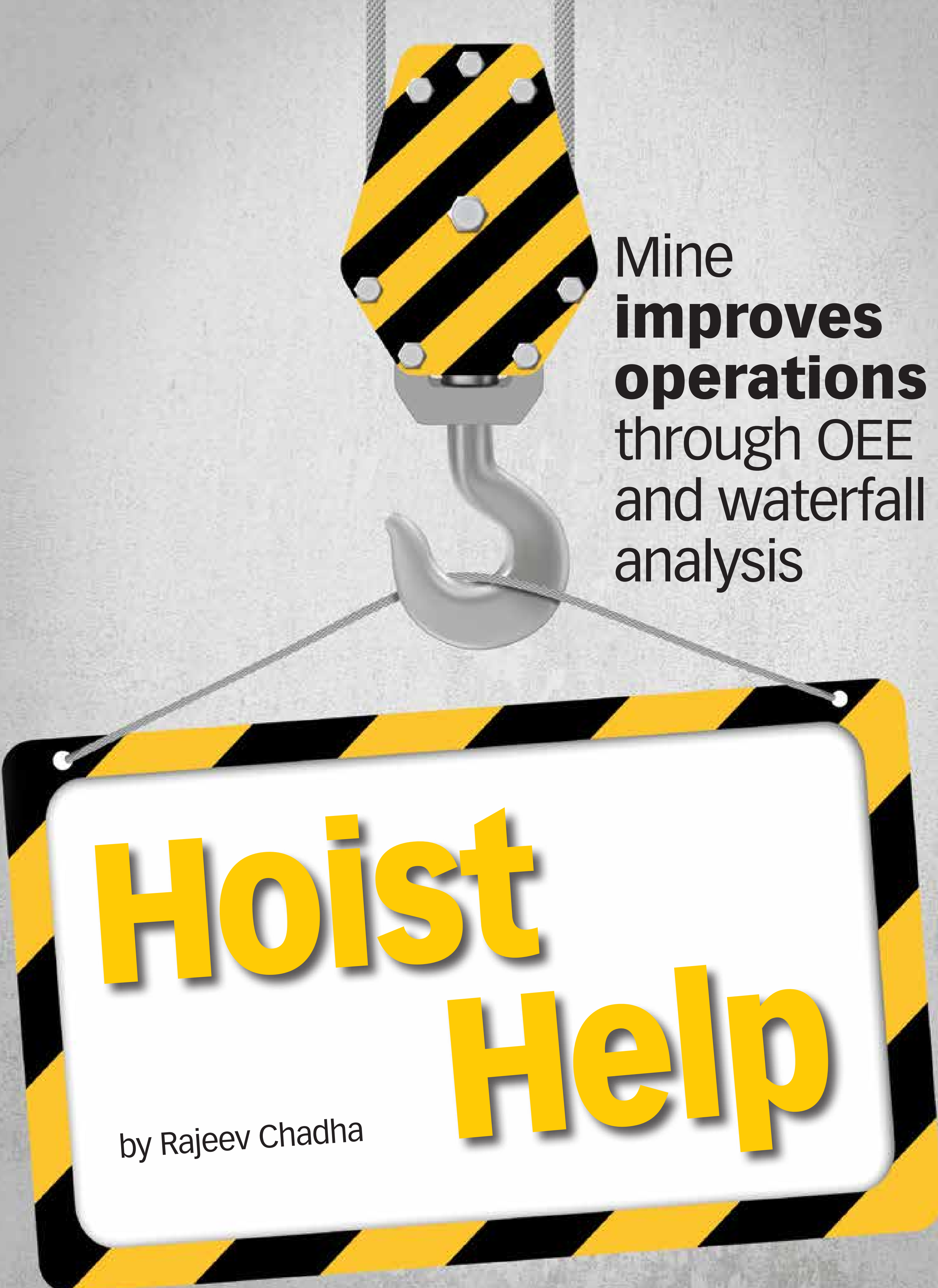


Hoist Help

Mine **improves operations** through OEE and waterfall analysis

by Rajeev Chadha

OVERALL EQUIPMENT EFFECTIVENESS (OEE) and waterfall analysis are proven continuous improvement analysis tools that have been used in the manufacturing world for many years. Recently, these techniques have been carried over to the mining sector and used successfully to enhance the performance of Potash mine sites in Canada.

