Criticality Assessment

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Introduction

This document provides an overview of equipment criticality assessments in mining, manufacturing and process plants. This document incorporates evolutionary changes in the methodology as it has been implemented in a range of industries and sites.

Underlying assumptions needed to support the methodology are listed and should be used for consistency in any future project.

This methodology discussed here results in a criticality assessment capable of achieving the following outcomes.

1. The assessment should be applied at the asset hierarchy level that best suits the intended application. While carrying out the criticality assessment at higher levels of the hierarchy (e.g. asset, skid or plant level) can reduce the amount of work involved in the assessment the level of resulting detail is often inadequate to provide guidance on how to manage the risk identified by the assessment. If the assessment is carried out at the failure more (or failure mechanism) level the increased level of detail will increase the amount of effort required to carry out the assessment but the significant increase in data resolution greatly improves the development of strategies to manage the risks identified.

2. The criteria to be included in the assessment should be designed to meet the needs of the organisation.

3. Major cost contributors must be identified and assessed separately where their consequences are significant and their causes are not clearly identified and assessed elsewhere. By default, financial impact is separated into production loss and secondary damage as a minimum as any mitigating actions will differ depending on the underlying cause.

4. Criteria prompt sheets are structured to eliminate any ‘double counting’ that might arise if similar considerations were included under more than one criterion.

5. All data assessed should be recorded with the Mean Time Between Failures (MTBF), Likelihood and Consequence scores retained in the data sheet and not just the resulting risk score.

6. Numeric scores are preferable to combinations of numbers and letters. If letters or combinations of numbers and letters are required to maintain consistency with Corporate or other standards, the number scores used in the workshop should be mapped onto the corporate scores at the reporting stage.

7. Provision for comments should be included with each criterion and for each line item as well as for overall comments.

8. By default, results are reported at the hierarchy level at which the workshop was conducted. If scoring is required for aggregate assets (e.g. at skid or plant level) the method used to combine lower level criticality scores to give an overall score must be approved by the Technical Authority (TA) before being generated in reports.
Overview
Criticality is a vital component of operations and maintenance management as it allows the various groups within the organisation to ensure that work is preferentially focused on the most important machines/equipment in the plant. Similarly, criticality levels impact significantly on maintenance plans, spare parts assessments, training, documentation, call-in policies etc.

Criticality analysis is used to create a ranked list of equipment (a Criticality Ranking) identifying which equipment has the most significant impact on the business and which equipment (or systems) will benefit most from the application of a particular operating or maintenance strategy. In particular, criticality ranking is vital when making decisions about which equipment is most important for planning and scheduling maintenance work.

Individual equipment can have more than one Criticality Ranking depending on which aspect of the equipment is being considered. In practice, some common Criticality Ranking criteria include:

- Safety
- Environment
- Asset Damage
- Production Loss
- etc.

By considering these criteria (and others as necessary) and assigning a Criticality Score to each, it is possible to build up a Criticality Profile for each machine. Of particular importance is that this approach generates an audit trail for future review. This audit trail facilitates refinement of the assessments over time as additional information becomes available or when a change to process or equipment necessitates a reappraisal of the criticality.

Methodology
Each machine is assessed at the hierarchy level appropriate to the end use to which the assessment will be put. Ideally the assessment should be carried out at the level at which discreet failure can occur which is typically the failure mode level.

During the assessment each failure mode of a part -> component -> asset is assigned a Criticality Rank for planning and other purposes. This methodology applies to rotating equipment, instrument & electrical equipment in particular. Typically, static/fixed equipment such as pressure vessels and pipework is managed through a Risk Based Inspection (RBI) program however Criticality can be uses in the absence of a formal RBI program.

The criticality assessment is begun by listing each asset of interest including equipment number and description as a minimum. ‘Functional Failure Mechanisms’ (failure modes) are identified for each piece of equipment and must include known failure modes as well as those considered realistic given industry experience. It is better to include more failure modes than less so as not to leave out some important failure mode from the assessment mindful of the increased workload associated with increasing levels of detail.

Discussion between Subject Matter Experts (SME) and experienced maintenance and operating staff is usually sufficient to generate a comprehensive list of failure modes. Where
there is uncertainty as to the failure modes to consider advice should be sought from experienced staff at other sites within the organization or from outside consultants experienced in maintenance.

The criticality assessment should includes an estimate of the MTBF of the failure mode to highlight the difference between the likelihood of the failure occurring and the likelihood of it impacting on the various criteria used for the assessment. The MTBF is common to all criteria while the Likelihood’s relate specifically to the individual criteria being considered.

There can sometimes be confusion as to what is being considered when estimating the various ‘likelihood’s’. Inclusion of the MTBF helps to eliminate this confusion.

The Likelihood of the failure impacting on the various criteria is estimated using a risk matrix (figure 1) and standard set of guide sheets. As discussed above this is not the likelihood of the failure mode occurring (this would be the MTBF), rather if it does occur what is the likelihood of it impacting on the criteria being considered? Clearly there will be many instances where the occurrence of a failure will have different impacts on different criteria depending on the circumstances of the failure – e.g. timing, production cycle, product etc.

