A Practitioner’s Guide to FMEA in Mining Environments

FMEA / Reliability Engineering - Comminution and Classification Circuits

Abstract. *The FMEA is simultaneously one of the most powerful and most misused tools in the reliability engineer’s toolkit. This Technical Note addresses the most common failure modes of the FMEA process itself, scoping decisions that are too narrow or too broad; criticality assessments that conflate consequence with frequency; maintenance tactic selection that defaults to time-based intervals without interrogating the failure pattern; and the persistent tendency to produce FMEA documents that are technically complete but operationally disconnected. Worked examples are drawn from comminution and classification circuits.*

1. Scoping - Boundary, Hierarchy, Function

Scoping errors in industrial FMEA are rarely about the equipment list; they are about what constitutes the *item* being analysed. Two anti-patterns dominate:

- **Too narrow.** The FMEA is scoped to a nameplate asset (e.g., “SAG mill drive”), ignoring the functional envelope that actually delivers reliability. The lube system, cooling circuit, trunnion bearing oil supply, inching drive, and local MCC fall outside the boundary and receive no analytical attention despite being the dominant sources of failure.
- **Too broad.** The FMEA is scoped to an entire circuit (“comminution area”), producing a 300 row workbook in which each row is a generic failure description applied to multiple distinct equipment items. Resolution is lost; tactics become generic; the output looks comprehensive but is functionally unusable.

The correct discipline is hierarchical and function driven. Each item is analysed against a defined **functional statement**, what the item must do, under what operating conditions, to the required standard. The boundary is drawn to include every component whose failure affects the stated function, and to exclude everything else. Scoping errors are fixed at the scoping stage, not downstream.

2. Criticality - Consequence and Frequency Are Not the Same

A persistent pattern is the conflation of **consequence** (the outcome of a failure) with **frequency** (how often it occurs). Assessors rate a failure mode as “low criticality” because it is rare, or “high” because it is frequent, both are methodologically wrong. The correct treatment is:

- Consequence is evaluated independently across safety, environmental, production, and cost dimensions (see SEAMPAS Technical Note 03).
- Frequency is a separate axis that informs the priority of treatment, not the rating of consequence.
- Criticality is derived from consequence; tactic selection draws on both consequence and frequency and, crucially, on the failure pattern.

A rare failure with catastrophic consequence (a SAG mill shell crack) deserves specific controls regardless of its infrequency. A frequent but low-consequence failure (chute wear liner replacement) deserves a proportionate, efficient response. Collapsing these into a single “criticality” score conceals the distinction that should be driving the tactic.

3. Tactic Selection - Interrogate the Failure Pattern First

The single most common error in tactic selection is defaulting to time-based preventive maintenance without first understanding the failure pattern. Time-based restoration is statistically effective only for **age-related wear-out**. For random-pattern failures a new component is as likely to fail as an old one - time-based PM consumes resources without improving reliability. The correct sequence is to identify the dominant pattern, *then* select the tactic.

Failure pattern	Characteristic	Appropriate tactic
Age-related wear-out	Probability of failure rises with usage or age	Time- or usage-based restoration or replacement

Failure pattern	Characteristic	Appropriate tactic
Random	Flat hazard rate; new as likely to fail as old	Condition monitoring (if detectable) or redesign for robustness
Infant mortality	Elevated early-life failure, then stabilises	Commissioning discipline, burn-in, install QA - not ongoing PM
Detectable progression	Precursors develop over the P–F interval	Condition monitoring with planned intervention at PF threshold
Hidden failure	Undetected in normal operation; only revealed when demanded	Failure-finding task at defined interval (availability-driven)

Ignoring pattern produces an asset register populated with 4 and 12 weekly inspection tasks whose effectiveness is never interrogated. The PM programme grows; reliability does not improve; hours accumulate on work orders that deliver no statistical benefit.

4. Operational Disconnection - the Technical-Completeness Trap

An FMEA that identifies every failure mode, rates consequence correctly, and selects appropriate tactics can still fail operationally if the outputs do not reach the people who execute the work. Common disconnection points:

- Tasks are written at RCM task level, but the CMMS accepts only coarse work-order descriptions and detail is lost in translation.
- Criticality ratings are not populated in the asset register, so tactics are not resource-prioritised.
- Condition-monitoring P–F intervals are set, but no trigger is wired into the planning system.
- Redesign recommendations are logged but never tracked through engineering change.
- The FMEA workbook lives on a SharePoint site, not a live register; revisions do not propagate to maintenance practice.