At the Mosaic Potash ULC in Saskatchewan, miners used these quality tools to improve the performance of the mine's hoist operation. Virtually every improvement in the hoist operation—and upstream activities that increase the value of the total ore hoisting time—can reduce losses and contribute directly to the mine site's bottom line.

OEE measurement also was used as a key performance indicator (KPI) to reflect the success of the underground mining operation. A waterfall chart complemented the OEE analysis, especially for understanding and explaining the gradual transition in the quantitative value of an entity, which is subjected to increment or decrement. Waterfall charts also were used for various types of quantitative analysis ranging from inventory analysis to performance analysis.[1]

In underground mining, a hoist (or winder) is used to lift and lower conveyances within a mine shaft. The hoist is powered using electric alternating current motors that are frequency controlled.

The hoisting cable is wound around the drum. When one skip (or cage) conveyance is lifted, the second skip is being lowered. In a hoist room, drum hoists are mounted on concrete. The hoisting ropes run from the drum, up to the top of the head-frame, over a sheave wheel and down where they connect to the skip.

There are two common types of hoists used in North American mines: drum hoist and friction hoist. Drum hoists require less routine maintenance than friction hoists because the haulage cable is fixed to the drum and, therefore, requires less downtime. Drum hoists can continue to operate if a shaft bottom gets flooded, and less shaft depth is then required below the loading pocket. This is unlike the situation with friction hoists, where such flooding could cover the tail ropes. Because drum hoists do not have tail ropes, the hoisting system is more suited to slinging beneath a conveyance.

In 50 Words Or Less

- Miners in Canada wanted to improve the performance of a hoist, which is considered the lifeblood of any mining operation.
- An improvement team turned to two continuous improvement analysis tools—overall equipment effectiveness and waterfall analysis—to determine how to get the most from its hoist and other hoist-related activities.

Drum hoists need more space than friction hoists for the same service because all of the haulage cable must be accommodated on the drum when the hoist is fully raised. Drum hoists require rapid fluctuations in power demand, which can pose a problem if power is generated on site rather than provided through the main power grid.[2, 3]

Hoist performance

Conveying raw ore from the mine to the surface is one of the most important unit operations in any underground mining process. In this way, the hoist becomes the single most critical asset of the entire operation because it can expose the productive health of the mine site.

In other words, the hoist—as the single operating equipment working between upstream mining and downstream mineral refining processes—is in a unique position to reveal the location of a bottleneck in the value chain of the continuous refining process.

If you ask mine production staffers how well a mine is running, they will look at the hoist performance to see the production run of the last shift, and the conversation could go one of several ways:

- "It was OK. We managed to get the mill running."
- "It was terrible."
- "The hoist was running out of ore."
- "The refinery had a major breakdown."
- "Everything that could go wrong went wrong."

In the 1960s, Seiichi Nakajima developed the OEE hierarchy of metrics based on the Harrington Emerson way of evaluating labor efficiency.[4] This evaluation indicates how effectively a manufacturing operation is used.

The results are stated in a generic form, which allows comparison between manufacturing units in differing industries. The Harrington Emerson method is not, however, an absolute measurement and is best used to identify scope and method for process performance improvement. If, for example, cycle time is reduced, the OEE also can be reduced, even though more product is produced with fewer resources.[5]

From a simple hoist time and production tracking chart (Figure 1), you can conclude that ore hoisting was consistent in the first 20 days of the month until the upstream and downstream delay bars (red and green bars) exceeded 4.5 hours in a 12-hour shift. Overall, the downstream (that is, the ore refinery), represented by green bars, carried the bottleneck most of the time.

There were 35 occasions (green bars) when the refinery or mill stopped the hoist, compared to 21 times (red bars) the mine held up the hoist for want of ore. There was a minimum potential of 1,000 tons of ore per day improvement of hoist performance.