The Consequence of the failure mode occurring on the criteria is assessed in a similar manner using a standard guide sheet and the risk is calculated by multiplying the Likelihood by the Consequences.

\[ \text{Risk} = \text{Likelihood} \times \text{Consequence} \]

This calculation is carried out for the various criteria generating a risk profile for the equipment failure mechanism comprising the criteria, failure mechanisms and criticality scores.

The highest criticality score of all criteria and all failure modes making up the asset is typically used to indicate the Criticality Ranking of the machine as a whole however alternative scoring may be used with agreement from the responsible officers.
Assumptions
Underlying assumptions on which the Criticality assessment is based include the following.

- It is assumed that those carrying out the assessment have an adequate understanding of the systems, procedures and equipment involved or can access those with the necessary knowledge.
- Repairs to equipment carried out on site, or by off-site service providers, are done to a professional standard resulting in repaired equipment being restored to serviceable condition.
- Repairs are carried out promptly and without unnecessary delays ensuring the repaired equipment is available as soon as practicable.
- Any standby equipment is in serviceable condition at the time the failure occurs.
- Surveys (VA, Oil analysis, Thermography, NDT, etc.) are carried out on schedule and the results implemented promptly.
- Spare parts are available according to the current stocking levels for the equipment. This does not imply that it is assumed that spares will always be available just that if they are held that they will be managed as intended.
- Necessary documents and drawings are available when needed to assist those carrying out any replacements or repairs.
- Routine servicing maintenance (oil checks, greasing, etc.) is carried out according to the established schedule and to a professional standard of workmanship.
- The assessment aims to determine the impact of individual equipment failures on the criteria rather than the simultaneous failure of several pieces of equipment at the same time. (It is valid to carry out the assessment in this way because if each machine is operated and maintained correctly the likelihood of system or interrelated failures occurring is reduced. More complex assessments would require computer modelling to represent the interactions between equipment in a timely and realistic manner).
- Failure of both the duty and standby units is treated at a higher level failure mode (e.g. loss of power).
- The assessment is carried out for individual machines and the availability or otherwise of a standby unit affects the likelihood of loss of function. The availability of a standby unit does not affect the MTBF.
- The availability of a standby unit reduces the consequences of failure of an individual machine (i.e. function is maintained by the standby unit).
- Consideration is given to the ‘switch-over’ mechanism (automatic or manual, time delay etc.) to ensure that the standby unit is able to keep the system ‘up’ even if starting from cold after a failure of the duty item. In some instances the delay in bringing the standby unit on-line will be enough to result in system shutdown.
- The percent standby capacity is considered in the assessment and noted where the standby is only a partial replacement of the duty item. In these circumstances the consequences of operating on the standby takes account of the reduced capacity.
- The assessment is made for each failure mode as if it occurs in isolation. This is necessary to keep the assessment to manageable levels make it possible to complete the assessment in a useful time.

These assumptions are based on good maintenance practices and are realistic in a regime where ‘industry best practice’ maintenance is used. In the event that any of these assumptions are considered incorrect or cannot be realized at this time the necessary systems should be developed to meet these assumptions.
It is not appropriate to design in ‘poor practices’ either operating or maintenance and the quality and quantity of the non-hardware systems, e.g. planning, scheduling, spares management, document management etc. are all vitally important components in a ‘worlds-best-practice’ facility.

Application of Criteria

The scoring of each criterion used in the assessment must be applied in a consistent manner to ensure uniformity and to simplify the assessment task. Prompt tables for each criterion should be developed to aid the workshop assessment. Prompt tables are required to ensure a consistent approach is taken to the assessments. A common set of prompt tables should be used for all criticality workshops.

Production – This criterion is used to assess the production impact of specific failure modes. The likelihood of a particular equipment failure resulting in a production loss and the significance of the loss are considered for each failure mode and scores assigned to the likelihood and consequences. The availability of a standby unit is considered in the assessment generally lowering the likelihood and consequence scores. In addition, the ability of the standby unit to start automatically or in an acceptable time must also be considered.

Safety – This criterion is used to assess the likelihood of a specific equipment failure resulting in a safety incident and the consequences of the incident. The criterion does not take account of ‘cascade effects’ such as injury associated with multiple related or unrelated failures as these can occur in an almost unlimited combination making meaningful assessment impractical.

Environment – This criterion is used to assess the likelihood of a specific equipment failure resulting in an environmental incident and the consequences of the incident. The criterion does not take account of ‘cascade effects’ such as environmental damage associated with multiple related or unrelated failures as these can occur in an almost unlimited combination making meaningful assessment impractical.

Equipment damage – This criterion assesses the secondary damage resulting from a specific failure mode. The assessment focuses on any additional damage resulting from the failure mode and not on the failure mode itself which is adequately assessed by the other criteria.

Additional criteria - Additional criteria can be added to the assessment if necessary to improve the usefulness of the assessment and to maximise the return on the investment in workshops etc. It is important to realise that by increasing the number of criteria considered in the assessment there will be a commensurate increase in the time and resources required to carry out the assessment. Each criteria added will likely require input from additional subject matter experts as well as additional time to complete the assessment.

Examples of additional criteria include:

- Society/community impact.
- Public perception.
- Regulator risk.
- etc.