ASSET OPTIMIZATION SYSTEMS: 5 LESSONS FROM 10 YEARS IN MINING

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ABSTRACT

Maintenance needs information about assets to optimize availability and production needs information about performance and consumption to maximize output. In considering both these needs together as, “Asset Optimization”, the information systems that support them are critical. The theory of Asset Optimization derives from the Lean Manufacturing concepts developed by Toyota, but some changes are required to apply this to mining operations. In particular, mining operations require automated systems due to their geographic spread and they need a strong emphasis on capturing under-performance losses as well as delays and stoppages in production.

Leading metal miners and coal miners alike have applied these systems to good effect in the last 10 years. The concepts developed initially in minerals processing plants are now being applied to the mines themselves as well as the mining logistics chain. Production increases of 5–10% are achievable with the right implementation and consideration of some key lessons learnt in the last 10 years. Putting these lessons into action is one key step in the goal of optimizing asset performance and thus utilizing the resource at lowest cost.

KEYWORDS

Asset Optimization, Efficiency, Downtime, Production, Maintenance

INTRODUCTION

The mining business is not getting easier any time soon. Major market trends are creating structural changes that are generating major challenges to mining companies. The basics of efficiency and productivity and the systems to achieve these goals however are still of major importance.

As Dr. Tony Filmer (2009) has stated, “As a price taker in a commodity industry, each mining and metals business is seeking to sustainably reduce unit costs and maximize tonnage from capital assets. Business success is based on accessing the best resource base, and then utilizing this resource at lowest cost.” A recent study by McKinsey (2012) however has shown that while investment in assets in Australia for example has increased remarkably in recent years, performance has not followed that investment. “The amount of capital per worked hour is 25% higher than it was six years ago – but workers on average are producing only 7% more output per hour.”

Mining companies are continually looking for ways to use information and systems to address these issues but typically face problems of many disparate pieces of information, data duplication and time wastage in data gathering and a lack of a global perspective on plant information trends. One recent typical review at a coal miner identified problems in the operational systems landscape as:

- applications landscape is complex and fragmented;
- there are significant data quality issues;
- considerable effort is spent moving data between applications; and
- access to data is neither timely or easy
While it is possible and indeed necessary to work on the overall information systems architecture, the one system that can provide immediate benefits across the complete mining supply chain is the asset optimization system (sometimes called the “downtime system” or the “delay accounting system”). Getting this system right will result in many benefits in all areas of mining. Asset performance is critical to production output, energy efficiency, recovery, environmental performance and schedule performance.

This paper will first review the theory and background to asset optimization in mining and then review two case studies from real implementations over the last 10 years. The last part of the paper presents five generalized lessons for success.

THEORY OF ASSET OPTIMIZATION IN MINING

What is Asset Optimization?

Lean management principles tell us that we need to continually seek out and eliminate waste. In an asset intensive operation like mining, asset performance is critical and eliminating asset performance losses are a major part of overall performance improvement. The goal is continuous operation and this is achieved when all losses are eliminated and asset performance is optimized.

The method for determining asset performance losses was established by Taiichi Ohno, one of the founders of the Toyota Production System as reported by Smalley (2006), Taiichi Ohno had people stand at the problem machine for the entire 8-h shift and record the production plan versus actual amount in small increments, such as 15 minutes to 1 h. At the end of the shift, all the losses and the actual reasons why were identified in a Pareto chart.”

Stops and delays are causes of losses because every time a process is stopped and started, losses are accrued:

- Ramp-up to production speed
- Start-up waste
- Extra wear on machine
- Overtime to catch up on production
- Energy losses
- Fixed Costs are amortised over less output
- Demurrage or train delay penalties

Dunstan et al. (2006) in a review of the applicability of Lean to mining have laid out some of the key differences between manufacturing (as in the Toyota Production System) and mining operations. Some of the key differences include:

- Production is continuous and around the clock
- The environment is often physically challenging for the operators – for example in a coal mine with a long wall operation
- Variable environment and variable raw materials
- Geographically spread out teams – the long wall team is underground in the mine for example

In mining then, while the principles laid out by Taiichi Ohno still hold, there are some unique considerations. Because production is continuous, slow running is equally important as stoppages. Causes of losses can come from many areas including materials, people, poor practices and even the weather (for instance, rain causes the top speed of the mobile fleet to reduce). The distances are large, so it is impossible to visually detect loss events. There must be strong integration to the automatic control systems to automatically detect issues.
Review of Asset Optimization Information Systems

We have seen that there is great benefit in mining from measurement of the losses due to stoppages (availability losses) and slow running (performance losses) (Figure 1).

