Criticality Analysis:
Reducing Critical Failures or their Effects

Course No: K05-005
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Introduction

I spent the final year of my Air Force service commitment serving an unaccompanied tour of duty in South Korea. The year I spent there nearly coincided with the twentieth anniversary of the end of the Korean war. At the end of the Korean war, the United States established a rotating military force made up of members of the Army and Air Force who each spent a year there before returning home.

At the time, it was not uncommon for the base where I was stationed to experience continual problems that required engineering solutions. When one of those problems occurred, it was not uncommon to hear someone say, “It is surprising that a problem like that should occur, after all we have been here for twenty years.” Just as often you would hear another person respond, “No, we have been here one-year, twenty times.”

The circumstance leading to ongoing problems described by this example is not uncommon in plants and other facilities that have been existence for longer than twenty years. While it is uncommon for the precise situation described in the example to exist, it is not uncommon to find plants and facilities that share similar results. It is a problem associated with the lack of continuity, detailed record keeping, and organizational learning.

Plants and other facilities are made up of thousands of equipment items and tens of thousands of individual components. Few of those components have the same usable life or mean-time-between-failure. And even fewer have useful lives and failures on the same schedules. Therefore, something is always failing and, unless there is a very dedicated and comprehensive record keeping system, the only ones who will learn from each failure are the individuals assigned to respond at the time of the failure. Going forward, the next generation of personnel will need to relearn the same lessons that have been learned, but were forgotten, in the past.

The alternate experience to the one described above would be one in which:

- A system or file in which all equipment items and their related components are identified.
- A system or file for each equipment item where critical characteristics are collected. This system of file would provide fields to collect the same elements as does a Fail Modes and Effects Analysis.
- A system or file that is automatically updated with the information collected during the design process and updated during the operational and maintenance life of each element.
- A system or file that is capable of being automatically updated as issues in the asset’s environment changes. These issues include the value of the product being made, the cost of resources needed to maintain the asset, environmental requirements, MTBF, MTTR, etc.
- A system or file that has the capability of producing the information needed to support future decisions that will be made by users of the system.

Many facilities have installed some form of enterprise resource management software (ERM) or enhanced Computer Maintenance Management System (CMMS) that is intended to provide a system for collecting the corporate memory needed to solve the problem of repeated failures. While those systems are very useful, they require several elements to be successful.

First, they require links to other systems that will automatically collect the information that is required. To make the automated data collection effective, it is necessary to design and organize the database in a way that mirrors the configuration of your assets and processes. That means you must perform many the same steps of analyzing your process and instrument diagrams or flow sheets to identify each and every one of the elements to be tracked as you would during a Criticality Analysis.

After the structure is has been assembled that provides memory locations for each of the desired data element, the next step is to fill each of those locations with data. This can be done in one of two ways. First, you can fill each field with the "best available" data, much the same as you would do when performing a Criticality Analysis. Or, as an alternative, you can wait for the fields to be filled based on your experiences during the following fer years.

Filling the ERM pr CMMS database with data coming from experience means that you will live with the same failures as you have in the past for another complete life cycle of all the elements. That means your performance may not improve for another ten years or so.

This strategy is not likely to benefit the person who implements it. But it will help the career of his or her replacement.

As an alternative, it is possible to perform a Criticality Analysis in a relative short amount of time using only simple spreadsheet software (Excel) and the best currently available information. While not perfect, the Criticality Analysis can continue to be used and corrected or improved long into the future. It will provide the physical basis for organizational learning and memory that does not currently exist.

In addition, if a future decision is made to install ERM software or modify the CMMS to collect failure data, the information and fields contained in the Criticality Analysis can be directly mapped and loaded into the corresponding fields of that software.

Much like swimming, many people like to dive into the process of problem-solving and improvement-making headfirst. Also, like many others who wish to avoid a broken neck when swimming, it is best to find out where the water is deepest versus where there are rocks near the surface. Criticality Analysis provides the kind of information collected by a cautious swimmer. For example:

- What items are most critical? (For instance, what is likely to cause outages?)
- Why are those items critical? (For instance, an outage will be extended by lack of spare parts.)
- What issues, while not the most critical are the most easily solved? (For instance, are problems caused by misunderstandings that can be corrected?)
- What are the common problems have systemic causes? (What practices when corrected will have multiple effects?)
- What parts or the facility are being undermaintained? (Are undermaintained utilities affecting numerous plants?)

Criticality Analysis provides the technique that can be applied at even small and simple facilities to answer those questions and help improve performance. The objective is to provide enough information on a single row of a spreadsheet to allow a scan of that row to identify both the equipment items that are likely to produce undesired effects and to also show where the current techniques being used to avoid those failures and effects seem to be inadequate.

As a way to supplement the effect of simply reviewing rows on the spreadsheet, a set of reports can be assembled that will point to instances where both the effects are unacceptable and current systems for avoiding them are inadequate.

Criticality Analysis – High Level Description

It is useful to begin by providing a high-level description of a Criticality Analysis in the process of being assembled. While this description, will be provided you with details of both the Criticality Analysis and the set of reports that will be helpful in using the information being assembled, it is best to begin with a look at the overall process from the 30,000-foot level.

1. *Selling the program and assembling resources*

As with any program that requires the investment of scarce resources, it begins with selling the idea to those individuals who control the needed resources. Selling is done by describing the process, the resources needed to perform the analysis, the benefits that are anticipated, the timeframe in which those benefits will be realized, and the cost/benefit relationship calculated in a way that can be compared to alternatives uses for the resources.

It is important not to oversell the program by exaggerating the results that are expected. It turns out that if the knowledge gained from a Criticality Analysis is properly applied, there is little need to overstate its value. Simply acting upon the opportunities uncovered by the analysis will provide a very attractive return on investment.

Once the program has been sold and the needed resources have been approved, the next step is to identify the individuals who will participate in the analysis. It is important to identify the individuals who have the needed knowledge and not simply those who are most available. If individuals with little experience or knowledge are used, it is likely that the analysis will be filled with guesses and conjecture. The results will be of little value.

2. *Training and gathering information*

The next step is to train all the participants on how the Criticality Analysis will be performed and the role they will be expected to play in the process. It will be best to perform simulations of the overall process as a part of the training. When individuals understand how the data will be used and how changes will be made, truly knowledgeable individuals will be excited for the possible outcomes.

Once trained, the participants should be allowed enough time to gather information. In some instances, participants will have kept records that can be used during the analysis. In other cases, participants may not have their own files but, they may know where the information is available. They should have time to gather the best sources of information possible.

3. *Creating spreadsheets and gathering reference information*

In preparing for the workshops, there are several things the facilitator must perform. The first is to create several spreadsheets.

The first spreadsheet, the Equipment Status spreadsheet, is one that lists all the required equipment information tracked by your current EDM or CMMS for items known to deteriorate and cause system failures. This spreadsheet is intended to provide a great deal of data that exists and is important to an accurate and efficient analysis but typically not kept in participants memories. It will include data like the Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR) and other information that is needed but frequently not known or recalled by participants. An example of this spreadsheet is provided in following pages.

The second, the Criticality Analysis spreadsheet, is the one that will be used to assemble information during workshop discussions. An example of this spreadsheet design is also provided in the following pages. (This spreadsheet is created by linking the partial spreadsheets that are provided herein together end-to-end.)

