ASSET PERFORMANCE MANAGEMENT DRIVES MINING PROFITABILITY: INCREASING COAL PRODUCTION WITHOUT SIGNIFICANT CAPITAL INVESTMENT

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ABSTRACT

Too often, mining companies believe that making significant capital investments are required to drive profitability. In reality, updating asset reliability programs using work identification methodology, building critical skills and knowledge bases in core operations teams, and developing a comprehensive, adaptable Mine Management System can be less expensive and more sustainable approaches to building a more profitable world-class mining concern. USC Consulting Group (USCCG) has implemented its maintenance management system at various mines throughout North and South America. A recent project required development and implementation of an entirely new maintenance and management program at multiple sites for a major international energy company.

INTRODUCTION

Many industrial sectors are experiencing massive growth in fixed assets and this is especially true for coal companies. As worldwide demand for low-cost energy continues to climb, increased availability of such major assets as haul trucks, shovels, and bulldozers has become essential to boosting production. For example, the top ten mining companies, driven by startling growth in commodity pricing over the past several years, have increased their fixed assets from $61 billion in 2003 to $110 billion in 2006.

Commodity price increases from 2003 to 2006 ranged from a low of 25 percent to a high of almost 500 percent, averaging more than 100 percent across a sample of nine commodities, including aluminum, copper, lead, platinum, and zinc.

The need to leverage fixed assets has never been more critical, since, for many industrial sectors, the value of a one percent improvement in asset utilization, based on price increases alone, is twice what is was four years ago. Given that the asset base has doubled along with price, a one percent increase four years ago conceivably could generate a four percent increase in 2007, compared to 2003.

But that has not been the case. Assets have become more expensive to maintain and operate, which has diminished the value of increased production. Because of this, our client, an international energy producer, with over a dozen coal mines, sought to further leverage its fixed assets by keeping maintenance and operating costs low. To ensure that its multi-billion-dollar fleet of mobile mining equipment was well maintained and capable of meeting present and future production demands, the company determined that it needed to dramatically revamp its Asset Reliability Program.

To help them accomplish this objective, they retained Ivara Corporation, the leading asset performance management software company, and Ivara partner USC Consulting Group (USCCG), a reliability consulting firm with the maintenance and operating know-how to develop such a program. Our assignment was to develop a Work Identification methodology, transfer skills and knowledge to a client team, and equip them with the tools they would need to accelerate the mining company's return on investment over a three-year period.

While improving the reliability of the mining equipment, the actual business of digging up coal could not be ignored. To manage both simultaneously required a comprehensive, adaptable Mine Management System (MMS). Developing such a system is often an interactive process, involving the mine engineers, operations, and maintenance personnel to determine what their assets can achieve over the next year to 20 years, and coordinating with the finance department to determine at what cost this production will be met. From these plans the detailed one-year plan is often broken down into monthly buckets and, from there, to weekly plans.

Each week, maintenance, operations, and engineering get together to review their attainment to the plan. By how much did they miss the plan? Was the right sequence followed for development and production benches? What do they need to do together over the next week or month to recover and what equipment reliability will they need to get there? Even with this strict focus, the mine plan can often go wrong from the very start.

The company established four specific goals as part of their new Asset Reliability Program and Mine Management System.

1. Develop leading and lagging Key Performance Indicators (KPIs) that allow the Asset Reliability Program and Mine Management System to monitor performance.

2. Implement a maintenance program of condition-based proactive maintenance and a capacity plan based on maximizing the use of existing assets.

3. Optimize mine production through effective use of equipment and personnel.

4. Continuously track the operating conditions, maintenance requirements, and history of all assets on site, while ensuring that the information is actionable.

Creating a Foundation of Knowledge

Prior to retooling the Asset Reliability Program, the team trained and equipped the mining company's Core Teams, a total of 15 employees based at three sites, in the analytical and facilitation skills they would need to make the transition from the old to the new approach. For two months, the Core Teams received instruction in Ivara® EXP Asset performance Management software, Ivara® Maintenance Task Analysis (MTA), Ivara® RCM2™, and the associated technical and facilitation skills they would need over the next three years.

The mining company then began examining critical and non-critical assets using the two Work Identification methodologies. RCM2 was chosen for the critical assets because it relies on formal analysis in a facilitated group forum to establish the foundation for a comprehensive Asset Reliability Program. MTA was used for non-critical assets because its semi-formal analysis, done in either a facilitated one-on-one series of interviews or group environments, fosters quick development and documentation of the basic requirements for an Asset Reliability Program [Moubray, 2001].