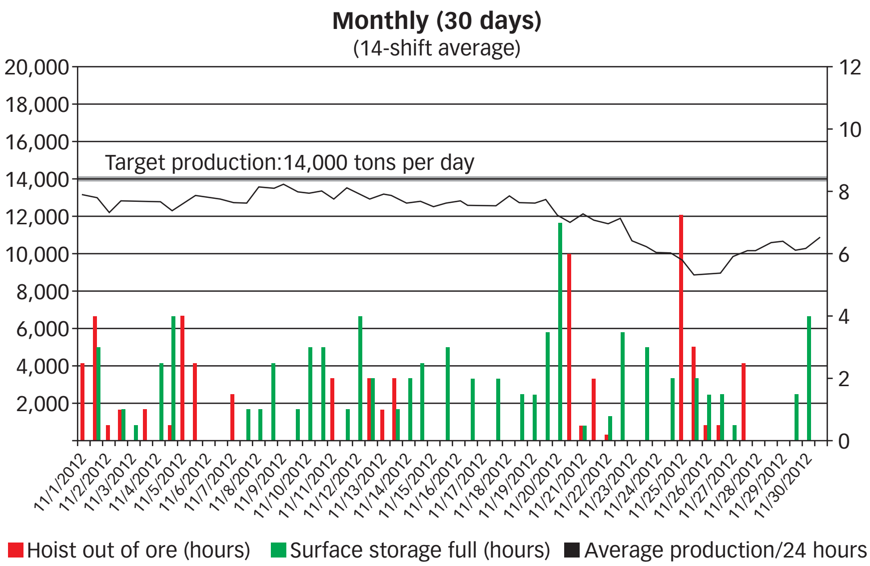
Neither production scheduling nor maintenance planning was particularly helpful to maintenance or continuous improvement teams trying to determine what really needed to be done to get these extra 1,000 ore tons processed. A seemingly positive response easily could hide a multitude of problems. In this case, the production team might meet the ore demand, but at what cost?

Waterfall charts

It was determined that waterfall analysis—a technique that's been around for years in the manufacturing, IT and financial industries—could be used for hoist performance reporting. Waterfall charts are commonly used in industry as a value analysis tool to show how a KPI changes from one state to another through a series of intermediate changes.

In a manufacturing unit, for example, you can project last month's production performance with respect to a target or budgeted value, and show the up and down effects of maintenance, inventory, production control and other inputs. Waterfall charts, known as bridge charts in the finance sector, are forms

Hoist production performance tracking chart / FIGURE 1



of data visualization that help determine the cumulative effect of sequentially introduced positive or negative values.

There is more than one way to create a waterfall chart in Excel. One approach is to create a stacked column chart with vertical columns showing changes, and transparent columns that help the visible columns float at the appropriate level. Usually, the initial and the final values are represented by whole columns, while the intermediate values are denoted by floating columns. The columns are color-coded to distinguish between positive and negative values.[6]

When the technique is applied to OEE, it becomes a consistent and user-friendly way of showing the real impact of hoist performance. A waterfall might appear to be an unusual model on which to base an OEE production report, but when the objective of the exercise is to reduce nonvalue-added time in the production process, it's a good way to visualize how well things are working.[7]

Gather performance data

To perform hoist OEE and waterfall analysis, it's important to collect basic data and information about the hoist. If minute-by-minute information related to hoist inspection and preventive, planned and breakdown maintenance is compiled and compared with delays from upstream and downstream operations, an accurate picture of the hoist value stream can be mapped.

Ideally, hoisting, or skipping the ore from mine to refinery, is a continuous 24/7 operation, but any glitches in the underground or surface operations can directly cause the stoppage of the hoist. Ore storage bins at both ends of the hoist are the buffers that reduce this impact, but the relatively small size of skips as compared to mine and mill storage doesn't work every time to maintain the continuity of the operation.

At a minimum, the following 10 data points (in minutes) are usually required to complete hoist OEE and waterfall calculations:

1. Time of hoist ropes and skips inspection.
2. Time of mechanical preventive maintenance.
3. Time of electrical preventive maintenance.
4. Time of mechanical breakdown maintenance.
5. Time of electrical breakdown maintenance.
6. Time of planned mechanical repairs.
7. Time of planned electrical-instrumentation repairs.
8. Upstream mine delays in supplying ore.
9. Downstream refinery delays in consuming ore or ore extraction.
10. Total tons of ore hoisted in a month or week.

When entering the data, the operator should be careful about the duplicate entry of ore delays into the data collection system. The upstream delays always should be accounted for before the downstream delays. The hoist downstream always will have an opportunity to use the time delays caused upstream.

