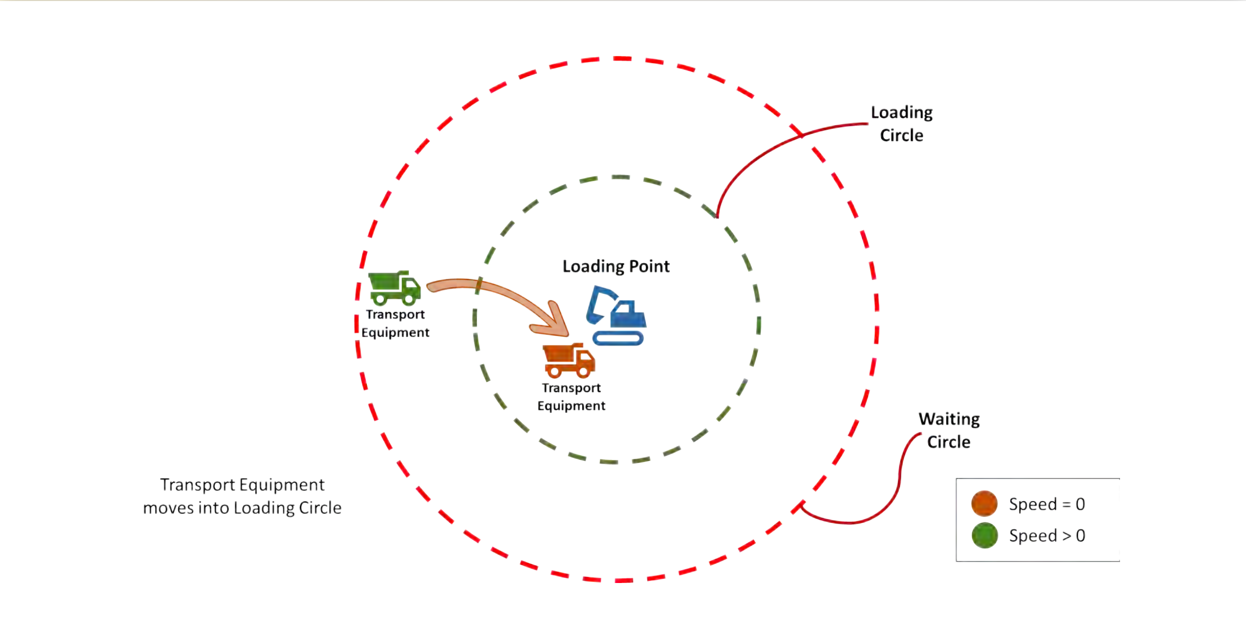

Figure 2: Loading time

When the transport equipment enters the "loading circle" and stops (Speed = 0), the system considers the prevailing period as loading time until the next activity type is derived.