Building the Asset Reliability Program

Over the next four months, the Core Teams were mentored as they conducted MTA and RCM2 analyses on three large assets: a CAT 789B haul truck, a CAT 5130B track hoe, and a P&H 4100 shovel**.**

Core Teams assigned to each asset consisted of subject matter experts (SMEs) including asset operators, mechanics, electricians, and corporate management. Through a Work Identification methodology, the Core Teams were able to determine the proper equipment

maintenance requirements and intervals, so that the right work would be done at the right time. By developing Preventive Maintenance (PM) using condition-based indicators, scheduled restoration, and discard intervals, the company was able to build a proactive maintenance system.

When this system is fully implemented, there will be a higher percentage (more than 80 percent) of tasks driven by some form of condition monitoring and a much lower percentage (less than 20 percent) of time-based tasks, or tasks related to operating age. In addition, the failure analysis will identify the corrective work to be performed when early signs of failure are detected.

Condition monitoring tasks, driven by an understanding of failure modes, create a picture of equipment health from visual inspections and the appropriate use of predictive technology (thermography, vibration, and non-destructive testing) and online equipment data (pressure, temperature, flow, amps, etc.). Managed appropriately, this data prompts actions that can prevent further failure, much like monitoring one's blood pressure to prevent a catastrophic stroke.

The Core Teams' methodology was applied to every component of the assets. These were broken down into such major classifications as engine, hydraulics, steering system, and fire suppression. As a result, 454 Failure Modes were created for the CAT 789B haul truck, 412 Failure Modes for the CAT 5130B track hoe, and more than 559 Failure Modes for the P&H 4100 shovel.

As Work Identification was completed on each asset, the Core Teams integrated their findings using updated PM check sheets, inspection routes, and modifications to the assets to address safety, environmental, and operational concerns.

The Right Tool for the Job

Ivara® EXP Enterprise is considered by many reliability professionals to be the leading asset performance management software solution. EXP is an enabling and sustaining tool used to manage the health of assets. It accelerates the Work Identification process in both MTA and RCM2. It also allows knowledge to be captured in a central location, ensuring that the MTA and RCM2 failure modes are actually implemented, instead of just collecting dust in a binder. Indicators were created to allow component inspections based on pre-set intervals. These indicators are tracked easily so that component performance can be analyzed even while maintaining an asset hierarchy. EXP then determines if check sheets should be issued, based on run-time hours, miles, days, or any input that the SMEs identified as indicative of the component's failure curve [Hoyland and Rausand, 1994].

New check sheets, PMs, shutdown and start-up maintenance programs, and calendar-based inspections were developed using condition-based and scheduled maintenance. Inspection data from paper and electronic PDA check sheets were entered into EXP to determine if the inspected component was in the normal, alarm, or critical state. In the

case of an alarm or critical state, EXP issued a repair task, which was subsequently verified by the maintenance planner. EXP tracked component history to determine operating history and historical failure rates. In total, EXP tracked over 6,000 components on the 3 assets. As the Work Identification templates are applied to the remaining fleet, components that need to be tracked will increase to approximately 100,000. Typically tracking that many components is an overwhelming task, but by using EXP, the task as automated.

Without EXP, maintenance planners are required to compare reported asset conditions against defined condition states and then determine the corrective action, if any, to be planned, scheduled, and assigned. EXP captures and monitors the asset state based on inspection inputs and then "pushes" the proactive tasks to the Computerized Maintenance Management System (CMMS), thus significantly simplifying the resource scheduling and planning activities.

Accelerating the Return on Asset Reliability

As each site completes the implementation of its Asset Reliability Program, the company is able to use the experience to design a template for future implementations at all its worldwide sites. Additional Work Identification is ongoing at the three original sites so that, over the next several years, every major capital asset will be evaluated and integrated into the Asset Reliability Program.

The rate of implementation is greatly increased during reviews of the templates. Differences in part failure modes and operating context are pinpointed and any other failure modes are added. An asset's individual components can be included in the template and applied to assets of a similar class. Using this technique, templates from multiple assets can be combined to accelerate the review of a new asset.

