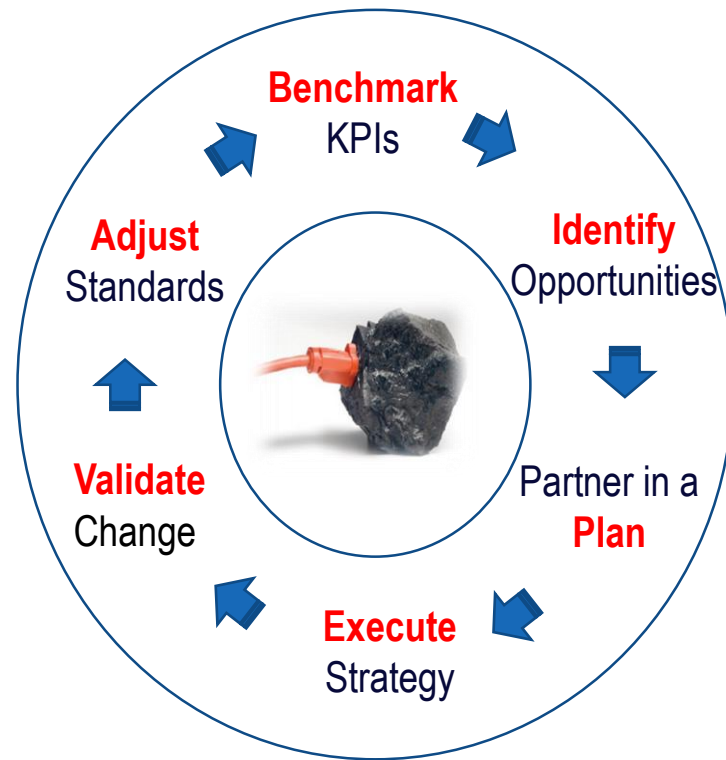

Smart Solutions 2018

Joseph Hirschi
Productivity Analyst
Smart Solutions, UG



What Is Smart Solutions?

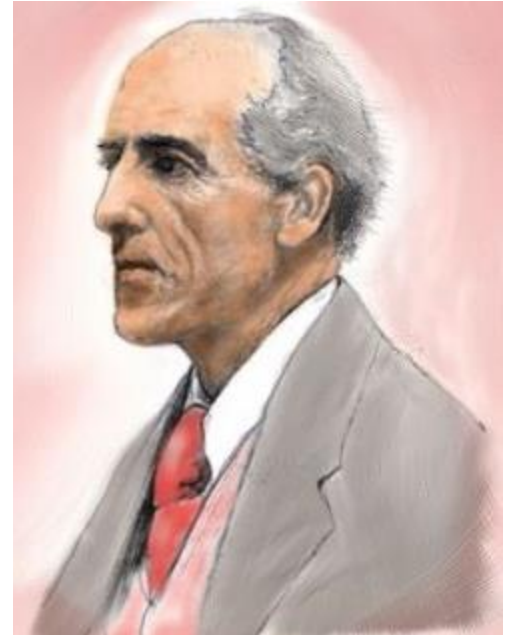
- Smart Solutions is best described as a **continuous improvement service**.
- Maximizing productivity is always a top priority for mines, but **identifying** where **inefficiencies** occur is not always easy, especially in an underground mine.
- Smart Solutions collects streaming and historical **data**, which is processed with our **sophisticated analytics software** to provide detailed assessments of operational characteristics.
- Eliminating recurring inefficiencies one event at a time leads to a culture of **maximum productivity**.



Pearson's Law

“When performance is measured,
performance improves.