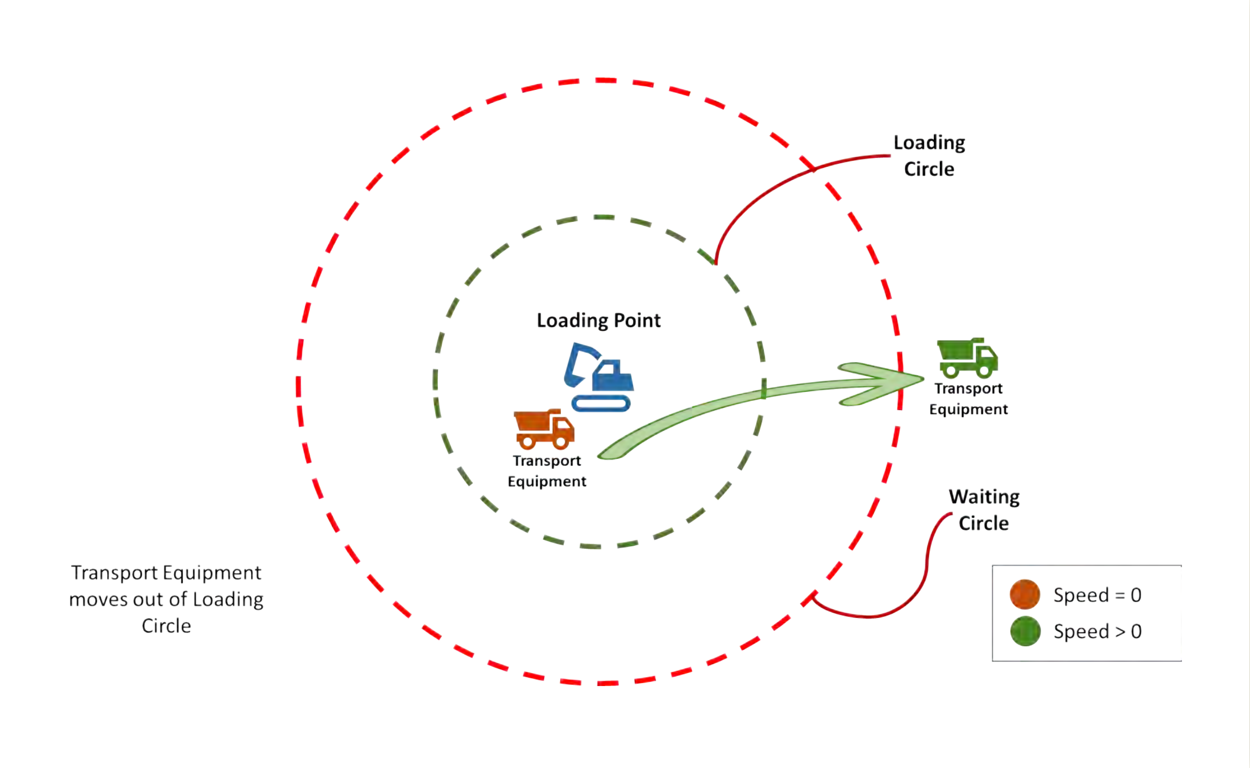

Figure 3: Loaded travel

When the Transport Equipment exits the "Loading Circle" & "Waiting Circle" and is moving (Speed > 0), then the prevailing period is considered by the system as Loaded Travel Time until the next Activity type is derived.

Equipment trip-level KPI derivation

The equipment trip-related KPI derivations are explained below:

S.No.	Trip KPI	Logic
1	Trip Start Time	First timestamp of "Queueing at Loading" or "Loading" for that trip cycle
2	Trip End Time	Last timestamp of "Empty Travel" for that trip cycle
3	Trip Cycle Time (hrs)	Trip End Time - Trip Start Time
4	Trip Average Speed (kmph)	$\frac{\sum \text{Displacement of location of the trip window}}{\text{Trip Cycle Time}}$
5	Loaded Travel Speed (kmph)	$\frac{\sum \text{Displacement of location during Loaded Travel}}{\text{Loaded Travel Time}}$
6	Empty Travel Speed (kmph)	$\frac{\sum \text{Displacement of location during Empty Travel}}{\text{Empty Travel Time}}$
7	Lead Distance (km)	∑Displacement of location during Loaded Travel
8	Individual Activity Duration (hrs)	Last timestamp of the activity - First timestamp of the activity
9	Total Trip Count (Nos)	Count of trips during the shift window

Table 3: Trip-level KPI Derivation

Overall equipment-level KPI derivation

The overall equipment-related KPI derivations are explained below:

S.No.	KPI	Logic
1	Run Hours (hrs)	∑Engine ON hours for the duration (shift)
2	Productive Time (hrs)	∑Engine ON hours during all the trip window
3	Non-Productive Time (hrs)	∑Engine ON hours outside of all the trip window
4	Idle Hours (hrs)	∑Engine ON hours when Speed is 0 for the duration (shift)
5	Utilization (%)	$\frac{\text{Run Hours}}{\text{Shift Duration}}$
6	Production (MT)	Total Trip Count × Rated Capacity of Equipment
7	Productivity (TPH)	$\frac{\text{Production}}{\text{Run Hours}}$
8	Total Distance Travelled (km)	∑Displacement of location for the duration (shift)
9	Tonne Kilometre Per Hour (TKPH)	$\frac{\text{Production x Distance Travelled}}{\text{Run Hours}}$
10	Live Speed (kmph)	$\frac{\sum\text{Displacement of location for last 3 data points}}{\text{Time window of the 3 data points}}$
11	Average Speed (kmph)	$\frac{\sum\text{Displacement of location for the duration (shift)}}{\text{Shift Duration}}$
12	Delayed Start (hrs)	First Engine ON Timestamp - Planned Shift Start Time
13	Early End (hrs)	Planned Shift End Time - Last Engine OFF Timestamp
14	Performance	$\frac{\text{Productivity}}{\text{Rated Productivity}}$
15	OEE (%)	Utilization × Performance