The next step is to identify the industry standard for hoist availability, performance, quality and OEE. Every hoist operation is different because of hoist design, cycle time or ore bulk density. Unlike manufacturing, it is difficult to find a common industry standard for hoist performance parameters. In the absence of industrial data, it is advised to start with borrowing world-class OEE levels from the manufacturing world.

Hoist production performance tracking chart / TABLE 1

Description	Value	Comments
Total available time per month (minutes)	43,200	24 hours x (days in month) x 60 minutes.
Time not scheduled for skipping		Inventory control, items outside of company control (weather and external supplier).
Scheduled hoisting/ skipping time	43,200	(Total available time – idle time).
Scheduled hoist downtime	5,820	Planned maintenance, breaks, travel, safety and meetings.
Unscheduled downtime	8,925	Wait for operator, breakdowns, setups, start-up, adjustments, upstream and downstream ore delays.
Total downtime minutes	14,745	Scheduled + unscheduled downtime.
Uptime minutes	28,455	Scheduled time – total downtime.
Availability	65.9%	(Uptime/scheduled uptime) x 100%.
Rate (maximum demonstrated performance rate or MDPR) in tons per hour (TPH)		Designed rate or MDPR in TPH = best four-day run during the last 365 days.
Actual tons produced	346,198	Total production (ore tons in a month).
Actual production rate (TPH)	729.99	Actual production rate = tons produced / uptime.
Speed loss (TPH)	0.01	MDPR – actual rate (Loss could be from training new operator, running half circuit or skips not full).
Speed loss (tons)	4.5	(MDPR – actual production rate) x uptime.
Performance efficiency	100%	(Actual production rate TPH / MDPR) x 100%.
Quality	100%	For hoist, all tons produced are considered to be good.
Overall equipment effectiveness (OEE)	65.9%	OEE = availability x performance efficiency x quality.

The world-class OEE for manufacturing is usually about 80%, with variations in availability between 85 to 90%, and performance at about 90% or higher. Quality in manufacturing is usually represented by the average outgoing quality level of the process. The ore quality for hoisting can be constantly treated at 100%, however, because hoisting is a physical operation, and no transformation occurs.

Thus, world-class OEE = availability x performance x quality = 0.9 x 0.9 x 1.0 = 0.81 ≈ 80%

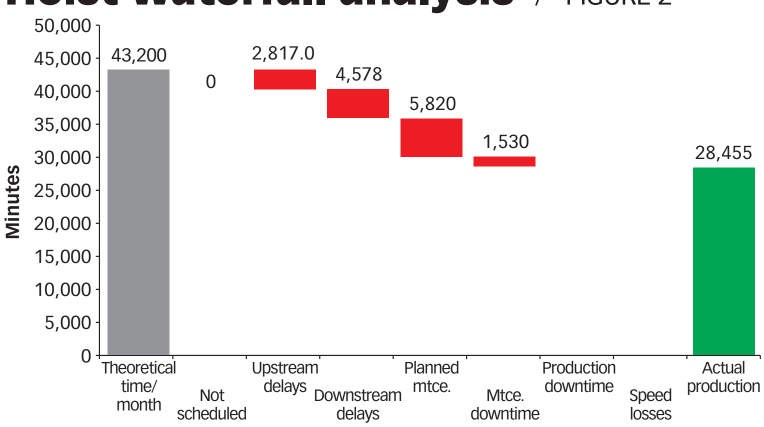
Now, let's perform an example exercise of hoist OEE using the spreadsheet popularized by the Society of Manufacturing and Reliability Professionals.[8, 9] Table 1 (p. 37) shows typical data entry and comments.

The first input in the worksheet is the total number of days in the month followed by the number of days the mine site decides to run. That means each operating minute within the month is under the control of mine management.

The next step is entering the data collected during the shifts throughout the month and calculating the total uptime and availability of the hoist. For performance efficiency, you need the total ore tons hoisted during the month from the cost-accounting department and a comparison with designed or maximum demonstrated production rate (MDPR) capacity of the hoist. This can tell you how much speed loss occurred.

The final step in the spreadsheet is calculating the OEE and unveiling improvement opportunities. The broad conclusions about production, maintenance and continuous improvement efforts, including controlling the speed loss, can be determined.

Hoist waterfall analysis / FIGURE 2



Mtce. = maintenance
Hoist maximum demonstrated performance rate capacity = 730 tons per hour

Waterfall analysis and results

The waterfall diagram (Figure 2) illustrates the ore hoisting process in the form of a value stream. It shows red buckets of time lost in various activities at the mine site. These activities and operations can be categories in terms of value-added, nonvalue-added (waste) and business nonvalue-added activities to better understand the process from a business point of view.