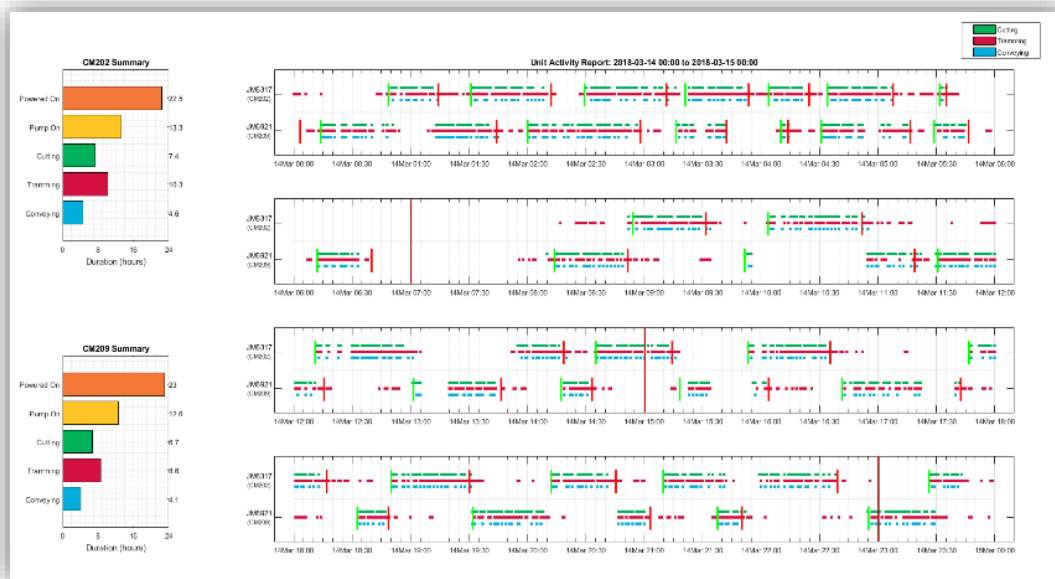
When performance is measured and reported,
the rate of improvement accelerates.”



Statistician Karl Pearson
1857-1936

Maximizing Machine Productivity =

How much **Time** is it working?



Maximizing Machine Productivity =

How much **Time** is it working?

How **Hard** is it working?



Maximizing Machine Productivity =

How much **Time** is it working?

How **Hard** is it working?

Why is it **not** working?



Smart Solutions Continuous Improvement Process



Streaming data is generated at the CM and routed to the customer LAN.





Smart Solutions



Machine data is routed to the cloud where it is processed with proprietary software. “The List” is populated by all connected machines.

[illegible]

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Using Joy's sophisticated analytics, Data Analysts interpret processed data for machine utilization and health status, and for operator efficiency.



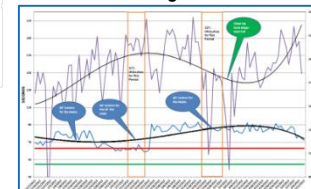
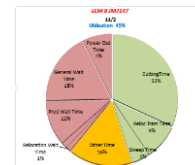
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[illegible]

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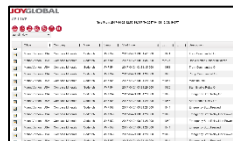


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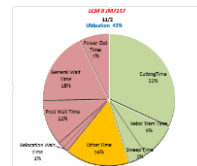
LINE	TIME	TYPE	STATUS	LOCATION	OPERATOR	PERCENTAGE	REMARKS
1	10:00:00	START	OK	101	JOY	100%	START WORK
2	10:05:00	STOP	OK	101	JOY	100%	STOP WORK
3	10:10:00	START	OK	101	JOY	100%	START WORK
4	10:15:00	STOP	OK	101	JOY	100%	STOP WORK
5	10:20:00	START	OK	101	JOY	100%	START WORK
6	10:25:00	STOP	OK	101	JOY	100%	STOP WORK
7	10:30:00	START	OK	101	JOY	100%	START WORK
8	10:35:00	STOP	OK	101	JOY	100%	STOP WORK
9	10:40:00	START	OK	101	JOY	100%	START WORK
10	10:45:00	STOP	OK	101	JOY	100%	STOP WORK
11	10:50:00	START	OK	101	JOY	100%	START WORK
12	10:55:00	STOP	OK	101	JOY	100%	STOP WORK
13	11:00:00	START	OK	101	JOY	100%	START WORK
14	11:05:00	STOP	OK	101	JOY	100%	STOP WORK
15	11:10:00	START	OK	101	JOY	100%	START WORK
16	11:15:00	STOP	OK	101	JOY	100%	STOP WORK
17	11:20:00	START	OK	101	JOY	100%	START WORK
18	11:25:00	STOP	OK	101	JOY	100%	STOP WORK
19	11:30:00	START	OK	101	JOY	100%	START WORK
20	11:35:00	STOP	OK	101	JOY	100%	STOP WORK