A good Asset Optimization system ensures the mine or plant is operating at its peak efficiency by identifying where, how, and why production losses are occurring. By reporting scheduled and unscheduled events, as well as underperforming equipment, the system enables a complete analysis of causes of losses. This gives you the information you need to prioritize maintenance, improve operating procedures, and prioritize capital expenditure.

Automatic capture of loss events frees operators from paperwork and removes the inaccuracies and inconsistencies of manual systems. Complex issues are broken down into common causes, enabling continuous improvement in reducing costs and streamlining operations. Key features required from a system include:

- Data collection – Automatic record creation on occurrence of a downtime event or manual entry
- Editing and validation – Adding of additional details such as cause location, classification and cause code.
- Information validation business processes and workflows if desired
- Audit trails (to provide traceability if data is changed) and flexible security (to allow add/delete/edit access to appropriate people only)
- Ability to capture real (where production has ceased) or virtual downtime (slow running)
- Ability to capture time overruns or delays on maintenance or project activities, as well as continuous production
- Complex event capture conditions (e.g. “conveyor is running but motor is drawing low current”)
- Ability to automatically assign causes where possible from alarms and other process data
- Ability to split events (e.g., the plant is down for scheduled maintenance, but there are delays in re-starting for production reasons).
Presentation of information should include Pareto Analysis, Gantt Chart Analysis and Pie Chart Analysis (Figure 2), as well as flexible delivery of information by Report, Dashboard or Mobile App (Figure 3).

Figure 2 – Gantt Chart Analysis Chart for Asset Losses

Figure 3 – Mobile App Visualization

CASE STUDIES IN MINING ASSET OPTIMIZATION SYSTEMS

There is now 10 years experience of asset optimization systems in the mining industry. There is a documented record of these systems helping mining and resource companies increase productivity, asset utilisation and the business bottom line. This section of the paper reviews two case studies. These are BHP Billiton’s Cannington Mine and a major coal miner. Both of these cases are located in Australia with Cannington being one of the first mines to adopt these asset optimization techniques in the world. The coal mining example discusses a more recent implementation and shows how the method has been extended across the mining supply chain in recent years.

BHP Billiton Cannington Case Study

Located in North West Queensland, Australia, Cannington is a mining and processing operation and the world’s largest and lowest cost producer of silver and lead. In 2000, “Operating Excellence”, (OE),
a Six Sigma common improvement language and methodology was introduced across what was then BHP, to generate consistency, rigor, discipline and data-analysis into the decision-making processes.

Using the OE methodology, in 2001, Cannington chartered a project to reduce unscheduled stoppages at its processing plant and achieve AUD$1 million in savings over a two-year period. Having determined that the usability and richness of information available from its legacy systems would not suffice in its current state, Cannington worked with Citect (now part of Schneider Electric) to implement new supporting systems.

An OE coach who had completed training in the use of the Six Sigma quality process and tools led the project. In keeping with a key Cannington business strategy; “make decisions, based on knowledge”, the project was aimed at allowing users to drill down and analyze root causes of downtime, and prioritize maintenance or improvement projects to optimize uptime. With the right information, the site could more accurately measure the availability of different process areas, and analyze equipment performance and production patterns to begin improving plant process performance. Using this methodology, Cannington could compare availability of different process areas, and then drill-down into each area to identify the main causes of downtime within that area. This would then allow isolation and resolution of the largest bottlenecks before moving on to the next one.