The Maintenance Management System

As the Asset Reliability Program was developed, ongoing operations still had to be measured and controlled. By devising a core set of leading and lagging KPIs, on which successful programs rely, maintenance and operations teams were able to address work management issues outside the Work Identification portion of the project. Using the KPIs, the mining company was able to determine where it stood in such areas as Schedule Attainment, % Work Planned, % Proactive Work, Backlog, and Mean Time Between Failure [Campbell and Reyes-Picknell, 2006]. Once the company knew where it stood, work management controls were implemented and monitored to improve downtime, tonnage per truckload, unitization, and adherence to scheduled hours [Wireman, 2004].

On the 3 assets included in the project.

- Schedule Attainment increased from 68% to 91%
- % Work Planned increased from 45% to ~83%
- % Proactive Work increased from 65% to ~87%

This activity showed clearly that poor planning and scheduling, along with unplanned maintenance, significantly eroded production capacity. By learning the client's entire operating system from top to bottom, the team was able to quickly identify and address the key areas where the capacity erosion was occurring.

World Class Maintenance Management

Climbing the ladder to world-class status begins with determining where a company stands against world-class reliability maintenance principals and standards. This requires an in-depth survey in all key maintenance areas, including organization, work order system, planning and scheduling, inventory and purchasing, reporting, and automation. Then, typically, a pictorial overview of the current flow of maintenance information is developed. This requires involving every employee in a review of his role in the maintenance process and putting every activity into a schematic diagram. Once this view of current operations is in place, the percentages of the day spent on adding value, performing nonvalue-added tasks, or idly waiting for something to happen is documented and graphed for all to see. This is usually an extremely enlightening experience.

A visual management system that displays daily targets for each trade is then installed to help keep everyone focused on individual turnaround times and that of the mining assets. Most importantly, management skills at various levels are upgraded through training and on-the-floor coaching.

The Right Equipment at the Right Time

Determining whether use of the haul truck fleet, loaders, and operators has been optimized consistently over a number of shifts is not as simple as it might seem. If the mine moves a lot of BCM for the day, everyone goes home satisfied with a good day or even a great day. We see results like these reflected in good shifts, days, and occasionally, up to a record month, but we rarely see it reflected in the consistent, credible attainment of the mine plan and budget.

The difficulties arise first with the equipment mix, including the variety of truck sizes, ages, and manufacturers, as well as the mix of load units. Add to this the variation in haul distances and the ever-changing conditions, e.g., weather or equipment reliability issues, and it all has a great impact on the shift. Often the mine conditions change very

early in a shift, which leaves the pit foreman and dispatcher to make the best decisions they can with their remaining equipment.

In this instance the mine dealt with this complexity by ignoring it. It was much easier for them to break down the monthly or weekly plan into a flat daily plan, aiming for the same volume to be moved regardless of equipment, planned maintenance, or pit conditions. On a good day the plan could be exceeded easily. On the flip side, the pit could work very hard, exerting every effort, but, because of bad weather, unplanned breakdowns, or even planned maintenance on a key shovel, the attainment to the plan could look terrible – and, even worse, demand some explanation! This eroded the mine plan's credibility and, by extension, the mine management team's credibility with the operators in the pit.

In this type of situation, the early challenge is to understand the flow of the pit and what is actually happening, and the only way to do this is to go out in the pit to observe the process in action. Typically, we have seen that as attainment to the mine plan drops, the natural response is to push more trucks and assets (cost) out into the pit. The logic behind this is that more trucks and equipment means more volume. However, this is a very slippery slope. Pulling more trucks into the pit to the detriment of any planned maintenance means a constant search for more trucks (in this case even starting up some old ones). Availabilities drop as planned maintenance is lost and production volume suffers. Ultimately costs increase while production decreases.

By delving into the facts of the process and flow, we are able to see, in many cases, that the larger number and mix of trucks actually causes bunching, with the newer, faster, and often bigger haul trucks delayed behind smaller, slower, older trucks. More trucks often just create more bunching with increased wait times -- and increased employee frustration -- at the loaders and dumps.

The solution requires a very bold step. Placing some of the trucks in maintenance removes them from this cycle, reduces bunching, and can sometimes increase - or at least not reduce – production volume. Relieving this congestion enables the mine managers to dig down into more detail to the next level of opportunity.

Knowing Where and When Equipment Should Be Ready to Go

The complexity and diversity inherent in the operation because of constantly changing mine conditions must be considered. This is where capacity planning plays an important role.

Capacity planning in its most basic form is math. Most mines know their cycle times - spot, load, haul, and dump times. These are often very well monitored through the use of a Mine Management System (MMS). But how this system provides real-time data that is

meaningfully reflected against a live plan that can change as circumstances change is the real challenge. Getting live data for the operating equipment through MMS to feed an improved OEE (Overall Equipment Effectiveness) is a step in the right direction. [3] This allows us to look at the shift and ask: Did we get the most out of the equipment?