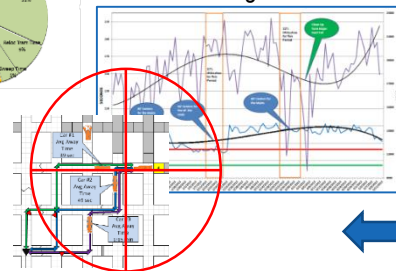
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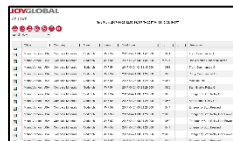


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Machine ID	Machine Type	Machine Status	Machine Location	Machine Operator	Machine Hours	Machine Fuel	Machine Oil	Machine Water	Machine Air	Machine Temp	Machine Pressure	Machine Flow	Machine Speed	Machine Torque	Machine Power	Machine Efficiency	Machine Availability	Machine Uptime	Machine Downtime	Machine Maintenance	Machine Repairs	Machine Parts	Machine Cost	Machine Value	Machine ROI	Machine Profit	Machine Loss	Machine Net	Machine Gross	Machine Total
1	Excavator	Online	Site A	John Doe	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
2	Excavator	Offline	Site B	Jane Smith	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
3	Excavator	Online	Site C	Mike Johnson	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750
4	Excavator	Online	Site D	Sarah Lee	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
5	Excavator	Online	Site E	David Kim	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
6	Excavator	Online	Site F	Emily White	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
7	Excavator	Online	Site G	Chris Brown	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
8	Excavator	Online	Site H	Alex Green	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
9	Excavator	Online	Site I	Mia Black	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
10	Excavator	Online	Site J	Noah Gray	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400



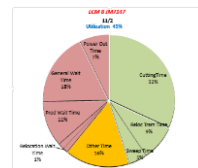
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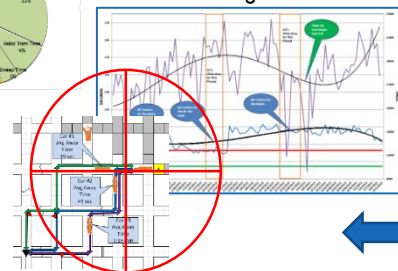
Engineering access to connected machines gives a clear advantage. Machine performance and fault diagnostics can be monitored in real time.



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Productivity Analysts then compare operational characteristics to developed standards. Findings are validated with time studies and discussed in regular team meetings.





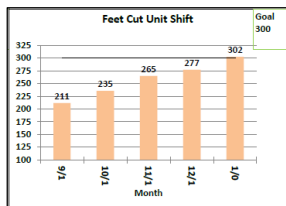
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[illegible]

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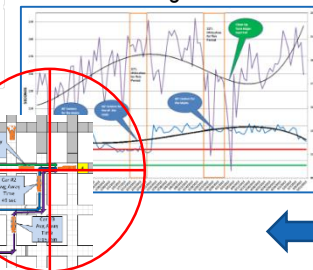
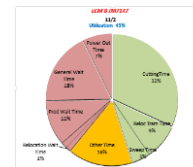
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Smart Solutions Continuous Improvement Process