While the Criticality Analysis spreadsheet is organized in the order that equipment items are encountered working through the process and instrument diagrams or flow sheets, the Equipment Status spreadsheet is organized in the following manner:

Equipment Status Spreadsheet												
Location or Operating Area	Equipment Type	Equipment Number	Equipment Function	Purchase Date / Age	MTBF	MTTR	Dominant Failure Mode	Failure Mechanism	Is PdM Consistent with Failure	Will PM Restore Useful Life?	Other Significant Plans (Like	

Figure 1. Equipment Status Spreadsheet

Criticality Spreadsheet Section 1					
Criticality Analysis Asset Description YEAR Completed					
Item Number	System	Location	Asset (Equipment ID)	Function Description	P & ID / Drawing No.
1					
2					
3					
4					
5					
6					
7					
8					

Criticality Spreadsheet Section 2												
Equipment Status Spreadsheet												
Location or Operating Area	Equipment Type	Equipment Number	Equipment Function	Purchase Date / Age	MTBF	MTTR	Dominant Failure Mode	Failure Mechanism	Is PdM Consistent with Failure	Will PM Restore Useful Life?	Other Significant Plans (Like	

Figure 2.Criticality Analysis Spreadsheet

Criticality Spreadsheet Section 3														
HEALTH/SAFETY FACTOR					DOWNTIME FACTOR (SPARED?)					THROUGHPUT or OUTPUT FACTOR				
0	1	2	3	4	0	1	2	3	4	0	1	2	3	4

Criticality Spreadsheet Section 4														
				3										
ENVIRONMENT FACTOR				UTILIZATION FACTOR				AVG TIME OF REPAIR						
0	2	3	4	1	2	3	4	0	1	2	3	4	5

Figure 3. Criticality Analysis Spreadsheet

Criticality Spreadsheet Section 5															
ECONOMIC IMPACT					MEAN TIME BETWEEN FAILURE (LIKELIHOOD)					PSM EQIP?		CHEMICAL HAZARD			
1	2	3	4	5	1	2	3	4	5	5	0	0	1	2	3	4

Criticality Spreadsheet Section 6									
				5					
TEMP <20 or >140?		PRESS > 150 PSIG		SAFETY CRITICAL EQUIP (ESD)		Calculated Criticality Rank	Assigned Criticality Rank	Blind Failure	Comments / Notes
3	0	3	0	5	0	Sum All	1 to 5	Y/N	

Figure 4. Criticality Analysis Spreadsheet

First according to the operating unit or system where equipment is located.
Second in the alphabetical order of the generic name of the specific equipment category. (Blower, Compressor, Fan, etc.)
Third in numerical order of each equipment item.

This system for organizing spreadsheets will make it simple and easy to find equipment items when conducting the Criticality Analysis.

While participants will focus some of their attention on the spreadsheet during the workshops, he or she will also focus attention on the Process and Instrument Diagrams or Flow Sheets to guide the order in which equipment items will be discussed. As a result, it will be important to have both full-size copies of those drawings and 8-1/2 by 11 or legal sized reductions of the sheets. Smaller copies will be useful for making notes and seeing details close up that cannot be seen on larger sheets posted on a wall or projected using a projector.

Occasionally, there are other references that are useful during workshops including a variety of data provided in reports, lists or other studies (like PHA or FMEAs).

4. *Conducting the workshops*

When conducting the workshop there are a variety of caveats that should be observed:

- Schedule the sessions several weeks or a month in advance. Be sure that all participants promise to participate and that their supervisors are aware of the time commitment.
- Schedule a meeting room that is large enough to comfortably accommodate the entire group.
- Schedule meals and refreshments to be served, so there is no reason to leave the session between the start and the finish of each session.
- Confirm that participants understand their roles, the information they will provide, and the products expected to be produced.
- If necessary, post the rules of conduct for participants. Turn off cell phones during sessions. Identify rules for paying attention to the current discussion and avoiding other side bar discussions.
- Deal with other problems affecting progress as they occur.
- Most important, keep things moving,

5. *Checking for completeness and accuracy*

At the end of each day and the end of each analysis, check for completeness and accuracy. If there are a few things that need to be corrected, that is fine. But if there are a large number of items participants wish to rehash, agree to handle it separately and modify the way the analysis is being conducted to address those items being missed on the first pass.

Select a few of the items and show participants how the reports will be created and then, using the reports, how issues will be addressed.

For instance, one report will identify instances where exceptionally long downtime is being caused by either spare parts not being identified and stored under an approved folio or instances where parts are not being replenished in a timely way after they have been used from stock.

This is an example of a situation that might be easily solved. If the part has been approved for storage in the warehouse but is not replenished, the purchasing organization should be expected to solve the problem. It the part has never been approved for warehouse stock, the appropriate person should be asked to prepare a justification and a folio to create new warehouse stock.

6. *Creating and analyzing reports*

The next step is to use the use the completed Critically Analysis to create the set of reports that will be used to organize the actions that will be taken based on the knowledge produced from the report. There are a number of reports and all of them do not contain information of the same importance.

It is important to create the set of reports, review them, then create a list of individual activities that can be prioritized using Pareto analysis to ensure the most important items are addressed first. It is also important to analyze corrective actions based on which items will require time and resources and which can be accomplished quickly and with few resources.

You can create additional reports you feel will be useful to your plant by selecting different combinations of information.

Note that follow-up will begin by producing the reports so it is important to create the reports as quickly as possible.

7. *Preparing to take action*

As with the sales process discussed at the beginning of this program, it is important to sell the actions that should be taken based on the information that has been gathered. While some of the actions may be completed without significant or unprogrammed spending, other actions will require the approval of funds and resources for completion.

Keep in mind that if your plant has several operating units, it is likely that you will conduct several separate Criticality Analysis activities. As a result, you will create several action lists on several different timeframes. That being the case, you will be seeking several distinct approvals. There is typically only one source of resources for the overall plant, so you don’t want to consume all of the available resources based on the first list of recommendations.

If there are five operating units, it is most prudent to assign a maximum of 15% or the available resources to each of the five units until the analysis on all five units is complete. At that time, portions of the remaining resources can be allocated based on the return on investment of remaining items in all five lists.

8. *Taking action*

While the action items produced when performing Criticality Analysis will take a variety of forms and will be assigned to a variety of individuals to complete, all items should be completed using the same elements of a conventional project: namely scope, schedule, and budget.

It is likely that if you perform an audit of the typical items on the action lists, you will find that the reason they were not completed in the past is that one of the three elements of project management was missing.

- They were not complete because the extent of a scope of work was not well defined.
- The requirements were never completed because a finish date was not identified, or no one was held accountable for meeting it.
- No budget was assigned, and the activity was delayed so long that it was ultimately forgotten.

For the items to be addressed not, the solutions must be handled with the structure and discipline of a well-managed project.

9. Measuring results

It is important that every plant publish a set of Critical Success Factors that identify how well the plant is being managed and how far it is from meeting all expectations. The impact of addressing the items identified and corrected using Criticality Analysis must be apparent in improvements to the CSFs.

If CSFs do not improve with implementation of Criticality Analysis recommendations, either the CSFs are measuring the wrong things or the items from the Criticality Analysis that were corrected were the wrong items or they were not really corrected.

10. Closing the Circle

At the conclusion of sporting events, the winners celebrate. It is apparent who won and how important the victory was to them. The same is not always true of programs or projects that are completed in plants or facilities. When all the effort is complete, it is just on to the next thing.