For example, inspection of critical hoist and shaft components—such as rope inspection—is a government-regulated, nonvalue-added activity and cannot be compromised. Other production and breakdown delays can be identified and managed for better bottom-line results.

In this case, the major waterfall parameters include:

- **Total available time:** The reporting period is 30 days, equivalent to 43,200 minutes or a single month.
- **Hoisting not scheduled:** The time the plant does not operate (for example, during a power outage or inventory control). Normally, we schedule "zero off" minutes for the hoist operation.
- **Hoist scheduled time:** The ore supply goal and the time we intend to operate the hoist to run the refinery (upstream) at full speed. The hoist is scheduled to operate 43,200 minutes in the month.
- **Upstream delays:** The delays in ore supply by the underground mining operations. The hoist was out of ore for 2,817 minutes (46.95 hours or 1.96 days) in the month.
- **Downstream delays:** The delays from stoppage of surface operations. The hoist waited for 4,578 minutes (76.3 hours or 3.17 days) in the month for the refinery to take the ore for transforming it into product.
- **Hoist planned and breakdown maintenance:** A total of 5,820 minutes were used this month in hoist inspection and its preventive and other planned maintenance. The breakdown or reactive maintenance was for 1,530 minutes (25 hours or 1.01 days).
- **Speed losses:** The value in red represents total lost rate as defined by the OEE measurement. In this case, the total loss was 4.5 tons at the rate of 0.01 tons per hour. This is negligible and represented by zero on the waterfall graph.
- **Hoist availability:** From OEE calculations, hoist availability is the ratio of actual uptime and scheduled uptime. As the waterfall report cascades downward, the availability loss comprises two parts: its own availability and its upstream and downstream delays. In this case, 14,745 minutes (245.75 hours) are from avail-

ability losses such as breakdowns, maintenance, and out-of-ore and no-ore movement on the surface.

- **Hoist performance efficiency:** This is the ratio of the actual and designed (or MDPR) hoisting rate and is calculated to be 0.01 hours. This shows negligible performance losses. These losses, if present, would be from ramp up, minor stops, partial skips, freeboard height in skips and other speed losses.

With the value-added time as the true point of the exercise, the production goal was 43,200 minutes (720 hours), but we managed to add value to the business of 28,455 minutes (454.25 hours). After the baseline of value-added time is generated by capturing accurate information about the hoist, an environment of performance dialogue can be created.

Each element that makes up availability and performance can be allocated to groups or individuals as improvement targets.[10] Those elements and the value-added time total can be reviewed frequently (at least weekly), but to make real progress, you should review it in each shift. Some of the useful initiatives that work effectively for each improvement task are:

- Develop workout teams to do fault resolution. These teams are cross-functional groups that define the problem and initiate a short-term lean-continuous improvement project to solve the operation's related problem or issue. Blame the process, not the people.
- Prioritize the top five or 10 loss buckets in the site's continuous improvement campaign.
- Take a series of photos of the issues that must be improved.
- Perform root cause analysis for all the current issues, and implement irreversible corrective actions. Document an improvement plan of action to resolve the issue.
- Establish accountability by providing additional support to the person or crew responsible.
- Record progress and meet weekly to monitor resolution.

Transparency, team confidence

In Figure 2, the hoist OEE and waterfall analysis shows the upstream, self and downstream impact on the overall performance of the mine site. It's sobering to consider that virtually every improvement that increases the value of 28,455 minutes in a month of hoist operation either reduces the loss or goes straight to the bottom line as profit to the mine site.

In my experience, lean Six Sigma and quality management tools must be synergized with leadership skills at all levels of an organization. This will create a robust system of continuous improvement within the mine site, take the organization to a higher level of growth and increase the level of performance.

Furthermore, the direction should be toward improving the individual employee's alignment with the mine site's long-term performance plan by connecting it with an individual unit's performance.

The effort is supported by training planners and supervisors in workout principles and calculating the OEE of individual units (the mining unit or the unit operations in the refinery). This will promote transparency and team confidence. Eventually, it will increase the ability to improve the crew's performance, morale and organizational leadership. QP

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