Implementing Multi-Site Engineered Maintenance Plans

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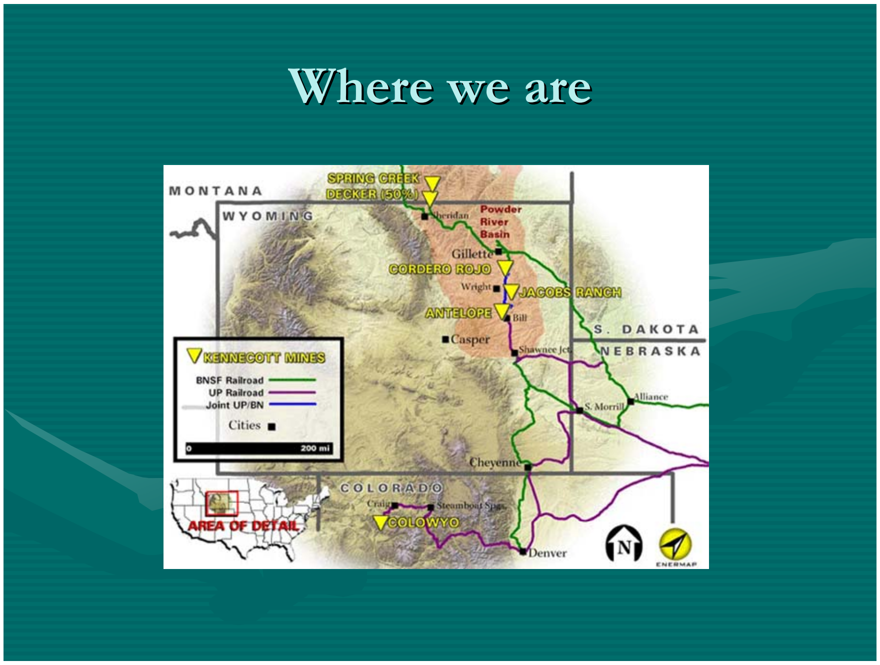
Abstract

This paper describes the approach used by Rio Tinto Energy Americas to revamp the Komatsu 830E 240 ton haul truck maintenance plans. RTEA has five mine sites spread over 500 square miles from the Powder River Basin of Wyoming to the Western Slope of the Colorado Rockies, with 140 haul trucks among those sites. These are large, off-road trucks with replacement values in the range of $3mm each. The best practice for initiating or modifying a maintenance program is to use a systematic process such as Failure Modes and Effects Analysis (FMEA). Combining FMEA with failure cause severity and probability of failures provides a means to prioritize where maintenance resources can be best applied. Planned Maintenance Optimization (PMO) is used to define maintenance tasks for the highest priority failure causes.

The project used a systematic approach, combined with a cross –functional team of experts that were able to gain support. Having the maintenance plans defined does not ensure the tasks will be carried out, and geographic challenges must be dealt with, as well as issues with direction coming from outside the property. Site maintenance managers and experienced maintainers must be viewed as stakeholders in rolling out maintenance plans. A cross functional team approach increased mine site buy-in and resulted in common planned maintenance tasks across multiple sites.



Where we are

Who we are

Colowyo Mine in Northwest Colorado produces 6 mm tons of high quality, low-sulfur coal annually; relatively high strip ratio, mountainous area, long winters. Colowyo operates 3 draglines, one large stripping shovel, and a fleet of loaders as primary loading tools. They move about 70 million yards of material annually with a fleet of primarily 240 ton trucks. Of these, six are Komatsu 830E. Some 6500 man-hours' of technical labor are dedicated to maintenance and repair of these machines.

Antelope Mine in Northeast Wyoming produces 36 mm tons of low-sulfur steam coal. The area is arid; rolling plains, mesas, canyons, and the mine straddles Antelope Creek, a tributary of the Cheyenne River. Antelope operates one large dragline, two 120 ton class stripping shovels, and three smaller shovels. Their loading fleet is complemented by two 55 yd front end loaders. A fleet of 36 trucks, 240 ton class, provides the haulage necessary. All are Komatsu 830E trucks. Antelope mine moves nearly 150 mm units annually (yards of dirt and tons of coal). We anticipate an annual investment of approximately 40,000 man-hours of technical labor in maintenance of the truck fleet.