It is important to take a victory lap when the Criticality Analysis effort is complete, and improvements have been made and results measured. It is not merely a way of saying "Look how much more money we are making", it is a way of showing "If we work together, we can accomplish anything we set our mind to do together".

Criticality Analysis – Detailed Description

Here we will continue the discussion with a detailed description of all the elements of the Criticality Analysis. But first, we will take a moment to define the meaning of the term "critical" as it is used in this analysis.

During the design of a new plant, the designers make a list of critical equipment. This "Design Stage" criticality would likely depend only on the location (the plant or system where it is located) and function an equipment item performs in the overall process.

For instance, any piece of equipment upon which the operation of a system or the entire plant is dependent would be critical. Also, any other item upon which safety or environmental performance depends (because the loss of function for those items is likely to cause an environmental or safety event) would be critical.

The definition of the term critical in the example above would simply depend on the "static" characteristics of position and function of the item.

On the other hand, that definition lacks the "dynamics" needed once the plant is in operation and being maintained. For instance, if a feed pump is spared, as most are, the failure of the first pump is unlikely to provoke the same kind of response as would the failure of an unspared feed pump. In fact, spared equipment is designed to be occasionally operated when one of the two equipment items has been removed for repair.

But, in addition to considerations of location and function, there are a number of other factors that will determine the actual response should the equipment item fail. The actual response is dependent on how plant personal has dealt with the specific circumstances. For instance:

- Does the system used to start a spare pump function quickly enough to prevent an outage?
- Does the availability of spare parts, workforce expertise, transportation plans, etc. allow the primary equipment item for be repaired before the spare equipment item fails?
- Do protective devices (like overspeed trips or overcurrent protection) adequately protect critical equipment?
- Is the relief system or flare gas system designed in a way that allows items like relief valves to be maintained without shutting down all connected assets?
- Or a number of other issues that may have changed since the assumptions for operations and maintenance of the plant were first made.

It is useful to collect the information and actual knowledge on how each equipment item is actually operated, maintained, and viewed relative to its true criticality.

In performing the Criticality Analysis described herein, we will be attempting to produce a point of view of Criticality that is dynamic and ensures that we are able to address a number of issues that go well beyond the static location and function. Many of those issues are not readily apparent or frequently considered during the conduct of day-to-day business. So, it is important to apply a tool like Criticality Analysis that will highlight those issues without the need to personally experience their ill-effects as the only mechanism for learning of their existence.

From here, we will take a different approach by providing a description more detailed than was provided earlier. Here, we will significantly reduce the altitude of our viewpoint to discuss information, sources, and analysis in far greater detail.

➢ Selling the Criticality Analysis Process & Competing for Scarce Resources

There are two ways that expenditures are justified. The first, and most common, is by showing that the expenditure is needed to continue to achieve the on-going operations and maintenance needed for day-to-day production. The resources are willingly spent because the current production would be impossible without the expenditure.

The second way resource expenditures are justified is the same way in which projects or major changes are justified. This approach is based on calculating the Return on Investment for the investment (ROI) then using that return to compete with other available investments.

The completion of the Criticality Analysis and the resulting recommendations will identify a significant a significant number of individual investment opportunities. In total, the result of having completed a Criticality Analysis for an individual unit or a complete plant will be the investment of a significant amount of resources.

As a result, it will be important to sell the overall Criticality Analysis program to management and others in your organization using the same basis that is used for projects. That it to justify the program the same way you might justify any other large project. Like a large project, the activities associated with Criticality Analysis will go on for a long time, will consume lots of resources and will produce very significant economic results. If you knew the ROI for the overall program, you could compare the expected results and ROI to the ROI of other current projects. Unfortunately, you seldom know the anticipated ROI.

An important thing to keep in mind is that recommendations coming from the Criticality Analysis tend to leverage the investment much more than other typical projects. The reason is the projects from Criticality Analysis tend to create a significant amount of run-time (or production capability) based on increasing the reliability and availability of an entire plant that currently exists by doing no more than placing individual components in inventory, creating agreements with suppliers or others to share inventories of spare components, by replacing current weak components with ones that are more reliable, or other actions that involve only small parts of the overall asset.

Some of the numbers needed to calculate an expected ROI might be difficult without having completed a Criticality Analysis at least once. It is frequently possible to convince management to allow you to perform a "pilot" on a small operating unit or only a part of a larger unit. Then it will be possible to calculate the projected savings and overall cost of the project based on the equipment count of the pilot facility and then apply that improvement rate to the entire facility.

A prudent assumption is that the poor practices applied in the one area that has been analyzed will apply to the overall facility. For instance, it there are too few components or spares in inventory in one area, there is likely to be too few spare parts everywhere.

Too few spare parts in inventory typically results in one or both of two adverse effects. Either the repairs are delayed, and production is lost due to extended downtime. Or repairs are completed without replacing the needed parts by gerry-rigging components to get the equipment back into service. This approach frequently leads to repeated failures and even greater downtime.

➢ Resources – Participants

While other resources, like meeting rooms, lunches and refreshments will be needed when performing the Criticality Analysis workshops, the most significant resources that will be needed are the participants who will prepare for and perform the analysis. They include:

- The facilitator

- A scribe or person performing computer input
- An operations subject matter expert (SME)
- A maintenance SME
- A technical or process SME
- Rotating equipment SME
- Instrument/Control Systems SME
- Fixed equipment SME
- Boiler/Heater SME – Ad Hoc
- Electrical SME – Ad Hoc

The difference between the Ad Hoc members and the other members of the analysis team is that other members are expected to participate throughout the entire workshops. Ad Hoc members participate only when the equipment in their area of specialization is being discussed.

Clearly, this organization can change from place to place and from one organization to another. For instance, some organizations combine the responsibilities of the Instrument/CSE SME with those of the Electrical SME. In that case only one person would be needed to cover the entire range of equipment

➢ General Format of each workshop

Each Criticality workshop will be conducted as follows:

- Depending on the size and complexity of the plant, operating unit or equipment item being analyzed, the analysis will require from several hours to several weeks to complete. Much has to do with how well-prepared participants are and how disciplined the workshop is conducted.
- It is useful to organize all areas that will be covered in advance. It will be difficult to achieve the desired progress if this is done on a piece-meal basis.
- A week or more in advance of each workshop, all participants should be trained. The training will describe preparations made in advance of the workshop so, there should be enough lead time for participants to complete their preparations.
- At the beginning of the first workshop, provide each participant with handouts including small size copies of Criticality Analysis spreadsheets, Equipment Status spreadsheets and process and instrumentation drawings or flowsheets. While full size copies of those items may be posted on walls or projected using a projector, there will be many instances where participants will need their own copy from which to read or find details too small to see from a distance.
- Beginning the actual work of performing a Criticality Analysis, sequentially go through each P&ID or flow sheet and with each drawing go through each equipment item that is subject to deterioration and failure.
- For each equipment item, sequentially discuss each characteristic on the Criticality Analysis spreadsheet. Use the best information available (without stopping or leaving

blanks) to complete each field. If any field needs to be further investigated outside of the workshop, highlight it for further analysis later.