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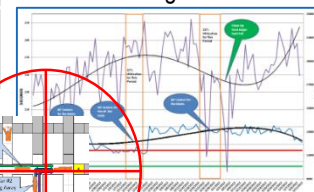
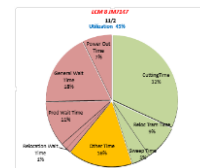
Machine ID	Machine Type	Machine Status	Machine Location	Machine Operator	Machine Hours	Machine Fuel	Machine Oil	Machine Water	Machine Air	Machine Temp	Machine Pressure	Machine Flow	Machine Torque	Machine RPM	Machine Load	Machine Cycle	Machine Cycle Time	Machine Cycle Count	Machine Cycle Time (min)	Machine Cycle Count (per hour)	Machine Cycle Time (min)	Machine Cycle Count (per hour)
1	Excavator	Online	Site A	John Doe	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
2	Excavator	Online	Site A	Jane Smith	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
3	Excavator	Online	Site A	Mike Johnson	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
4	Excavator	Online	Site A	Sarah Lee	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
5	Excavator	Online	Site A	David Kim	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
6	Excavator	Online	Site A	Emily White	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
7	Excavator	Online	Site A	Chris Brown	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
8	Excavator	Online	Site A	Alex Green	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
9	Excavator	Online	Site A	Olivia Black	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
10	Excavator	Online	Site A	Noah Gray	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
11	Excavator	Online	Site A	Isabella Blue	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
12	Excavator	Online	Site A	Ethan Red	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
13	Excavator	Online	Site A	Ava Purple	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
14	Excavator	Online	Site A	Lucas Yellow	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
15	Excavator	Online	Site A	Mia Pink	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
16	Excavator	Online	Site A	Benjamin Silver	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
17	Excavator	Online	Site A	Charlotte Gold	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
18	Excavator	Online	Site A	William Bronze	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
19	Excavator	Online	Site A	Amelia Copper	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
20	Excavator	Online	Site A	James Iron	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000



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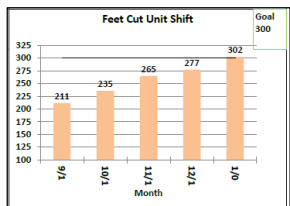
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Continuous Improvement is a loop that ends only with perfection or lack of will.

Opportunities Example

Given Parameters

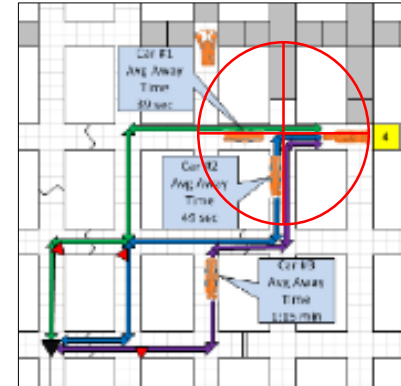
Average loads per shift	120
Shifts per day	2
Average minutes per place cut	40

Goal

Seconds Gained per load	2
-------------------------	---

Impact

Seconds gained per shift	240
Seconds gained per day	480
Minutes gained per day	8
Minutes gained per week	40



Gaining 124,000 tons per year at no cost.

Project Challenge:

Personnel at a mine knew their methods of operation were holding back production levels, and had tried to implement procedures to promote efficiency, but kept defaulting to a pattern of reduced capabilities. Mine crews were craving information, and eager to make positive changes, but lacked adequate bench marking or daily progress reports.

Solution Design:

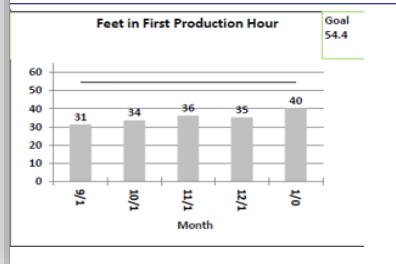
In partnership with the customer, Smart Solutions began tracking the mine's "feet mined in the first production hour" as a standard reporting package. The goal was to start at the beginning and identify all opportunities through the shift.

Start delays seemed to fall in an expected range. The higher priority was determined to be the slow rate at which units came up to full production.