Jacobs Ranch Mine operates in similar geographic and geologic conditions in Northeast Wyoming. One large dragline (115 yard bucket) and four large stripping shovels (80 to 120 ton machines) provide primary overburden removal; four smaller shovels (40 ton class) are primary coal loaders, supplemented by large front end loaders. Jacobs Ranch operates 43 trucks, 240 ton machines, as a haulage fleet, 35 of which are Komatsu 830Es. Approximately 220 million units annual production are required. The Komatsu 830E fleet will consume some 38,000 man hours of technical labor annually.

Cordero-Rojo Mine, a few miles north, does most stripping with three large capacity draglines. Pre-stripping is accomplished with three 60 ton class shovels. Cordero produces in excess of 40 mm tons of low-sulphur coal which is loaded by 4 shovels, 40 ton class. Cordero runs 38 trucks at 240 ton (Komatsu 830Es), and three at 190 ton as temporary surge capacity. Cordero exceeds 200 mm units annual production. Some 42,000 man hours technical labor is required to maintain the 830E fleet.

Spring Creek Mine in South Eastern Montana produces 20 mm tons of very high quality low-sulphur coal. Stripping is primarily accomplished with two draglines (60 yd and 40 yd class), supplemented by a 40 ton class shovel. A second shovel of the same capacity is the primary coal loader, supplemented by front end loaders. Spring Creek's annual production requirements are 80 mm units. They operate eight 240 ton trucks as well as a couple of 190 ton mechanical trucks to provide surge capacity. These machines are forecast to consume some 8,800 service man-hours.

The target of this improvement project was the fleet of 123 Komatsu 830E trucks; replacement cost of these trucks is in the range of $3mm each, and each truck will move approximately 3.5mm yards of dirt or tons of coal annually. The numbers add up; replacement cost of the fleet would be approximately $370mm, and the total units moved would equate some 430 mm tons annually. In total, we expect to invest in excess of 125,000 man-hours of technical labor annually to maintain the fleet.

Past improvement initiatives relative to this fleet have delivered results in some cases, but these results have varied from site to site and have not always been sustainable. We determined that a single project, by which we would select, design, and apply specific methodologies across all sites, would be more likely to produce universal, sustainable results.

We employed a “custom” maintenance program at each site; several service tasks were performed at varied frequencies; tasks performed at some sites were not done at all at others; there was almost no standardization for specific tasks, and little task standardization between sites. Performance, from an MTBF and availability standpoint, was generally similar between sites, although the distribution of downtime causes varied dramatically. This indicated that each site was addressing some issues adequately, while some were not being managed appropriately. The performance gaps were different at every site. An analysis of the variances between methods indicated that some tasks were inadequate, some were not employed at all, and some were not adding value to the process as they were unnecessary or were being duplicated by different work groups.

Several internal reviews were conducted to determine the potential value of process improvements. From an Asset Management perspective, the goal is to ensure that each machine can spend as much time as possible producing the capacity at which it is rated.

We identified two specific inadequacies with our current process; first, we did not have adequate data to understand the required repair maintenance that would be required at each scheduled outage. This typically resulted in the necessity to initiate repair work that had not been planned and for which parts or labor may not be available, with the result that additional downtime would be necessary to complete the work, and that the machines would not return to service as scheduled. It was necessary to ensure that the inspection tasks were actually identifying degradation of components far enough in advance to allow the jobs to be planned and resourced.

Second, we were consuming a standard amount of inspection time for each maintenance outage, and this time was not delivering quality information. We found that much of the time being spent was not being well spent, and believed that there would be additional repair time available if we re-engineered many of the inspection tasks.

Our goal was to improve inspection and routine maintenance quality, thus allowing increased operating hours per machine, without increasing the amount of labor being invested in the process. We determined that a full Failure Modes, Effects, and Criticality Analysis would be necessary to provide the foundation for Planned Maintenance Optimization. Several consultants were considered and a number of interviews conducted prior to selection of Alidade MER to lead the project.