- Once the Criticality Analysis is complete, use combinations of characteristics to create reports highlighting areas that should be addressed. An example are items with low MTBF combined with high impact on production. Another example are items with low MTBF and high MTTR. In this case, it would be important to determine the cause for the two weaknesses. If the high MTTR is caused by poor availability of spare parts, that problem might be easily solved.
- Review the final spreadsheets and reports. From them create a prioritized list of recommendations to be reported to plant management.
- Obtain approvals and proceed with fulfilling the recommendations.
- Track expected improvements.

➢ Training / Learning

The overall value of performing a Criticality Analysis is provided not only by the recommendations produced by the analysis. In addition to recommendations, anyone who participates in the process will learn a number of things he or she did not previously know. Those things include:

1. What is the condition of external factors that either help or hurt the performance of your asset?
2. For instance, do you have the appropriate number of spare parts on hand?
3. Is the reliability or availability of your assets being adversely affected by the lack of knowledge concerning failure modes or failure mechanisms and the predictive maintenance and preventive maintenance that should be applied to cope with those conditions?
4. Where can the information needed to reveal the status of those conditions be found? Does that information exist and is it accurate?
5. Lacking a Criticality Analysis, whose job is it to see those conditions are documented and addressed?
6. When an individual is accountable for the performance of certain assets, what does he or she need to do personally and what support can he or she count on others to provide?

Narrowing our focus to the specific items that should be included in pre-workshop training, the following should be addressed:

- What information does the Equipment Status spreadsheet contain and where is the information located?
- What information will the completed Criticality Analysis spreadsheet contain and how are the various fields completed?
- When are these spreadsheets completed and by whom?
- Describe each of the various meetings that make up the entire Criticality Analysis workshop, including:

  - An initial session
  - A session in which the Criticality Analysis is completed
  - A session in which the Criticality Analysis reports are discussed
  - A session in which recommendations are assembled and prioritized
  - The session in which the team presents prioritized recommendations to plant management
  - The session in which responsibilities are assigned for implementing recommendations
- Describe the rules that will apply during Criticality Analysis sessions including:
  - Arrive on time
  - Don't miss sessions
  - If you have to miss a session, send a substitute
  - Turn your cell phone off (there will be occasional breaks when you can answer messages)
  - One person talks at a time, no separate discussions
  - If you are double booked by someone, let them know you already have a commitment
  - Don't bring other work
  - Don't check e-mail on your cell phone
  - Don't surf the internet during sessions
  - The data keeper will have a computer so you can leave your computer behind
  - If you send a replacement, be sure he or she knows what will be expected of them

➢ The Equipment Status spreadsheet – Layout/Organization/Content

The Criticality Analysis will require a great deal of detailed information no one carries around in their mind. Much of that information will be gathered ahead of time using an Equipment Status spreadsheet. Details concerning how, why, and when failures occur and how they are repaired are frequently shrouded in mystery associated with the work being completed during off-hours and deep in the bowels of the repair shops. That is the reason why this information must be religiously collected and recorded in a manner that allows future use.

Most organizations use Computer Maintenance Management Systems (CMMS) or Enterprise Resource Management (ERM) programs to collect data that is used in planning for future maintenance and repairs. Much of this information will be moved to the Equipment Status spreadsheet so it can be easily used during the Criticality Analysis.

The following sections describe a number of the data types that should be collected by those systems then transferred to your Equipment Status spreadsheet when preparing to perform a Criticality Analysis. They will also provide information concerning how to organize the data so it can easily be accessed during the workshops. This is precisely the kind of information that will be useful in identifying situations that can make an equipment item more (or less) critical than knowing only its location and function.

Organization

The Equipment Status spreadsheet should be organized:

- By including all equipment items that have experienced deterioration and failures in an arrangement that will make it easy for participants in the Criticality Analysis to locate and use.
- Arrange first by the name of the equipment type in alphabetical order. (e.g., Blowers, Compressors, Pumps, Turbines, etc.)
- Arrange items in each category according to equipment number. (e.g., P-1234, P-1235, P-2234, P-2235, etc.)

Mean Time Between Failure (MTBF)

The Mean time Between Failure is the average amount of time between one failure of an equipment item and the next failure. The more instances of failure included in the calculation, the greater the accuracy will be. Properly designed CMMS and ERM software will perform the MTBF calculations automatically. If not automatically calculated, you will need to calculate the average of all past instances of failure for which you have data.

The shorter the MTBF, the less reliability an equipment item has. The most accepted approach at increasing MTBF is to determine the specific component or components that, because of the deterioration, fail on a regular basis. Once the failure mechanism is known, reliability can be improved by replacing the deteriorated component with one that in not susceptible to the failure mechanism.

Mean Time to Repair (MTTR)

The Mean Time to Repair is the average amount of time required to complete the repair of an equipment item. With this factor, it is important to clearly define the time to repair or specifically what constitutes a repair. It is easy to reduce the MTTR by taking shortcuts and not making a complete repair. A complete repair should be considered one that completely restores all deterioration and restores the inherent reliability and renews the useful life of the asset. If capable of operating for five years when properly new, the MTTR should be calculated based on completing that scope of work needed to restore than lifespan.

Taking shortcuts when performing a repair might shorted the MTTR but it will also shorten the MTBF.

Also be certain to include the time consumed by all maintenance steps. If there are delays during any step, the lost time should be included. That will encourage personnel to address the entire duration from failure to re-start.

Failure Modes – Component and Condition at Failure

There are a variety of ways used to describe the Failure Mode of an equipment item. I recommend using a term for failure mode consisting of the name of the specific component that initiated the equipment failure and its condition. (e.g., part xyz and condition abc)

It is important to use the same word to describe equivalent conditions so your statistics describing common failure modes are accurate. The instance, people occasionally use the words overheated, burned, burnt, baked, cooked, charred and a variety of other words to describe overheated. This practice will result in splitting the statistics for a single condition into a large number of failure modes. That it likely to cause you to address less chronic failure modes.

A typical example of a failure mode resulting in the failure of a pump might be overheated seal or overheated bearings. Using the proper form for identifying the failure mode can lead to properly identifying the specific component needing to be addressed and the specific failure mechanism causing the deterioration.

Failure Mechanisms

Again, while there are a variety of ways to classify failure mechanisms (or deterioration mechanisms), I prefer the most simplistic approach. There are basically only four failure mechanisms:

- Corrosion
- Erosion
- Fatigue
- Overload

There are a number of different kinds of corrosion, but they are the result of the same form of physical action. That is an electrochemical deposition caused by a potential difference between one metal and another or between one location and another. Once you have identified the failure mechanism as corrosion, you can start looking for the source of high potential, the source of low potential and the electrolyte connecting the two. Tour objective will then be to stop the physical action from occurring.

Erosion is the wearing away of material by the movement of a more abrasive material over its surface. Erosion has a distinct appearance and once you know the cause of deterioration is erosion, you can start looking for the source of abrasive material. For instance, if the replacement of an oil filter has been delayed, there might be the breakthrough of abrasive material causing bearings or the rotating shaft to wear, whichever is softer.

Predictive Maintenance – Trigger – Consistency with MTBF and Failure Mechanism

Predictive Maintenance is the activity intended to provide early identification of a failure mode at work causing deterioration. While different methods of identifying predictive maintenance are used, predictive maintenance is of little value if it is not selected to find the kind of failure mechanism that is known to exist in the equipment item being maintained.

Predictive maintenance is also of little value when conducted outside the range of time when the deterioration is likely to be present but before it can cause the amount of damage that can cause a failure.