Table 4: Overall KPI Derivation

Case study

Deploying this comprehensive solution at a prominent limestone mine site in India has brought significant productivity improvement. The solution helps track and monitor key performance indicators (KPIs) in real time. This development has proven to be highly advantageous for the mining company, leading to a remarkable increase in transport equipment productivity by 8% and loading equipment productivity by 14%.

Real-time tracking and monitoring of various KPIs allows the client to have a clear and up-to-date understanding of their operations, enabling them to make informed decisions promptly. By having access to real-time data, the company can identify any inefficiencies or bottlenecks in their processes and take immediate action to address them. This proactive approach to monitoring KPIs has been crucial in driving productivity improvements at the limestone mine site.

Furthermore, deploying this solution has enhanced the company's overall operational efficiency. Customers can optimize their resources by closely monitoring KPIs such as production output, equipment utilization, and workforce productivity. This has resulted in streamlined operations, reduced downtime, and improved overall performance at the mine site. As a result, the company has significantly increased productivity, leading to higher output and profitability.

The successful deployment of this solution at the limestone mine site has had a transformative impact on the operations. Enabling real-time tracking and monitoring of key performance indicators has empowered the company to make data-driven decisions and optimize its processes efficiently. It has substantially improved productivity, demonstrating the tangible benefits of utilizing advanced technological solutions in the mining industry.

Conclusion

The implementation of this solution showcases the significant advantages of efficiency amplification through the maximization of value with minimal data inputs in real time. By reducing the need for manual intervention to the greatest extent possible, the system streamlines operations and enhances productivity.

Furthermore, the integration of real-time alerts in cases of deviations from the baseline enables controllers to take swift corrective actions. This proactive approach to monitoring and responding to anomalies ensures that potential issues are addressed promptly, preventing any negative impact on operations.

Moreover, the ability to analyze historical data and extract valuable insights offers opportunities for continuous improvement and optimization of processes. Leveraging data analytics, organizations can identify trends, patterns, and areas for enhancement, ultimately leading to more efficient and effective operations.

Deployment of additional sensors such as payload sensors, fuel sensors, RFID, etc., can further enhance the system's design and functionality and provide a more comprehensive range of key performance indicators (KPIs). These additional data inputs can offer deeper insights into various aspects of operations, enabling organizations to make informed decisions and drive further improvements.

In conclusion, the solution discussed presents a holistic approach to optimizing operations through the efficient utilization of data and technology. Organizations can achieve greater efficiency, productivity, and overall performance by leveraging real-time monitoring, automated alerts, historical data analysis, and potential sensor integrations. This approach not only minimizes manual intervention but also empowers controllers to proactively manage operations and make data-driven decisions.

As organizations seek ways to enhance their operations and stay competitive in today's dynamic business environment, adopting advanced technologies and data-driven solutions will be crucial. By embracing innovations and continuously refining processes, organizations can drive continuous improvement and achieve sustainable success in the long run.

References:

1. How to Calculate TKPH, Magna Tyres: https://magnatyres.com/us/academy/how-to-calculate-tkph/
2. TKPH: Tonne Kilometre Per Hour, Heuver: https://www.heuver.com/knowledge/otr/tkph-tonne-kilometre-per-hour
3. Overall equipment effectiveness, Wikipedia: https://en.wikipedia.org/wiki/Overall_equipment_effectiveness
4. CALCULATE OEE, OEE: https://www.oee.com/calculating-oee/

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