The Process for Identifying Significant Failure Causes

An overview of the process was presented to the team by the facilitator. The overview covers the processes that align the team on the system to be analyzed. This includes determining the system boundary, drafting the system description, creating a functional block diagram, drafting descriptions of sub-system functions and creating a matrix of sub-system functional failures and the assets within sub-systems that contribute to significant functional failures.

After understanding the system and its assets, the process continues by selecting a pilot sub-system for team analysis. We analyzed the pilot system first as a group to ensure the FMECA process was understood and team members develop confidence in the approach. The pilot sub-system is then systematically analyzed using the process described below.

After the pilot system has been completed, the team was divided into two or more sub-teams. Each sub-team selected sub-systems to run through the FMECA process. The sub-teams were asked to complete analysis for several failure causes. After several failure causes had been analyzed each sub-team presented their analysis to the entire team. In this way the group was able to discuss differences and come to common practice in the analysis. Then sub-teams regrouped to complete their sub-system analysis; any unusual or unclear issues were brought to the facilitator or the full team for discussion and resolution.

The process steps are shown in the process flow chart found at the end of this paper. The steps for the actual FMECA analysis are:

1. Define the system boundary.
2. Develop a system description.
3. Create a functional block diagram.
4. Develop the sub-system descriptions.
5. Develop sub-system functional failures.
6. Create the functional failures and asset matrix.
7. Develop the asset/component failure modes.
8. Develop asset/component failure causes.
9. Develop asset/component failure effects.
10. Develop a risk prioritization and failure cause detectability value.

It is important to clearly define where the system begins and ends. When defining the system boundary judgment should be used when determining the scope of the analysis. Every FMECA project has limited time and resources, so selecting the boundary allow you to manage the project scope. Determination of boundaries can be adjusted during the course of the analysis as new information becomes known or as the team's perspective changes. We also need to make sure that assets that are on the boundary are clearly identified as being in the system or not being in the system; this is common for switchgear, valves and similar assets. Some assets that enter the system boundary may be part of central services, or may be part of control and monitoring systems. These must be declared to be in the system, or not. Central services should be considered for separate analysis but in any case they need to be clearly addressed in the boundary discussion.

After the system boundary has been established we can describe what the system is supposed to provide to the users. The main purpose of this step is to determine what the functions of the system are, and what the associated performance standards are in the systems operating phases. In addition to specifying what the users want the system to do, we must also determine if the system is capable of doing what is being asked of the system in its operating phases. When developing the system description it is beneficial to have technical publications and system drawings.

There are two categories of performance standards; primary and secondary functions. Primary functions describe why the system, sub-system or asset was acquired. Primary functions deal with system capabilities such as speed, output, carrying or storage capacity, product quality and throughput. Secondary functions are the functions that users expect beyond its primary functions. These are issues such as safety, control, containment, comfort, structural integrity, economy, protection, efficiency of operation, compliance with environmental regulations and appearance.

Functional block diagrams are top-level representations of the major functions that the system performs. The blocks are labeled as the functional sub-systems. The block diagram is composed only with functions; not equipment or assets names. Groups of assets or assemblies make up the sub-systems, but at this point we want to identify the system and sub-system functions that will need to be preserved for the system to perform to standards.

Arrows are added in the diagram denoting interfaces and interconnections. Interfaces are the inputs and outputs that cross the system boundary. Interconnections are inputs and outputs that occur between sub-system functions. The functional block diagram outward pointing interfaces and interconnections provide the primary functions that must be preserved.

Breaking systems into sub-systems and analyzing them by sub-system makes the analysis more manageable. As a rule of thumb, systems should be broken down into four to eight sub-systems. More complex functional block diagrams can be used, but it makes tracking status more difficult. Consider making complicated systems into multiple systems and linking them in a higher level functional block diagram. Input and output interfaces and interconnections must be explicit in terms of the element that crosses the boundary or goes between sub-system blocks. During the FMECA analysis assume that all input interfaces and interconnections are delivered at specified performance standards to the sub-system as the analysis is done; for instance the correct electrical power is supplied to a transformer or motor from the outside source.