A key specification was that the new system be operator error proof so that automated reporting systems would not report on spurious data. This meant most data was gathered automatically and that manually entered data used for automated analysis, was entered via pick-lists rather than free-format text. If an operator entered data such as “Blocked Chute”, or different words to describe the same problem then the reports would be meaningless. Consistency of information was of critical importance to Cannington and was a key criterion of the new system.

When a loss event was captured, an automated notification was sent to operators to prompt them to enter information immediately. Data entry was much faster and more accurate using picklists. This process helped alleviate many data consistency problems that Cannington had experienced with previous systems. Once the operator completed data entry, it was available for confirmation by a supervisor. Once confirmed, the event was locked and an audit trail created for any further changes to the event details. The identity of the operator and supervisor are automatically captured by the system for validation. When updating the details of an event, operators can select Cause locations/equipment from the plant hierarchy, making navigation and data entry very simple. Cause codes and Classifications are then selected from picklists filtered for that location. The concept of classifications and causes is shown in Figure 4.
Coal Mining Case Study

This miner owns and operates multiple mines and a ship-loading terminal. With the exception of two underground longwall operations, the mines are open-cut, using dragline and truck/shovel fleets for overburden removal. The asset optimization system was first implemented in several coal wash plants. Significant effort was made in change management. Changing operator behavior is just as important as maintenance and capital upgrades in achieving asset optimization. One of the key initiatives was to give operators access to the monetary impact of losses. Five minutes delay may not mean much to most operators, but 150 t of lost throughput at approx $100/t may have a little more meaning and focuses attention on real opportunities for improvement. Operators also use this “real $” figure as a shift-to-shift measure of their performance and take pride in improving their shift or crew performance above others.

Since implementation, managers have seen a positive change in operator behavior and site morale. Production crews are paying attention to other crew’s numbers as the solution is delivering a broader perspective of the overall business. The contribution of better asset performance is more easily seen. The system has consistently assisted in achieving an improved throughput of 5–10% and following that success in the plant, the asset optimization concept has been pushed both, back to the mine itself and forward to the materials handling process, as well as across disciplines to the maintenance area. In this way the entire mining supply chain is being optimized, not just the plant. Tables 1–3 give details on how the concept is applied in the mine itself (longwall operations), for maintenance decision making and in the logistics chain (train load out).

Table 1 – Shearer operation

<table>
<thead>
<tr>
<th>Issue</th>
<th>Asset Optimization Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Issue</td>
<td>Variation in the operation of the Longwall resulting in fewer shears per shift and lost potential coal. Potential benefits from targeted training &amp; feedback to crews.</td>
</tr>
<tr>
<td>Data Required</td>
<td>Identification of the duration of Gate end turns, Shearer cuts, Flint cuts and cleanup cuts for each shift. Number of shears per shift, tonnes per shearer cycle.</td>
</tr>
<tr>
<td>Proposed Solution</td>
<td>Automatic capture of longwall delays and periods of below/above target running. Identify specific examples of significant variations to ideal practices (long turnarounds, over recommended shearer speed). Calculate the extent of variation in a shift and provide feedback and training to the crew. Share best practices in Longwall operation across crews and mines.</td>
</tr>
</tbody>
</table>
| How does asset optimization system help? | By automatically capturing:  
| | • Periods of longwall stoppage  
| | • Duration of turns, shear, flit & cleanups for each Shearer pass.  
| | • Automatic creation of KPI’s for detailed LW performance.  
| | • Automated shift reporting. |

Table 2 – Using Information to Make Better Maintenance Decisions

<table>
<thead>
<tr>
<th>Issue</th>
<th>Asset Optimization Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Issue</td>
<td>Damage occurred to a large conveyor belt feeding the plant. The belt was repaired with belt clips as a temporary measure whilst a new belt was ordered. This meant that the belt could not be run at full speed and that insufficient coal was being fed to the plant.</td>
</tr>
<tr>
<td>Data Required</td>
<td>Impact of slow running in terms of tonnage, also in terms of $ on a real time basis.</td>
</tr>
<tr>
<td>Proposed Solution</td>
<td>By tracking the lost production due to the slow running of the temporarily repaired belt the operations and maintenance staff were able to show that the cost of holding a replacement belt was economically justified.</td>
</tr>
<tr>
<td>How does asset optimization system help?</td>
<td>By automatically capturing lost tonnage due to slow running and automatically converting those losses to $ losses visible to senior management.</td>
</tr>
</tbody>
</table>
Table 3 – Train loading