The remedy is a deliberate transition from FMEA output to maintenance programme: a **correlation register** that maps FMEA outputs to AMT tasks (or equivalent), PF-interval triggers wired into the planning tool, and a revision cycle governed as part of asset management, not as a one-off project deliverable.

5. Worked Example A - SAG Mill Trunnion Bearing (Comminution)

Consider a single-train SAG mill with trunnion bearings supplied by a pressurised lube system. Naïve scoping treats this as “SAG mill - bearing failure”, with a uniform tactic of “6-monthly thermographic inspection; quarterly oil analysis.” Correct scoping defines the item as the **trunnion bearing function** is to maintain rotor support under dynamic load at acceptable friction and draws the boundary to include the bearing housing, labyrinth seal, journal surface, lube pump, filter, cooler, pressure switch, temperature sensor, and return line. Failure modes and tactics then resolve as follows:

Failure mode	Pattern	Tactic
Loss of lube oil pressure (pump, filter, line)	**Random**	Pressure trend monitoring; redundant pump; condition based filter change
Oil contamination (seal failure, cooler leak)	**Random**	Oil analysis (elemental + ISO cleanliness); seal integrity inspection
Bearing wear (journal, housing)	**Age-related**	Thermography + vibration trend; condition based replacement at PF threshold
Overheating (cooler fouling, flow restriction)	**Random**	Oil-temperature trend with planning trigger; scheduled cooler clean

This resolution is unavailable at “SAG mill bearing failure” level. The detailed scoping transforms a generic inspection package into a structured programme combining condition monitoring, redundancy, and lubrication quality control.

6. Worked Example B - Hydrocyclone Cluster (Classification)

A hydrocyclone cluster classifies mill discharge into overflow (to downstream process) and underflow (recirculating load). Naïve FMEA reduces this to “cyclone wear” with a monthly visual inspection, treating every cyclone in the cluster as an equivalent line item. Correct FMEA defines the item as the **cluster function** to deliver a consistent particle-size distribution at target throughput and pressure - and resolves the failure modes to the component level at which the tactic actually applies:

Failure mode	Pattern	Tactic
Apex / spigot wear	**Age-related**	CBM via overflow PSD trend; planned replacement at PF threshold
Vortex-finder wear	**Age-related**	Pressure differential trend; time based replacement at demonstrated wear life
Feed-distributor maldistribution	**Operational**	Cluster loading monitoring; scheduled internal inspection at planned shutdown
Isolation valve seizure (hidden)	**Hidden**	Scheduled actuation test (failure finding) at defined interval

The resulting tactic set is differentiated by failure pattern, not uniform by asset type. The monthly visual inspection is retained only where it genuinely supports a detection or intervention decision.

7. Key Takeaways

- Scope FMEAs to a clear **functional statement with a defined boundary**, not to a nameplate asset, and not to an entire area.
- Separate **consequence from frequency** in criticality assessment; derive criticality from consequence, let frequency inform priority.
- Before selecting a tactic, **identify the failure pattern**. Time-based PM is the right answer only for age-related wear-out.
- The FMEA is an **input to a maintenance programme, not an output**. Build the correlation register, wire the PF triggers, and govern the revision cycle.
- Expect iteration. Good FMEAs are developed over cycles as operational data accumulates; Rev 1 is never the final revision.

References and Further Reading

SAE JA1011:2009 Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes. SAE International.

SAE JA1012:2011 A Guide to the Reliability-Centered Maintenance (RCM) Standard. SAE International.

IEC 60812:2018 Failure modes and effects analysis (FMEA and FMECA). International Electrotechnical Commission.

ISO 55001 Asset management - Management systems - Requirements. International Organization for Standardization.

Moubray, J. Reliability-centred Maintenance (2nd ed.), Industrial Press.

SEAMPAS TN03 Maintenance Criticality Frameworks: Beyond the 2×2 Matrix.

About this Technical Note

SEAMPAS Technical Notes are short, focused treatments of specific problems in physical asset management and reliability engineering, drawn from field application in mining, minerals processing, oil and gas, utilities, and heavy rail. They are intended for practising engineers, maintenance managers, and asset management leaders responsible for translating principle into practice.

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