Use software, a large whiteboard or flip chart that allows the team to discuss the block diagram as it is being developed. Microsoft Visio or other graphics based software is preferred because you can capture the information, edit on the fly, and print if for inclusion in project documentation.

Sub-system blocks have a similar process applied to describe sub-system description as was performed for system descriptions. We need to know primary and secondary functions so that we can evaluate significant sub-system functional failures. The FMECA spreadsheet should have a tab for documenting the sub-system functional description statement and the interconnections. A new spreadsheet tab will be generated for each sub-system.

Next we link the sub-systems with the assets that make up the sub-systems. There should be one tab in the FMECA spreadsheet that identifies the assets associated with each sub-system. This step is a critical step in the analysis. The matrix provides a means to identify the assets that will have one or more failure modes associated with significant sub-system and system functional failures. It becomes the object of the FMECA process.

It is most appropriate to define failure in terms of the loss of specific functions rather than the failure of the asset as a whole. We use the term "functional failure" to describe failed states. When we identify functional failures, we are then able to distinguish between the causes of those functional failures. When we have specific failure causes we can develop plans to deal with those causes. With this understanding we can develop a definition for functional failure:

The inability to fulfill a function to a standard of performance which is acceptable to the user.

A common mistake in FMECA and RCM is to do the analysis in too much detail. Beyond a certain point analysis is either unproductive or not worth the time relative to the significance of the event. A great deal of time can be lost in digging too deep.

Functional failures can come in different forms; such as partial or total failure. Partial failures occur when the asset does not perform a function up to the standards of performance expected. An example would be when a pump is supposed to provide 150 gpm of fluid at 60 psig, but only achieves 150 gpm at 25 psig. Total failure would occur when the same pump was unable to provide any fluid flow. After determining the functional failures for the sub-system we must then relate the sub-system assets with those functional failures. With the sub-system functional failures identified and the assets that are related to those functional failures linked we have the information needed to complete the FMECA.

In conducting FMECA we are concerned with <u>significant</u> failure modes; not all possible failure modes. Failure modes, which are those that have occurred or those that are probable but may not have occurred, are a major part of significant failure modes. Significant failure modes are likely failure modes plus failure modes that have unacceptably high consequences, even if not likely. When we combine judgment and available data we can arrive at appropriate levels of failure mode analysis. The distinction between all failure modes and significant failure modes allows the FMECA to be bounded and not suffer from analysis-paralysis. We define failure mode as:

Any event which results in a functional failure.

To arrive at the failure modes it is common practice to list the asset/component functional failures, then to list the failure modes that can result in those functional failures. In describing failure modes we must attribute them to a physical event. Examples:

- Primary Functional Failure: Fails to pump any fluid
    - Failure Mode 1: Pump shaft broken
    - Failure Mode 2: Pump drive motor bearing seized
- Secondary Functional Failure: Fails to contain fluid
    - Failure Mode 1: Pump shaft seal failure
    - Failure Mode 2: Pump housing erosion/corrosion

There can of course be multiple failure modes for each functional failure; even for the same asset/component.

Failure causes identify the means that resulted in the functional failure. Each failure mode can have multiple failure causes. Again, we must apply judgment to keep from over-analyzing the assets. Failure cause refers to the mechanism that leads to the failure mode. Example:

- Failure Mode: Pump shaft broken
    - Failure Cause 1: Pump to drive motor misaligned

- Failure Mode: Pump fails to contain fluid
    - Failure Cause: Pump shaft mechanical seal worn

If we have a clear understanding of the physics of failure we may be able to eliminate or reduce the frequency of the failure mode through re-design, operating practices, and condition monitoring or other proactive maintenance tasks.