So, when evaluating predictive maintenance: 1. Determine that it can identify the kind of failure mechanism that is likely to be present and 2. Determine that it has been triggered or is being applied during the period of time when the failure mode is likely to be active. If both are true, the predictive maintenance is consistent with the known failure mechanism. If not, you may be wasting your efforts.

Effective predictive maintenance will trigger the accomplishment of preventive maintenance in a timely way.

When asked if predictive maintenance is consistent with the known failure mechanism(s), the answer is "yes" only if the failure mechanism is known and the predictive maintenance is capable of identifying its presence.

Preventive Maintenance – Trigger, Scope, and Outcomes

Much like predictive maintenance, preventive maintenance has to be triggered at the right time, not before it is needed and not too late. When done too early, the predictive maintenance will waste the useful life of components. If triggered too late, the failure will be allowed to occur.

It is important that the appropriate scope of work be done during preventive maintenance. If you only address the specific issue that experienced the most rapid deterioration, it is possible that another failure mode of following along closely behind and there will soon be another failure and outage. It is best to thoroughly inspect the equipment item, measure the as-found conditions to identify other deterioration and restore the inherent reliability and useful life of the equipment item.

When asked if preventive maintenance is designed to renew the life of the equipment item, the answer is "yes" only if the preventive maintenance will restore the inherent reliability and the full useful life.

Columns contained in the Equipment Status spreadsheet

The following are the columns to be included in the Equipment Status spreadsheet:

1. Location, Operating Area or System (where installed)
2. Equipment Type
3. Equipment Number
4. Equipment Function
5. Purchase Date / Age
6. MTBF
7. MTTR
8. Dominant Failure Mode (Failure Mode typically causing the equipment failure)
9. Failure Mechanism
10. Is Predictive Maintenance Consistent with Failure Mechanism?
11. Will Preventive Maintenance Renew Equipment Life?
12. Other significant details (like planned replacement)

- ## The Criticality Analysis spreadsheet

The Criticality Analysis spreadsheet is the principal point of attention when conducting a Criticality Analysis. It is important to review all the items that will be recorded during the analysis to identify the best source of information for collecting and recording each item. There might be instances in which the data can be directly mapped from a current database into the Criticality Analysis spreadsheet thus decreasing the amount of work and increasing the accuracy.

For instance, if a Process Hazard Analysis (PHA) has been conducted, it is likely to contain some of the needed information. If some form of Failure Modes and Effects Analysis (FMEA, FMECA, or RCM) has been completed, it too will contain much of the needed information. As discussed earlier, these documents may contain only the "static" characteristics of many items, but not the "dynamic" factors that will be needed for the Criticality Analysis.

The information gathered from these sources are intended to highlight the issues that exist but, may not identify the indirect causes of issues or the path to their recovery. As an example, the MTTR for an equipment item may be too long because of the lack of on-site storage of the proper parts. The unusually long downtime will be noted but finding the cause will require additional investigation.

In addition to assembling the Equipment Status spreadsheet described above, it is important to identify and use the best sources of other supplemental information. As sources of information tends to vary from location to location, it should suffice to say it is important to identify and employ the most accurate and convenient sources at your site.

Note that each of the characteristics being assessed (not the identification or informational columns) will be a rating using a numerical code that highlights its importance relative to the criticality of the equipment item. When each row is complete, all the ratings will be added to determine the relative rank of the item's overall criticality. This composite rating can be used to prioritize investments.

These ratings will also be used when preparing Criticality reports. For instance, when an equipment items has a low MTBF and a high MTTR, the combination suggests that the item is out of service a great amount of time and might have low availability.

The following paragraphs will discuss the organization and completion of items on the columns of the Criticality Analysis spreadsheet.

List of Column titles

- Several columns ensuring the definitive identification of the Equipment Item being discussed
- Several columns dedicated to displaying the information that will be transferred from the Equipment Status spreadsheet (so it can be conveniently used in discussions during the Criticality Analysis workshops)
- Health and Safety Factor
- Downtime Factor

- Throughput or Output Factor
- Environmental Factor
- Utilization Factor
- Average Time to Repair Factor
- Economic Impact Factor
- Mean Time Between Failure Factor
- PSM Factor
- Chemical Hazard Factor
- Temperature Factor
- Pressure Factor
- Safety Critical Equipment Factor
- Blind Failure Factor
- Combined Equipment Criticality
- Comments

➢ The following is detailed description of the information in each column contained in the Criticality Analysis spreadsheet

<u>Several columns ensuring the definitive identification of the Equipment Item being discussed</u>

In most if not all cases, the following information will definitively identify each equipment item and distinguish it from all other equipment items.

- Plant or unit where installed
- Equipment ID number
- Equipment function

<u>Several columns dedicated to the recording the information that will be transferred from the Equipment Status spreadsheet</u>

This data will be added to the Criticality Analysis simply for convenience. Having it there relieves participants of the necessity of looking back and forth from the Equipment Status spreadsheet to the Criticality Analysis spreadsheet.

It is possible that reviewing this information in the workshop will trigger memories of specific issue that caused the poor performance. For instance, participants might know that a lack of spare parts has caused long delays in completing the repairs. Or they may know if comprehensive repair was not being accomplished because operations demanded soonest possible return of failed equipment items or their spares.

It those kinds of items are highlighted during the discussion; they should be added to the Comments column at the far right of the spreadsheet. This is particularly true if the item that was mentioned should become a recommendation or action item.

These columns include:

- MTBF
- MTTR
- Dominant Failure Mode (most frequent failure mode)
- Failure Mechanism
- Predictive Maintenance (PdM) Consistency
- Preventive Maintenance (PM) Completeness

Health and Safety Factor

For this item, the Criticality team is evaluating the severity of injury or illness resulting from all of the activities associated with the occurrence of the dominant failure mode of an equipment item. If an operator is frequently exposed to injury or illness when the dominant failure mode occurs or a mechanic is exposed during the repair after the failure mode, they should both be considered.

Assume that the actions of those individuals are properly planned and executed using appropriate procedures. Do not blame the equipment for human failures.

The ratings used will be as follows:

- 0 – No effect
- 1 – Minor injury
- 2 – Serious injury
- 3 – Lost time injury
- 4 – Permanent injury / Fatality

Downtime Factor

For this item, the most important considerations are:

1. What is the MTBF
2. What is the MTTR
3. Is the item maintained during turnarounds and is the item capable of running from one turnaround to the next without interruption?
4. Is the item spared and is the spare properly maintained.
5. Is the system that transfers operations from the primary to the spare dependable?

For this item, consider only the downtime resulting from the failure of this equipment item only. If the item is maintained during downtime caused by some other requirement, ignore that downtime in this discussion.

Again, assume that the dominant failure mode occurs. What will be the effect of the failure? Rate this factor using the following categories:

- 0 – No effect
- 1 – Minor interruption to smooth operation
- 2 – Downtime 12 hours or less
- 3 – Downtime 12 hours to one week
- 4 – Downtime greater than one week

Throughput or Output Factor

Occasionally, the failure of an equipment item can adversely affect the flow rate through a plant (or production rate at which it can operate) or the ability to produce on-spec product. In the second case, the output of on-spec product will be affected both when the off-spec product is being manufactured and when off-spec product is being re-run through the manufacturing process and fresh production is displaced.