<table>
<thead>
<tr>
<th>Issue</th>
<th>Asset Optimization Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Issue</td>
<td>Underloaded trains are arriving at the washery. Waste of limited rail resources and adds to stockpile full downtime at the mine.</td>
</tr>
<tr>
<td>Data Required</td>
<td>Exactly how much coal is being carried on each train and what is the opportunity for extra coal with no extra train trips?</td>
</tr>
<tr>
<td>Proposed Solution</td>
<td>Ensure that train loads are within -5% of 1300 t load limit. Identify the circumstances or behaviors that lead to under loading and eliminate them.</td>
</tr>
<tr>
<td>How does the asset</td>
<td>By automatically capturing a record per train of time, duration &amp; tonnes the amount of under loading is measured objectively. Specific trains (time, crew, stockpile level) are isolated enabling effective investigation and commenting. Generating a shift/day/week/month average and including it in reports any drift back to under loading is highlighted immediately.</td>
</tr>
<tr>
<td>optimization system help?</td>
<td></td>
</tr>
</tbody>
</table>

5 LESSONS FOR ACHIEVING SUCCESS WITH ASSET OPTIMIZATION

The experience of 10 years in case studies like those above has yielded five key lessons for achieving success with asset optimization systems. These lessons are summarized as follows:

1. The Asset Optimization system is not just a “fault recording system”, but also an identifier of business improvement opportunities. Following an understanding of “Lean” concepts, it is the driver of asset performance improvement.

2. Spreadsheets do not work sustainably. Whilst being a flexible and powerful analysis tool, there are too many problems to rely on spreadsheets in a production environment. Some of these problems include manual entry errors, version control, lack of transparency, and no audit trail for manual changes.

3. When implementing Asset Optimization, take the opportunity to re-integrate the production, maintenance and energy departments. One of the barriers to a more co-operative relationship has been disconnected information systems. New systems remove the “gap” and can be used to provide the elusive “one source of the truth” to drive global improvement.

4. Advanced Planning and Scheduling will not work without reliable capability. Whilst new tools incorporating the latest optimization methods are available to globally optimize schedules, these tools will be less than successful if the assets in the supply chain do not perform reliably.

5. New technology can do many things, technology is easy, but organisational change is hard. Implementation of an Asset Optimization system will change work practices in the organization. There is a need to invest solidly in change management.

Understanding Asset Optimization

The Downtime system is not just a “fault recording system”, but an asset productivity system and a business improvement opportunity system. Management needs to understand and support the process and not expect a “silver bullet”.

Following lean principles, “stabilise first is the first principle”. If the process is not stable, tonnes output will be lower than is possible. If the process is not stable, it will be difficult or impossible to isolate cause and effect relationships, which makes improvements difficult. After stabilization is achieved, focus can be placed on developing one way to run a process by setting standards for start up, ramp up, operation and shut down. This involves establishing what the key critical control variables are, and in what range they should operate and developing training material and management systems to lock in the methods. The cycle is then repeated as improved methods are trialed then adopted.
The continuous improvement cycle assumes that the change implemented by a team becomes permanent and the basis for a new round of improvements. Unfortunately, this is not always the case. A key obstacle is “sliding back to the old ways”. This unravels the project’s stated benefit and removes the basis for further improvement. This “sliding back” is particular problem with manual business processes - particularly when the change involves people who were not members of the team. How does one transfer the understanding and acceptance of a change to others? This is further exasperated if the other people are beyond “line of sight” in another depart or shift. On the other hand, software systems provide automated business processes that broadly communicate and enforce the change. All the people affected see the change and the effect can be made across multiple business systems.