The Process for Prioritizing Prospective Maintenance Tasks

Each failure cause needs to be evaluated independently for the effect that the particular failure cause has. When evaluating the failure effects, the analysis must consider safety, regulatory (environmental, FDA, etc.), mission or production capacity and corrective action costs. Each of these four failure effect categories must also be considered at the local component level, at the system/sub-system level and the impact on the entire plant or cost center.

Once the failure effects have been considered there should be a brief narrative statement that describes the significant effects of the failure cause; such as “oil leak causes local safety hazard and process shut down”. The effects are then used for input to the risk prioritization process. A criticality value is developed by using a table of values, which is then combined into a severity rating. The combination of severity and assignment of probability provides a single value that will allow prioritization of failure causes; the single value is the risk prioritization number or RPN.

Once each failure cause has a RPN, the entire list of failure causes can be sorted by RPN in descending order. This allows the team to identify the most important failure causes to be assigned maintenance tasks. In this way, we ensure that the limited resources of the maintenance organization are aligned with the most important failures.

The final step of the FMECA is to determine detectability of the failure cause. This step might be performed as part of the FMECA or it could be part of the Planned Maintenance Optimization process described below. Detectability is defined as the likelihood that the operator or others would notice a developing failure before the functional failure occurs, or as it occurs. The use of detectability for FMECA on existing systems is helpful for developing a reliability management plan.

The detectability value can be used to determine if installing sensors, using predictive maintenance (PdM) technology or other activities should be considered. Implementing these activities may be considered if they provide sufficient notice of defects. Detectability is simply a means to begin the discussion on which planned maintenance task, if any, should be the first to consider when developing maintenance tasks.

Planned Maintenance Optimization: Validating the Benefit of the Tasks

Planned Maintenance Optimization (PMO) begins with selecting the target range of failure causes. The first step is to identify safety and regulatory related failure causes that have high criticality scores (in our case these were safety and regulatory scores of 4 or 5 on a 1 to 5 scale). For failures that have the potential for high safety and environmental impact we want to ensure there are tasks to reduce the impact or probability of these failures. Failure causes that had a 4 or 5 in the safety or regulatory criticality were included in the target range.

The second step is to sort the remaining failure causes in descending order from the highest to lowest product of severity x probability (RPN). We select a target range cut off point; typically the highest 25% to 35% of the RPN ranking to start with. Other values for the target range are acceptable; it is a judgment call. If more resources are available the team can select more failure causes by going lower in the ranking.

From the failure causes in the target range, sort them by sub-system, then by asset to systematically evaluate each failure cause. The PMO process consists of the following steps; a flow chart of the PMO process is included at the end of this paper:

1. Identify prospective task type and classify the task (start with the detectability value).
2. Determine if the task type is applicable.
3. Determine if the task will be cost effective.
4. Document the optimized tasks; which may be run-to-failure.

The table below provides an example of how tasks can be classified. Because different types of defects are more appropriately addressed by specific types of maintenance, it is important to select the right task type. For instance, it is inappropriate to address random failure causes using time based maintenance. Random failure causes are best dealt with through condition based maintenance. Infant mortality is best dealt with through precision maintenance. Age related failures are best addressed through time based or frequency based maintenance tasks.

Task Classification

Type	Time Based	Condition Based	Failure Finding	Servicing	Lubrication
Objective	Renew or replace on a time or number of events basis	Monitor a condition relative to a standard.	Dedicated task to determine if a failure has occurred.	Clean or replenish a consumable substance	Provide lubrication
Code	TB, FB	CBh, CBp, CBi	FF	S	L
When Used	When there is a predictable Wear out period	When a defined condition can indicate a developing defect in time to avoid unplanned downtime	When off line or hidden defects result in failures; typically testing of safety or protective devices	When there is a need to restore system efficiency, removal of moisture/dirt, (blow down air tanks, clean strainers, etc.) etc.	When appropriate to reduce the rate of wear and friction (oil, grease or other lubricant)

We then determine if the prospective task is applicable by determining if the task can identify a defect in time to avoid unplanned downtime, can identify a hidden failure or can restore the condition of an asset to its inherent reliability. For the prospective task, go to the task type column and determine if the task satisfies the applicability descriptions.