*Feet lost in the first hour
can never be gained back.*

Data produced by Komatsu's smart, connected products revealed **the customer was averaging a rate of 27.6 feet in the first production hour of a shift.** This was measured as an average of the footage reported 60 minutes from the time the conveyor was first turned on during the shift.

Komatsu crews then looked into what factors were limiting production at the start of the shift. During site visits, it became clear, previous shift workers were not leaving workspaces ready for a new shift to begin production in a timely and productive fashion. **There was no systematic approach to readying the unit for a new cutting cycle or ensuring that equipment was serviced and staged properly.**



Bits often were left in poor shape, rocks and debris covered the machine, adequate cable was not pulled up and available, and the machine was left in areas already completed or not yet ready to cut.

The customer had made previous attempts to establish better processes between shifts, but employees returned to old habits in a matter of weeks because there was limited tracking or results.

The shifts needed to work as a team to promote change. But a lack of information and expectations meant the crews and workspaces were not working efficiently.

The Solution:

Using interviews with production crews, Smart Solutions personnel were able to compile a list of priorities. Using the list, the customer defined what constituted a "ready unit" and began training employees.

In partnership with the customer, the responsibility to achieve more "feet mined in the first production hour" was handed to the idle shift crew. When higher levels of production were achieved, that crew then got the credit.

Using data produced by its smart, connected products, Komatsu provided weekly reports on what teams were contributing to higher production rates. Connecting the efforts of one shift to the results of the following, was a new approach that promoted teamwork across shifts.



*Bringing all the working
crews into the process
gave a boost to the team
approach.*

By providing the actionable data defining low production levels, and then helping crews set and track methods to improve efficiency, Komatsu helped the customer bring accountability to the mine.

The Results:

By the end of 2017, comparison data showed a gain of 6.1 feet per Continuous Miner, per shift, over the year prior. **The gains resulted in an estimated 124,440 tons produced per year.**

These additional tons are credited to efficiency. There was little or no added cost to adopt this change. The gains were pure tons on the belt.

Analyst were able to identify opportunity in the setup procedure on an Idle shift. When a "ready unit" was defined and a cut sequence agreed upon, operators and repair crews were given specific tasks. Then, standards were recorded and workers trained so that the unit was exactly as expected every day. The start time efficiency rebounded. Savings were considerable.

Case Study

A Data Analyst was able to contact the longwall operator at a customer's mine when he saw a newly installed ranging arm warming up faster than expected. The component was ultimately found be overfilled with oil, and the breather was not installed. This scenario can lead to catastrophic failure of the drum seal and subsequent internal damage.

In addition to the cost to repair the arm, the 2 or more shifts to coordinate and replace the arm was averted.

Shearer Case Study

Possible Ranging Arm Seal damage averted

Project Challenge:

Over the years, we have seen several seal failures on the start-up of replacement ranging arms. The ultimate cause was linked to oil overfilling and no vent. These failures can cost tens of thousands of dollars in repair, and several shifts production.

The Solution:

- Shearer ranging arms are always in Komatsu inventory. These arms are built generically, no butt plate, covers or drums installed. Because they may sit for long periods of time before being issued to a job, they are prepared for long term storage.

"This may have led to a huge repair bill and days of lost production"

Long term storage includes filling the oil reservoir to the top, and removing any path for moisture ingress, the vents. A sign is always included on the arm to alert of this condition.

What happened in this condition? As the arm was brought to the shearer, the signs were inadvertently removed. The repair crew was not alerted to the oil and vent condition. When the job was completed, the shearer was returned to service.

The Results:

- The ranging arm, having RTDs installed and being monitored by Smart Solutions, started sending alerts almost immediately. Fearing the worse, Smart Solutions began frantically trying to contact the operator. Within just a few minutes, the concern was relayed to the Longwall Coordinator.

With the Shearer now stopped, the repair crew returned to the shearer. Confirming they had checked that the arm had oil to start, they then checked for over filling. The level was adjusted and the vent was installed. The shearer returned to service, with only minor delays.