In many cases the OEE is still based on some of the calculated optimums taken from the cycle time data, so the next level of detail needs to dig into what the optimum should have been for the changing conditions for that shift. To this a Capacity Model has added the ability to tie in pit conditions that allow us to evaluate how the pit performed with the varying equipment, in existing weather conditions.

It was important to make the interface between the capacity plan and the foreman easier if we wanted the tool to stay in place. This was accomplished through the use of "drag and drop" menu items. When configured, this tool allows supervisors to move equipment as quickly as pit conditions change and, from there, establish new optimum production goals. Foremen and dispatchers can look at the changing scenario in the pit and move their equipment around in a capacity plan to determine the best scenario. At the end of the shift, this can be used as a true reflection of what the optimum was, against which the actual production can be compared. This gives the pit crew credit not only when it has worked hard in difficult conditions, but also when it has pushed on easier days to not only exceed a level plan, but also achieve an extraordinary result.

In this way operations can work against a plan that reflects their actual situation, so they can achieve better results while at the same time working with maintenance and planning in a closer format to meet or exceed the mine plan - all at a reduced cost.

- By highlighting equipment and then assigning it to the specific bench for the day, the application calculates the maximum amount of material that can be moved from each site.
- Adding or removing resources automatically causes the shift's plan to update.

[3] Hansen, R. 2001. *Overall Equipment Effectiveness (OEE): A Powerful Production/Maintenance Tool for Increase*. Industrial Press. ISBN: 0831131381.

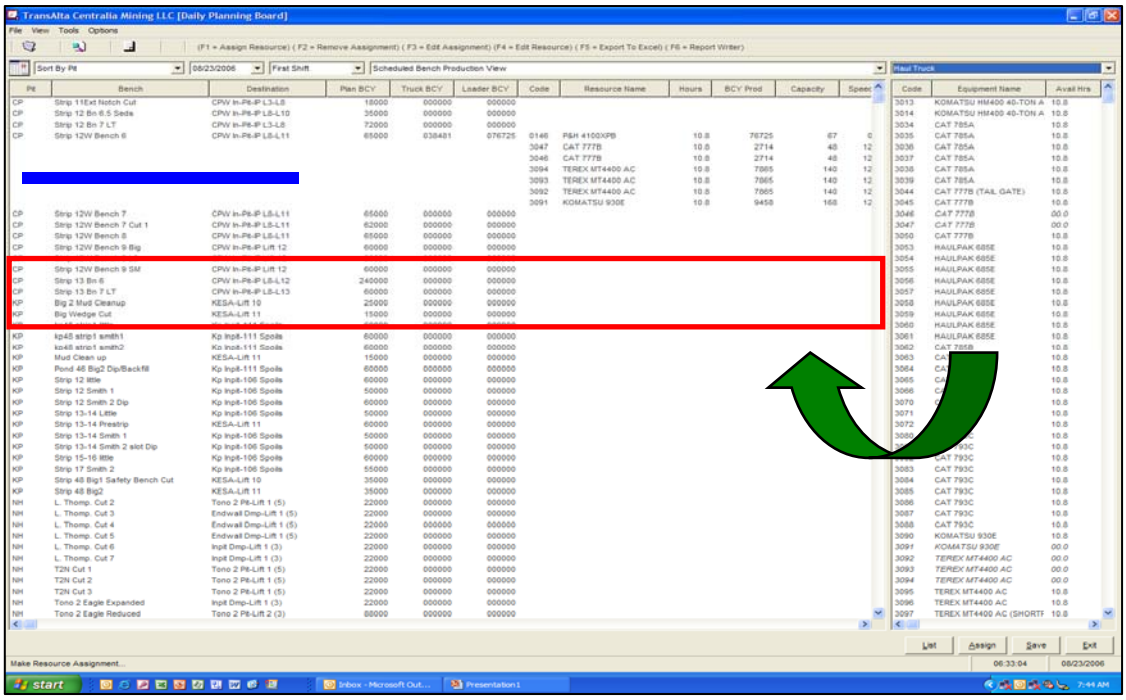
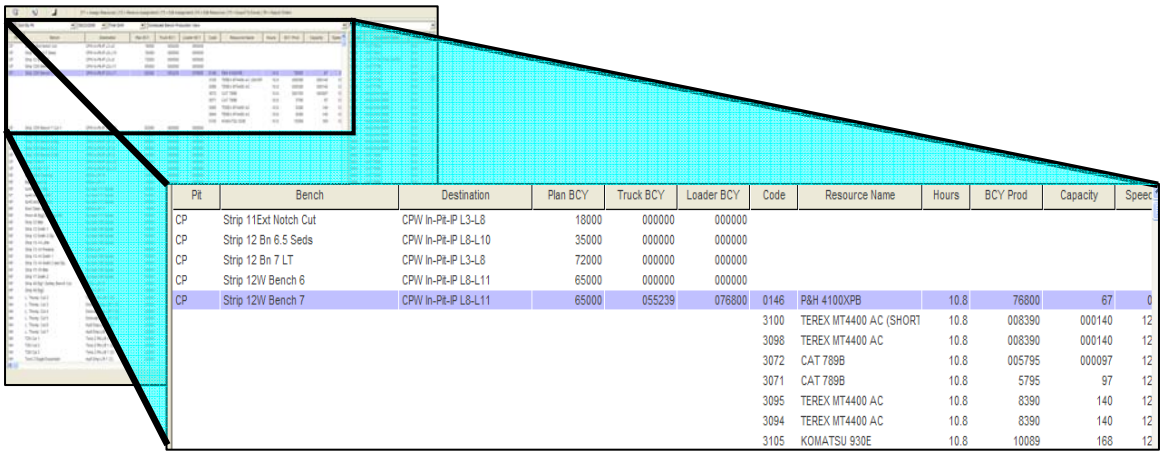