If the task does not satisfy the applicability rules for the prospective task type selected, one of the following actions are to be completed:

- Modify the prospective task to an applicable task
- Consider redesign of the system to reduce likelihood or impact of failure
- Consider deleting the task and accept run-to-failure as an outcome

The table below indicates the applicability rules applied to this project:

Task Type	**Applicability Description**
Time Based, Frequency Based	• Probability of failure increases at a specific age for all units in the population (wear out) • Large portion of population survives to a particular age • Task restores original resistance to failure; with negligible or no infant mortality
Condition Based	• A measureable characteristic corresponding to the specific failure cause can be identified • That characteristic can be measured accurately and consistently • Enough time exists between potential and actual failure so that corrective actions can be planned and scheduled
Failure Finding	• Failure is not evident to the operator • No applicable and effective time based, frequency based or condition based task can be done
Servicing & Lubrication	• Applicable by default • Ensure these tasks are well defined and reduce or eliminate the introduction of defects; dirt, wrong lubricant, etc
Safety & Regulatory Requirement	• Safety or environmentally required procedure • Regulatory procedure (FDA, OSHA, MSHA, etc.) • No better alternative can be approved

Next we determine if the task is cost effective. The task is cost effective if it increases the probability of acceptable performance at a cost that does not exceed the cost of running to failure. In order to determine cost effectiveness the team should use estimated values for task accomplishment, lost operational availability, materials, contractors, loaded labor rates and duration of outages (for planned and unplanned tasks). Evaluation of cost effectiveness should be based on annualized data. Note that usually there is imperfect information on costs. Therefore we must estimate these values.

If the task does not satisfy the effectiveness rules the following actions can/should be considered:

- Extend the time between task scheduling (periodicity)
- Sampling versus 100% inspection
- Convert to situational versus calendar based inspections
- Use an alternative, lower life cycle cost maintenance task

An important part of the PMO process is to eliminate maintenance tasks that are not in target range. These are no-value or limited value tasks based on the failure cause prioritization and available resources. No-value or limited value tasks are removed from the maintenance task list and placed in a deactivated task list.

Results are compiled by reviewing the tasks that are to be deleted/deactivated, those that have been modified and those that will be added. Double check the decisions. For the tasks that are to be modified or added, ensure the specific task descriptions are complete.

With the draft tasks specified create the standard format maintenance tasks. Assign task items to crafts and/or operator performed maintenance. Develop training for any new skills or tasks.

Total the hours for the original set of maintenance tasks. Total the hours for the revised set of maintenance tasks. Also, if available determine the baseline measures from the original maintenance plan regarding total downtime for planned maintenance and total downtime for unplanned maintenance. These will be use to determine the performance of revised planned maintenance tasks.

A final review and approval should be made by the site directors and site maintenance managers. This is an important step that results in the authorization to implement, but more importantly, high level support to implement. The review and approval should be completed in a timely manner to ensure the changes are implemented to capitalize on the effort.

Procure any tools or services necessary to support the revised maintenance plan. Provide training to operations and maintenance persons on any new requirements. Upload the modifications to the planned tasks into the computerized maintenance management software (CMMS) and place them on the schedule.

Measure and publish key performance measures to share status of the new plan.

Rio Tinto Energy America Haul Truck Project Results

The FMECA/PMO project was unique, in that we employed technicians, operator trainers and operators from all five mine properties. The FMECA portion of the project consumed three weeks, and the blend of personnel varied depending on which systems were being analyzed. Generally we had eight to ten personnel involved in the analysis team at any one time. There were eighteen people involved in the project at various points in the analysis.

We identified twenty-four unique systems that make up the Komatsu 830E haul truck. We analyzed a total of approximately 1,350 failure modes related to these systems, and condensed this to a final “failure mode count” of 1,116. The Planned Maintenance Optimization project focused on three-hundred thirty of these (30%) that were considered the most critical according to the analysis employed.