For this factor, one of the following codes should be selected:

- 0 – No effect
- 1 – Production loss less than 10%
- 2 – Production loss more than 10% but less than 50%
- 3 – Production loss greater than 50% but less than 100%
- 4 – Total production loss

Environmental Factor

Some failures result in environmental events. While some are not serious or even reportable, it is best to track their presence. That is particularly true if there is any possibility that they may become more serious in special situations. For instance, if seriousness of an event is mitigated primarily by the attentiveness of operators and there is a possibility that an event will produce distraction, then causes of distraction will be worth addressing.

Rate this factor using the following codes:

- 0 – No effect
- 2 – Internal record only
- 3 – Minor Impact - Reportable to an external agency
- 4 – Major impact – Likely enforcement

Utilization Factor

Not all equipment operates all of the time. Some items are needed only part of the time. For those equipment items, the portion of the time they are not operating is time during which they are not experiencing wear. It is likely that the MTBF will be longer for these items. In addition, the MTTR is almost meaningless because maintenance and repair can be performed during periods the equipment items would normally be out of service.

This factor is ranked using the following categories:

- 0 – Not used

- 1 – Used occasionally
- 2 – Operates up to 50% of the time
- 3 – Operates 50% to 90% of the time
- 4 – Operates more than 90% of the time

Average Time to Repair Factor

The average or Mean Time to Repair is a factor that is typically calculated within your CMMS or ERM system. While different organizations use different methods to identify the start and the finish of the repair time, it is best to select events that identify the entire period an equipment item is unavailable to be operated.

The entire time to repair includes a number of steps for which different organizations are accountable. For instance:

1. Time from failure to notification
2. Time from notification to start of repair in place or transportation to a shop
3. Time spent identifying the failure mode and developing the comprehensive repair plan
4. Time spent actually making the repair
5. Time spent completing the activities in place or returning it from a shop
6. Time spent putting the equipment item back in service

If you are measuring item four only, you are capturing less than half the time the equipment item is out of service and therefore less than half the justification needed to make improvements. You are also ignoring elements of downtime that might most easily be improved.

Use the following categories to evaluate the MTTR factor.

- 0 – No effect (Downtime does not impact operations)
- 1 – Less than one shift
- 2 – More than one shift but less than 24 hours
- 3 – More than one day but less than three days
- 4 – More than three days but less than seven days
- 5 – More than seven days

Economic Impact Factor

The economic impact factor is one that is frequently difficult to determine. Rather than spending the time needed for extreme accuracy, it is better to use categories that can be quickly selected and provides a reasonable estimation of this portion of the cost of a failure. Once all of the resources for any event are combined, it is frequently surprising how large the economic impact has grown. Anytime the throughput rate is affected, the dollars quickly mount.

Use the following categories to evaluate the economic impact of a failure.

- 1 – Less than $250 k per event
- 2 – More than $250 k but less than $500 k per event

- 3 – More than $500 k but less than $1 M per event
- 4 – More than $1 M but less than $ 10 M per event
- 5 – Greater than $10 M per event

Mean Time Between Failure Factor

The Mean Time Between Failures is the single factor that is most revealing about the maturity of your reliability program and the actual reliability of your facility. It is not uncommon to find facilities with many equipment items with a MTBF of around one-year. In fact, when that condition exists, it is likely that you will find personnel are spending their time learning how to fix things faster instead of how to keep them running longer. Becoming very good at fixing things is not a good sign.

When performing this analysis, one of the truly troubling findings are a number of small nuisance items that simply keep people busy all of the time. This situation is like the difference between a million bee stings and a bullet directly through the heart. Unfortunately, both have the same result.

The objective of measuring this factor is to determine the effectiveness of your predictive maintenance, preventive maintenance, and corrective maintenance. If PdM is not finding deterioration when it starts and if PM and CM are not restoring inherent reliability and useful life, your MTBF will shrink.

Use the following categories to evaluate the MTBF of each equipment item.

- 1 – Greater than 4 years
- 2 – Greater than 2 years but less than 4 years
- 3 – Greater than 1 year but less than 2 years
- 4 – Greater than 6 months but less than 1 year
- 5 – Less than 6 months

PSM Factor

The PSM factor is a simple Yes or No question if the equipment item comes under Process Safety Management rules (regulated by OSHA 1910.119). The objective is to determine if adequate physical or administrative controls are in place to meet the guidelines.

When the response is yes, it is you should expect to see the kinds of care in place that prevent a moderate to high likelihood of failure.

The following two responses are to be used.

- 0 – No, it is not PSM regulated equipment
- 5 – Yes, it is PSM regulated equipment

Chemical Hazard Factor

Possibly the most technically demanding factor to categorize is that of hazards produced by the inherent or natural response of certain chemicals when not contained and isolated from either other materials (including air) and/or a source of ignition.

This factor is intended to highlight those instances in which a failure to an equipment item operating at high pressure and high temperature can produce dramatic effects.

The following categories are used to rank the hazard resulting from the failure of an equipment item.

- 0 – No fire/health impact
- 1 – Small or limited likelihood for reaching the temperature required for ignition
- 2. – Likelihood release will disperse before reaching ignition temperature or producing extended period of exposure
- 4 – Ignition somewhat likely, short exposure can result in incapacitation, explosive detonation is somewhat likely
- 5 - Ignition upon release is certain, short exposure can cause serious injury or death, explosive detonation is very likely

<u>Temperature Factor</u>

Unlike the last factor, this factor is intended to identify all those instances that may result in injuries of any degree, If the dominant failure will result in a release and workers come in contact with the material, some form of injury is possible. This situation is characterized when the operating temperature is less than 20 degrees F or more than 140 degrees F.

- 0 – A No response
- 3 – A Yes response

<u>Pressure Factor</u>

Like the last factor, this factor is intended to identify all those instances that may result in injuries of any degree, If the dominant failure will result in a release and workers come in contact with the material, some form of injury is possible. This situation is characterized when the operating pressure is greater than 150 psi.

- 0 – A No response
- 3 – A Yes response

<u>Safety Critical Equipment Factor</u>

This factor is intended to identify and emphasize the importance of Safety Critical Equipment (ESD). Such equipment includes:

1. PSVs
2. Parts of burner management systems
3. Overspeed trips on turbines
4. Etc.

Categorize the response in the following manner:

- 0 – No it is not Safety Critical

- 5 – Yes, it is Safety Critical

Blind Failure Factor

Another serious form of failure is one that can occur without being noticed. This situation is by far the most significant when the blind failure happens to a Safety Critical equipment item, like a PSV or turbine overspeed trip. The purpose of highlighting this situation here is to ensure equipment with the possibility of blind failures are frequently function tested. Even when function testing a device, it is important to consider how accurate a function test will be. For instance, if a PSV is plugged, will a trip test identify the plugging or will it be necessary to X-ray the valve body looking for internal build-ups.

Categorize this factor using the following:

- 0 – Not subject to blind failures
- 5 – Is subject to blind failures

Combined Equipment Criticality

This column should be completed by first adding the numbers in all the columns for each row, then ordering the equipment items according to the sum of the rankings. Our final objective here is to complete this column by inserting one of the following criticality codes:

- 5 – Critical with apparent need for action
- 4 – Critical
- 3 – Essential
- 2 – Essential Spared
- 1 – Everything Else

To achieve that objective, start by finding the equipment item with the highest combined ratings. Divide that maximum number by three. Look at the lowest item of the top one-third. Ask yourself, does this point make a good breakpoint between critical and essential? Do the same exercise for the lowest item at the two-thirds point of the list.