Figure 1: Capacity Plan example



Pit	Bench	Destination	Plan BCY	Truck BCY	Loader BCY	Code	Resource Name	Hours	BCY Prod	Capacity	Speed
CP	Strip 11Ext Notch Cut	CPW In-Pit-IP L3-L8	18000	000000	000000						
CP	Strip 12 Bn 6.5 Seds	CPW In-Pit-IP L8-L10	35000	000000	000000						
CP	Strip 12 Bn 7 LT	CPW In-Pit-IP L3-L8	72000	000000	000000						
CP	Strip 12W Bench 6	CPW In-Pit-IP L8-L11	65000	000000	000000						
CP	Strip 12W Bench 7	CPW In-Pit-IP L8-L11	65000	055239	076800	0146	P&H 4100XPB	10.8	76800	67	0
						3100	TEREX MT4400 AC (SHORT	10.8	008390	000140	12
						3098	TEREX MT4400 AC	10.8	008390	000140	12
						3072	CAT 789B	10.8	005795	000097	12
						3071	CAT 789B	10.8	5795	97	12
						3095	TEREX MT4400 AC	10.8	8390	140	12
						3094	TEREX MT4400 AC	10.8	8390	140	12
						3105	KOMATSU 930E	10.8	10089	168	12

Figure 2: Capacity Plan synopsis of one-day schedule for each dig site.

- After populating the planned efficiencies and hours for the equipment, the program gives a quick synopsis of the day's schedule for each dig site.
  - Scheduled Load Unit BCY is compared to Truck BCY to show if we are over or under trucking shovels.

- This helps to ensure that priority load units are maximized and shows which units can be "robbed" in order to hit the overall mine plan
- Will allow Goal-Seeking and "What-if …" scenarios to be run quickly and easily

CONCLUSION

The result of completing all these activities was a World Class Reliability and Mine Management System where:

. work was identified proactively;

. three major assets were templated for worldwide implementation in whole or on a component-by-component basis, resulting in ~1300 Failure Modes identified;

. three Core Teams were trained and are now capable of conducting additional analysis and training other Core Teams at other sites;

. 27 condition-based PM routes have been implemented;

. more than 500 people were educated in the Ivara® RCM2 and Ivara® MTA – Work Identification methodologies;

. a management operating system was installed throughout the mining sites;

. KPIs that reflect current operations provide better control of operations;

. attainment to production goals increased significantly as the capacity of existing equipment was maximized; and

. a management system was installed that ensured the optimum balance between attaining production and maintenance goals, and is adaptable to changing real-time circumstances.

Best of all, this mining company will realize a projected ROI of 3:1 over the next three years. This is based on dramatically improved reliability of every major asset, the happy result of integrating the benefits of an overhauled reliability system with a more informative and controllable operating system. The increase in availability will improve tonnage for all existing assets and allow for new assets to come online using the same reliability program. The company now has the knowledge and tools it needs to continue down the path of success.

References

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