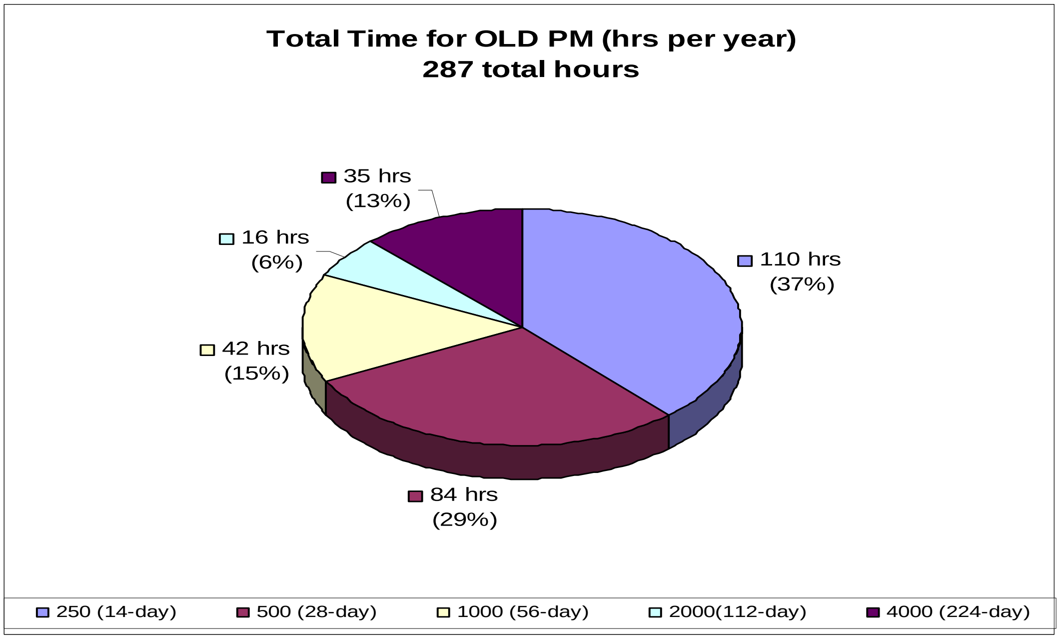
The PMO project was initiated immediately following the FMECA process. This project involved generally the same personnel that had been involved with the FMECA, but was completed in about 50% of the time. We spent a total of eight days developing the PMO with the same group of personnel, typically eight people at a time; generally, looking at each failure cause and finding an existing task that addressed it. If a task did exist, we examined it to ensure that the frequency met the standard developed in the FMECA, that there was a standard for the task (measurements, pressures, temperature, etc.), that the task was logically positioned in the range of tasks (location on the machine, etc.) and that we had a reasonable estimate of the effort and time involved. If no task existed, we built one.

When the tasks were grouped according to frequency, they were distributed to planners and inspectors at each property so these people could identify gaps that might be present, correct errors that may have been made relative to specific measurements, offer opinions relative to failure cause progressions (required frequencies), and determine whether the times allotted for each task seemed reasonable to them. This process consumed significant time but did result in a few modifications being made. These changes, in some cases, required a modification at the FMECA level; in some cases, they were simply an adjustment to the task description, measurement standard, or estimated time required.