Daily Reports

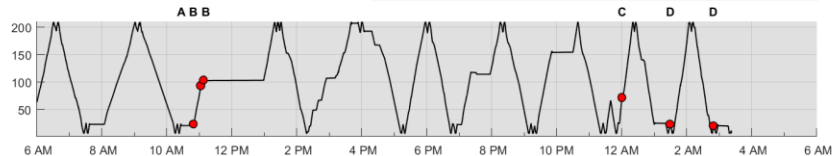


Longwall Daily Report

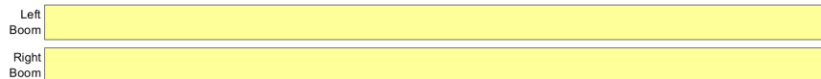
Start Time: 2018/04/19 06:00:00
End Time: 2018/04/20 06:00:00

Top 5 Alarms by Total Downtime

	Alarm	Count	Downtime (min)
A	Right Cutter Pre-Jam OL Trip (Haulage Stop)	1	0.9
B	Conv: Maingate EP Cooling Water Flow Fault	2	113.2
C	BSL: Flightbar No Count Retract Shutdown	1	1.4
D	Post ESR Power Missing While ESR Was Comma...	2	1.7

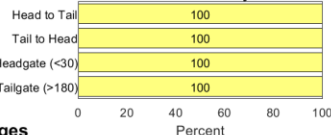


Automation Trend

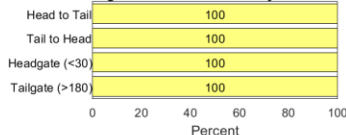


Automation Key
Off
Override
RecordedRoof
FX2
PitchSteering
Other

Left Boom Auto Summary



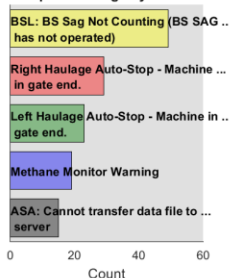
Right Boom Auto Summary



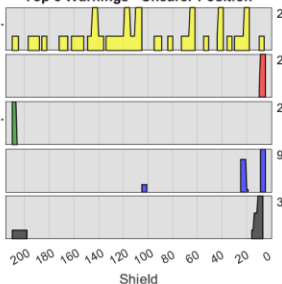
Parameter Changes

Time	Parameter
04/19 07:20	Haulage.Cutter_Feedback_Amp_Limit changed from 100.00...

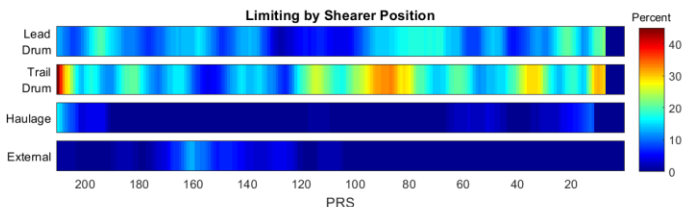
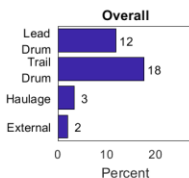
Top 5 Warnings by Count



Top 5 Warnings - Shearer Position



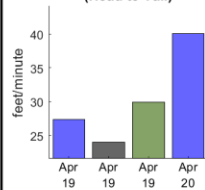
Shearer Limiting



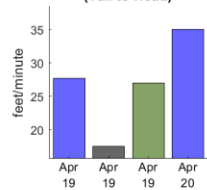
Shift Comparison

Shift Key
23:00:00 - 07:00:00
07:00:00 - 15:00:00
15:00:00 - 23:00:00

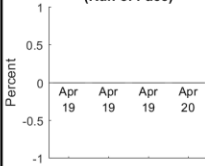
Shearer Speed Average (Head to Tail)



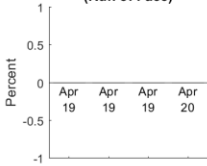
Shearer Speed Average (Tail to Head)