**Spreadsheets Don’t Work Sustainably**

Whilst spreadsheets are a flexible and powerful analysis tool, there are too many problems (manual entry errors, version control, lack of transparency, too easy to manipulate) to rely on spreadsheets in a production environment. The issues with spreadsheets can be illustrated by noting the manual shift log shown in Figure 5. Times are rounded to the nearest 15 minutes and some descriptions make sense only to the writer (“trouble same as start of shift”). In a typical effort at analysis, these sheets would be collected and transposed to a spreadsheet, thus inviting further loss of precision and accuracy through the transposition process. As spreadsheets are combined with other spreadsheets for further analysis (downtime, production, energy consumption for example), timeliness and data trustworthiness are lost. This leads to further losses in “challenging the data”.

![Figure 5 – Manual shift log from coal mining operation](image)

A system is required that is automatic, timely and trusted information. An example of this is automatic shift reporting that is available immediately after the end of shift (see Figure 6).
Use One Truth to Drive People Integration

Though not a universal rule, the relationship between maintenance and operations can often be less than harmonious. At a review meeting analyzing why targets have not been met, the answer from operations might be “delays caused by equipment breakdowns and slow maintenance response.” The Maintenance viewpoint might be “poor operating practices and lack of access for preventive work.” The asset optimization system can be used as the “one source of the truth” to forge a new working relationship focused on real improvement as discussed in the coal mining case study above.

Other Optimization Depends on Asset Performance

Advanced Planning and Scheduling systems are starting to make an impact on mining operations (for example, see www.solveitsoftware.com). An example of an optimized schedule is shown in Figure 7. These systems offer tremendous improvement in co-ordination across an operations, but may be for nought without reliable performance from the operations. This consideration also applied to other kinds of optimization (such as that aimed at recovery or spare parts optimization for example). Consider that asset optimization systems should be deployed first, as the basis for all performance lies in asset performance.
**Invest in Change Management**

As in all systems improvement efforts, the key problem today is not technical, but rather one of change management. As Machiavelli noted in 1532, “There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.” If information is timely, reliable and accurate, the key is to channel the newly available energy into productive efforts to utilize that information. The technology is now readily available, but, of course, this information does not reduce the role of people in utilizing the technology.

There is much literature on change management available, but one of the key initiatives that can be taken is to establish work processes that “institutionalize” the new way of working. Typically, for asset optimization systems, a good set of work practices is shown in Table 4.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Actions</th>
</tr>
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</table>
| **Shift**  | Stoppage records are completed by operator  
Verified by the Shift Supervisor |
| **Day**    | Stoppage records are checked by relevant engineer or process owner and modified as required |
| **Week**   | Weekly stoppage data is collected and reviewed at stoppage meeting  
Stoppage Review Group (all engineers and supervisors and Process and Reliability Managers) analyse stoppage records together and actions are assigned to complete based on equipment priority  
Minutes are tabled and sent out with these actions and tracked for completion  
Stoppage investigations are completed according to priority |
| **Month**  | Pareto charts by count and duration are tabled and analyzed to ensure that actions are captured for the reason for stoppages. |
| **Quarter**| Cumulative Pareto charts by count and duration are reviewed by the Process and Reliability Managers to ensure that problems are fixed |

**CONCLUSIONS**

There is now 10 years experience with Asset Optimization systems in mining. Significant benefits are shown in many operations around the world. Implemented in conjunction with a continuous improvement process, these systems have proven a consistent benefit of 5% to 10% improvement in production.

Leading miners are now extending these systems up and downstream, to provide information on the bottlenecks and losses in the entire mining delivery chain. With a consistent process and consistent system across the value chain, operators, engineers and managers can start identifying and implementing the next round of improvements and productivity gains.

The steps to achieve success are known, and lessons include:
1. Understanding Asset Optimization  
2. Spreadsheets Don’t Work Sustainably  
3. Use One Truth to Drive People Integration  
4. Other Optimization Depends on Asset Performance  
5. Invest in Change Management

Putting these lessons into action is one step in the goal of utilizing the resource at lowest cost.
REFERENCES