If the one-third point and the two-thirds point do not make good breakpoints move the breakpoints up or down as required.

Finally, go through the entire list assigning the Combined Equipment Criticality codes as 4 - Critical, 3 – Essential, or 1 - Everything Else, with the following adjustments:

The first adjustment is to go through all of the comments that were added in the final column of the spreadsheet. If your team identifies items that require some form of action, a note should have been added to the “Comments” column. An example might be the need to check a safety critical item that is subject to blind failures for them.

(When performing a Criticality Analysis is it not uncommon to have situations in which a member of the group stands up and want to immediately go check something. When this happens, you will know that you identified a serious current problem.)

In the cases where you find critical items with significant comments, move those items up to category 5.

The second adjustment is to review all the essential items to find those that are spared. Move the spared items down to category 2.

Comments

As mentioned above, the Comments column is primarily intended to capture items for which immediate action should be considered. It is suggested that the participants keep their own notes for other items they wish to follow up. The official Criticality Analysis spreadsheet should be used to collect data that needs to be addressed as a part of the organized response.

Conducting the Criticality Workshop

Keeping things moving

The secret of making progress and ultimately completing the analysis for your entire facility or asset is to keep things moving. Once you announce the equipment item being discussed, try to complete the discussion of that item in a minute or so. Acknowledge that few things about this analysis are perfect. Once the first pass at the analysis is complete, there will be several opportunities to identify mistakes and make corrections.

Two kinds of mistakes are possible:

1. Instances where you have overstated the criticality of an item
2. Instances where you have understated the criticality of an item

In the first case, the principal problem will be that unnecessary resources will be spent. There are typically a number of guard rails in place to prevent unnecessary spending of resources. Assume that those guard rails will ultimately prevent needless spending.

The second case is more likely to allow a more serious problem to be missed. Part of the reason that every workshop includes the most knowledgeable individuals available is that someone in the analysis team will recall significant situations. When facilitating a workshop and someone believes the criticality of an item is being understated, use the higher ranking and if the analysis is incorrect, allow the guard rails described above will self-correct the mistake.

Using P&IDs or Flowsheets to Guide the Discussion

As mentioned earlier, P&IDs or Flow Diagrams (or in the case of performing this analysis on non-process assets, like heavy mobile equipment – other engineering drawings showing all equipment items) will be used to guide the discussions to ensure that all equipment items have been discussed.

Those drawings are typically created on sheets that provide a numerical scale in the horizontal margin and an alphabetical scale in the vertical margin. Those scales can be used to locate every item for participants when it is being discussed. (Say C-5) The discussion will begin with equipment items found in the upper left-hand corner, then proceed horizontally across the sheet until reaching the right-hand margin.

Then drop one row down to the next string of equipment items running from left to right and continue the analysis on an item by item basis until reaching the right-hand margin.

Continue this processes moving left to right then top to bottom until reaching the lower right-hand corner of each P&ID.

Continue through the stack of P&IDs from the first to the last until the entire unit is complete.

Note that the Equipment Status spreadsheets are assembled in an alphabetical then numerical basis so, while not in the same sequence as the Criticality Analysis, the information should still be simple and easy to transfer. On the other hand, if the data from the Equipment Status spreadsheet is transferred to the Criticality Analysis spreadsheet before the workshop, you will avoid having to look back and forth between the two sheets during the workshop.

<u>Use Generic Files and Pre-work to Complete Columns</u>

There are a number of steps that can be taken before a workshop is started. The more fields that are completed in advance, the quicker the workshops will be completed.

1. Go through the drawings in advance to select the order of analysis and fill out the identification columns.
2. Identify generic descriptions that apply to a number of items performing similar functions or located in the same areas. It is possible that all the equipment in a specific plant or system operate at the same maximum temperature or pressure and will have a number of categories rated in the same manner.
3. Have the record keeper review the drawings and spreadsheets in advance so he or she can queue up the next item as soon as the last item has been completed.

Check for Completeness and Accuracy

When the spreadsheet is complete and before the team is released, perform a cursory review of the Criticality Analysis spreadsheet. Ask the group if they feel anything has been missed or any mistakes have been made.

As a way of engaging the group in this exercise, ask each participant to select two or three items he or she feels is most significant to this exercise. Which do they think will benefit most by this study.

Go back and review those items to ensure all the fields have been properly completed. If you identify any problems using this technique, continue to select more items to see if there is a chronic problem or if there has been only a small number of typos or simple mistakes.

Depending on your findings, identify the source of the problems and how best to solve them so everyone feels confident in the results.

Creating and Analyzing Reports

Once the Criticality Analysis spreadsheet is complete, the data can be used to identify a variety of instances where some form of action should be taken to improve the overall performance of the asset. The fields contained in the Criticality Analysis spreadsheet can be used either individually or grouped with other factors to highlight circumstances that lead to unacceptable results. For instance, it the MTBF is low and the MTTR is high, the equipment item will frequently fail, and each failure will require an extended recovery. That combination leads to very poor availability.

As a starting point, we will review the characteristics we hope to enhance using the data from the spreadsheet.

- Reliability – Reliability is defined as the likelihood an asset will survive for a specific period of time. Here we are hoping to find that the likelihood of survival between extended maintenance intervals of four years or more will be very high (say 95% or more).
- Availability – Availability is the portion of time that an asset is able to perform its intended function. Here we hope to find that our asset requires only a small portion of total time being out of service for any kind of maintenance or repair (say less than 2%) leading to an availability of 98% or more.
- Maintainability – Maintainability is the ability to restore the inherent reliability of an asset in a ratable or predictable amount of time. Here we expect to be able to say, “I can service or repair that item in X hours” and then do exactly what we promise. Lack of proper training, tools, or parts result in either unpredictable downtime or unpredictable results or both.

One of the benefits of using excel to assemble all the data during the Criticality Analysis is that filters can be set to automatically identify the equipment items falling into each report.

The following are a number of reports that can be assembled and then presented as part of the findings from the Criticality Analysis.

<u>Maintenance Strategy Report</u>

There are two characteristics that were quantified that can be highlighted as needing clearly articulated maintenance strategies. Items with an overall criticality of 3, 4 or 5 and items with a safety criticality of 5 should have a well-defined and practiced maintenance strategy.

That means that all of those items should be considered for each of the following forms of maintenance:

1. Predictive Maintenance
2. Preventive Maintenance
3. Turnaround (or Outage Opportunity) Maintenance

Project Opportunity Report

During the discussions that occur as part of the Criticality Analysis, it is common for participants to highlight opportunities that will require small projects to capture. Those items should be recorded in the Comments field. Those items from the Comment field should be assembled into a list of opportunities generated during the Criticality Analysis.

Throughput Opportunity Report

The data collected during the Criticality Analysis identifies a significant number of instances where improvements will result in increased throughput. The intersection of the following categories highlights instances where equipment performance improvement will result in increased plant throughput. These items can be prioritized in order of the anticipated improvement to provide the list of items that should be attacked first.

Filter for the intersection of:

- Throughput losses of 2 or greater.
- MTTR of 3 or greater
- MTBF of 2 or greater

Economic Opportunity Report

Much like throughput losses, Economic losses are triggered by an outage frequency identified by the MTBF.