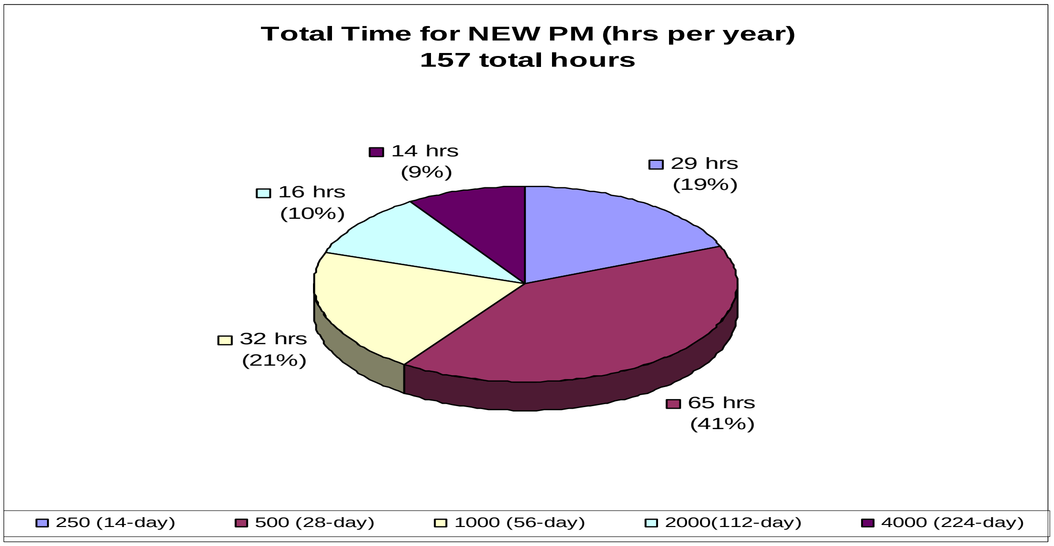
PM	Annual times	Mechanic Hours	Welder Hours	Electrical Hours	Old PM Avg Time (hr)	New PM Avg Time (hr)	Total Time for OLD PM (hr per year)	Total Time for NEW PM (hr per year)
250 (14-day)	11	8	0	2	10	2.67	110	29
500 (28-day)	6	8	2	4	14	10.79	84	65
1000 (56-day)	3	8	2	4	14	10.79	42	32
2000(112-day)	1	10	2	4	16	16.48	16	16
4000 (224-day)	1	24	6	5	35	14.46	35	14
						Total	**287**	**157**

% Difference New vs. Old = 45.2%

A significant change was found in the required time for inspection and routine service tasks for each machine; essentially, a reduction of 45%. The new tasks require 130 man-hours less labor annually.



The distribution of system requirements is shown in these graphs;



The implementation has occurred over the last six months, and the results have validated the assumptions on which the project was based. We have reduced the number of hours required to perform routine inspection and maintenance tasks, although we are performing some that were not being previously done at all, and some to a significantly higher standard. The benefit of reduced time requirements for those services has allowed more effective compliance to schedule; every site achieved 100% Preventive Maintenance Schedule compliance last quarter. Obviously, we will not give all the credit for that to the FMECA/PMO project, but it was an important component.

When all inspections and routine services are completed on time, there is time available to perform repairs; overall, availability of the Komatsu 830E fleet has improved. There are a number of issues that can affect the results; weather, parts availability, relative quality of operators or trainers, relative age of the fleet, etc. We have added newer machines to the fleet, but we have not replaced any older ones, so we believe the impact of the new machines is minimal. In the second and third quarters of this year, availability of the fleet improved by 1.2% over the same period last year.

A 1.2% change in this number accounts for some 8,500 hour's operating time, replacing more than 1.5 trucks, or eliminating the need to own that much capacity; calculated capital reduction is some $5mm. More importantly, the change in availability affects the 9% of the time the machines were out of service; a 1.5% reduction in downtime indicates that required downtime has been reduced by 13%, and no additional personnel or man-hours have been committed.

The success of this project has led us to the second major project, performance of an essentially identical process for the dragline fleet. These machines are massive, complex machines, so we have performed the initial FMECA on a specific machine and the tasks developed in the ensuing PMO have been rolled out at this time. We are in process of designing modified tasks for similar machines, to gain as much as we can through duplication of the early work.

In conclusion

The FMECA/PMO processes deliver results in a variety of areas. An unintended result was that the members of the project team, from various disciplines around various sites, gained a good deal of knowledge from each other, and appreciation of the work done by different work groups. The intended results are still being evaluated, but we can say that we have reduced the amount of maintenance labor required, and have reduced haul truck downtime. This has not translated into increased repair requirements; in fact, total maintenance requirements have decreased as well.

The success of the first project has caused us to move to the second (dragline) analysis, and we are now initiating a similar project at a fixed processing plant. We intend to leverage the experience we have gained and spread this methodology across all of our operations.

Increased reliability, reduced costs. Great project.