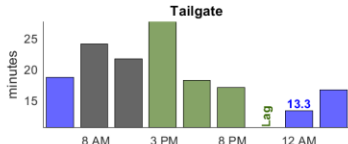
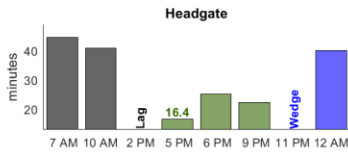
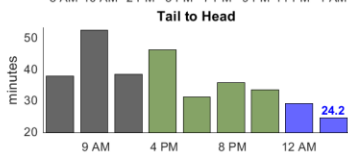
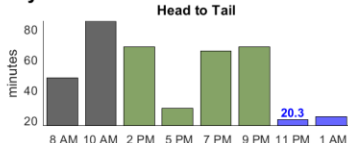
Left Boom Automation (Run of Face)



Right Boom Automation (Run of Face)

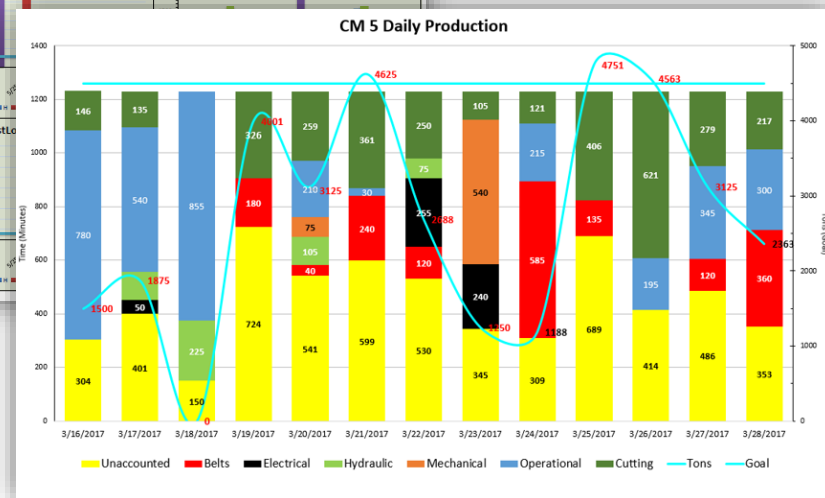


Cycle Durations



Weekly Dashboard

Weekly productivity dashboards are used to monitor trends. Shift and crew data can be graphed and charted on a host of KPIs. Continual monitoring allows a view of subtle changes in productivity. Early diagnosis of inefficiency in the process is key to maintaining maximum productivity. This summary is also helpful in identifying opportunities. This report identifies cutting hours per day as a possible opportunity.



Customer Access Data Trending Tools (newly developed)

Typical Faceboss Machines have in excess of **400 data tags**. Data tags are points within the computers that change status as events occur. To view these tags, we use **Graffana**.

Recent developments have allowed Komatsu to share access to this data with our customers. Combinations of styles and trends allow near **unlimited comparison of machine data**, both live and historic (30-day).



Products and Deliveries (Example)

- **Remote Health Monitoring**
 - Data Analysis
 - Custom Analytics
 - Help Line
- **Productivity Analysis**
 - Shift/Daily/Weekly Reporting
 - Process Analysis
 - Mine site/Unit Analysis
- **Machine Condition Monitoring**
 - Monthly Conditions Assessment
 - Wear Analysis
 - Oil Sample Analysis
 - Vibration Analysis
- **Training/Coaching**
 - Maintenance Training
 - Operator Coaching
 - Custom Systems Training
 - Hands-on at the Machine Training

- Training Schedule
- Oil Analysis
- Vibration Analysis
- Dedicated Productivity Analysis

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- Bi-Weekly Meetings
- Monthly Condition Monitoring
- Monthly coaching/training

3

- Monthly Review Meeting
- Monthly Condition Monitoring
- Underground productivity Analysis

2

- Automated Shift reports
- Weekly Top Faults
- Weekly KPI Trending
- Monthly Utilization
- Quarterly Review
- Data Capture

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