Filter for the intersection of:

- Economic Loss or 2 or greater
- MTBF of 2 or greater

Throughput/Economic Opportunity Report

When items are on both of the last two lists, addressing each item will gain both throughput and economically.

Filter for items on both former lists.

Spare Parts Report

Once items with high MTTR are identified, it is useful to spend time identifying the reason for extended repair times.

Begin by identifying items with a MTTR of 3 or greater, then discuss the cause for the high MTTR with shop and warehouse personnel.

While the lack of spare parts is mentioned here, because it is a common cause, there may be other chronic problems that will be highlighted and should be included in your report. For instance, if several plant shares a common warehouse and the warehouse is some distance away, some repairs may be delayed. Common warehouses are organized as a way to save money. If the savings have been overstated and the impairment caused by delays understated, the assumed return on investment may be negative.

P&ID / Drawings Report

Another kind of problems that are identified during Criticality Analysis are mistakes on drawings or in databases. When those problems are identified, they should be recorded in the Comments field and assembled into a report presented at the conclusion of the exercise.

PSM Issues Report

Another intersection of issues is when a PSM item is experiencing frequent failures.

For this report, identify the intersection of:

- PSM – Yes
- MTBF of 2 or greater.

Blind Failure Issues Report

As with the last item, another critical issue occurs at the intersection of Blind failures with frequent failures.

For this report, identify the intersection of:

- Blind failure – Yes
- MTBF or 2 or greater

ESD Item Issues Report

ESD equipment should also be screened for frequent failures.

For this report, identify the intersection of:

- ESD – Yes
- MTBF of 2 or greater.

When presenting the reports shown above, it is best to plan to make several reports to management. The first report will have the objective of identifying the sensitivity of the plant leadership. Some processes are so hazardous, and some companies are so safety or environmentally sensitive that PSM failures, Blind Failures, and ESD failures come before anything else. On the other hand, some organizations would like to revise those reports to include only MTBFs or 3 or 4 or greater.

Other facilities are not hazardous, and the primary concerns are cost and throughput. In those cases the reports and ratings can be adjusted to address the particular situation.

Once you get feedback on the objectives of management, it will be possible to identify how the reports should be modified and how the individual items should be prioritized for action.

It is useful to keep in mind that there are only so many resources to spread around, so it is best to use the resources wisely and effectively. Completing activities that produce tangible results are likely result in more resources being approved.

The worst result is if you spend all the available resources on performing the Criticality Analysis and little making tangible improvements. Be careful to sharpen the edge of your recommendations to produce the most visible and profound improvements.

Preparing to Take Action

Experience will show that there are a wide variety of activities necessary to address the outcomes from a Criticality Analysis. There will be a number of varying situations in which the accommodations that currently exist are inconsistent with the criticality of the equipment items that are part of your facilities.

In various instances, any of the following actions may be required:

- While performing the Criticality Analysis, it might be realized that procedures being used are inconsistent for the criticality of equipment or of a system. As a result, procedures may need to be changed and people trained to conform to new procedures.
- In some instances, there might need to be new parts added to your inventory.
- In some instances, the procedures for ordering or delivering parts being stored at a remote location may need to be expedited.
- In some instances, equipment items may need to be analyzed and modified to eliminate failure mechanisms so MTBF will be longer or MTTR will be shorter.
- In some instances, the cost of making a change will cross the threshold, making the changes small capital expenditures.
- In some instances, the cost of changes might be so large as to be viewed as a major capital expenditure and a large complex project.
- Some changes may be completed while assets are operating.
- In other instances, changes may have to be integrated into major turnarounds.

The point being made here is that implementing all the changes required to either alter the equipment item or change its surroundings will need to involve many different techniques and individuals from across your entire organization.

Completing the Criticality Analysis and the associated reports, then prioritizing recommended actions and finally getting the recommendations approved is a long way from the end of the effort. Unlike studies intended to simply make us smarter, the Criticality Analysis is intended to highlight those situations in which physical conditions are inadequate to support current criticality of equipment.

Once the actions have been identified and approved. The next step is to organize the army of "doers" who will make the changes in a way that is consistent with the requirements, on schedule and on budget.

Taking Action

The role of organizing and facilitating the Criticality Analysis has many of the same elements as does the role of Project Manager when implementing physical changes.

Unlike managing a single project located in a single, well-defined area, the Criticality Analysis follow-up will cover the entire facility. Despite the differences, the key points of focus remain the same.

Those points are:

- Scope
- Budget
- Schedule

The scope of things being done must respond to the needs identified during the Criticality Analysis. The work must be accomplished within the approved budget for funds and other kinds of resources. The changes are all approved based upon completion within a specific timeframe. The risks associated with frequent or extended failures have to be eliminated in a specific timeframe. So do changes intended to improve throughput and profitability.

Measuring Results

In the months and years following the Criticality Analysis and the follow-up activities that were generated, it should be possible to further extend the use of the two spreadsheets and the Criticality reports that were created. As failures of equipment continues to happen, it should be possible to compare the Failure Modes, Failure Mechanisms, MTBF, MTTR and resulting incidents with those items as they were addressed during the Criticality Analysis and its action plans.

If things improve, that was the objective. If things remain the same or get worse, the results do not match the objectives of the program. In this case, it is important to audit results, find out why and take corrective action.

Closing the Circle

Identify Changes in the Asset

Closing the circle refers to keeping track of changes that may occur to either static or dynamic characteristics. The reason a Criticality Analysis was needed in the first place was that the two characteristics did not coincide. It is important to ensure that they do not again get misaligned.

In completing a tax return for a refinery or chemical plant one of the important write-offs is the depreciation of the asset. While that money is typically put aside to purchase a new asset on a specific schedule for items like mobile equipment, for assets like refineries or chemical plants that are not turned over on a regular schedule, the money should be spent on upkeep.

Companies that do not regularly reinvest to address deterioration, will see their assets become increasingly less reliable and available. While reinvesting at the same rate as depreciation is a good start, that amount might not exactly match the amount of resources that is needed. Or the resources being spent might not be reinvested in exactly the right places to counter on-going deterioration. In that case some items may deteriorate in an uncontrolled or an under controlled manner.

In the end, the condition of your assets will always be changing. Those changes can produce changes in either Criticality. To keep up with changes in criticality it is important to treat the Criticality Analysis spreadsheet as a living document and update it for the changes as they occur.

Identify Changes in the Surroundings

It is no longer unusual to see major assets, like refineries or chemical plants, change ownership. And it is not unusual for new owners to know little or nothing about operating and maintaining the newly acquired facility.

The practice of private equity firms buying assets then cherry-picking the assets to determine what will be kept and what will be sold is a common practice.

Since those firms do not have experienced plant managers or engineers, they know little about the value of spare parts. They know little about the need to maintain enough human resources to perform predictive and preventive maintenance. Run-to-failure doesn't sound bad if you don't know that failures can lead to fires and explosions.

As a result, many of the practices and the physical assets in the surrounds of facilities can change dramatically during the period of unqualified ownership. Once another turn in ownership occurs and the facility falls back into the hands of knowledgeable management, the number of problems lurking in the systems and their surroundings are not always simple and easy to recognize.

The Criticality Analysis provides a good tool for helping to identify and organize all the actions that must be taken to get things back to where they should be.

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