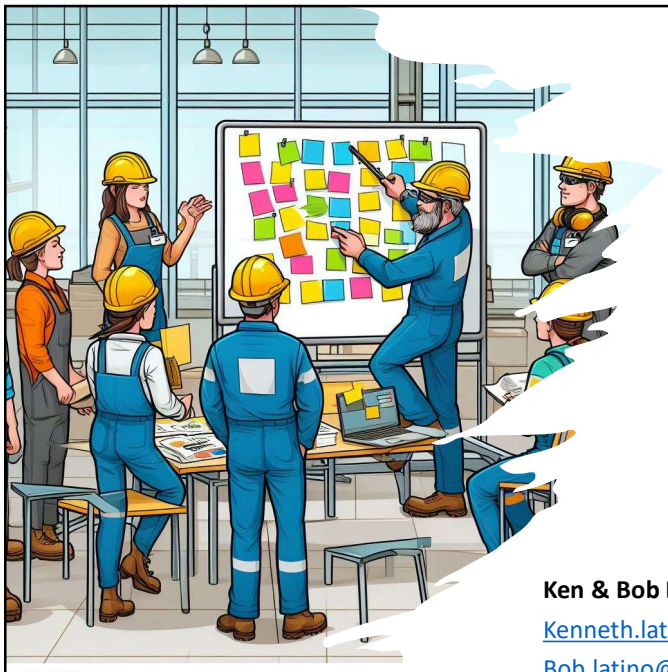

Root Cause Analysis Essentials Course

Ken & Bob Latino
Kenneth.latino@prelical.com
Bob.latino@prelical.com

Prelical
Practical Reliability Solutions

1

Workshop Rules

Criteria for a Successful Course

Ask Questions
There is no such thing as a stupid question, except for the one that is not asked!

Be informal but courteous
We are all here to learn so **be yourself** and sensitive to others.

Hold instructor accountable
We are getting paid to help you so please hold me (us) accountable to help you learn!

Have Fun
Just because we are learning does not mean we cannot have some fun!

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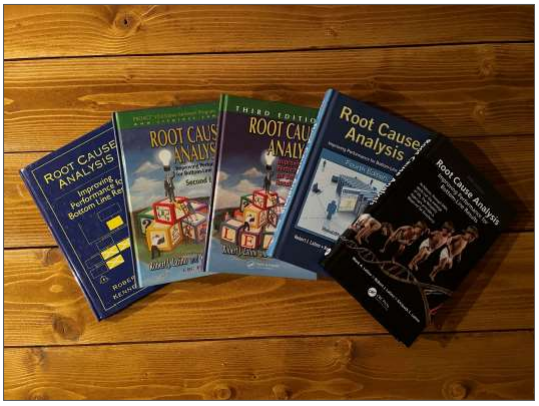
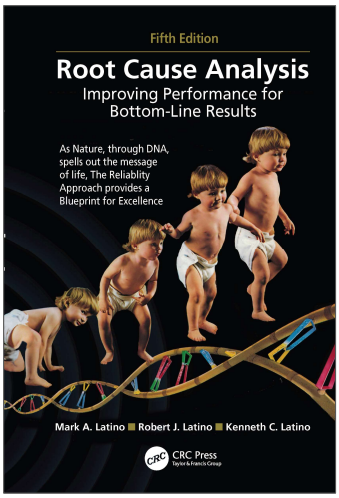
2

Class Introductions

3





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Charles J. Latino
1929 - 2007

Coined 'The Father of Manufacturing Reliability' in 1972

5

Latino Family Career Path

Reliability is in our DNA ☺

1972 — Charles Latino founded the Allied Chemical Corp. R&D Reliability Center (called Honeywell today). Research focused on Equipment, Process and **HUMAN** Reliability

1985 — Charles retires and purchases Reliability Center, Inc (RCI) . Bob joins a now independent RCI as an NDT Tech

2007 — Charles passes and Bob becomes CEO of RCI (a family-owned business)

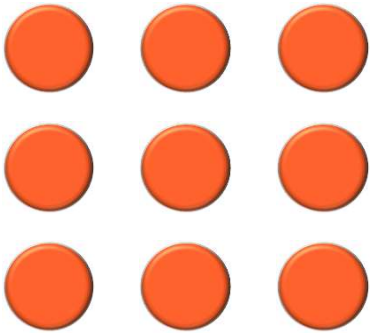
2019 — Latino Family enacts succession plans and sells RCI

2021 — Bob joins Ken's small firm at Prelical Solutions, LLC.

6

9-Dot Game

Connect all 9 dots using only 4 straight lines. Pen or pencil cannot come off the paper.



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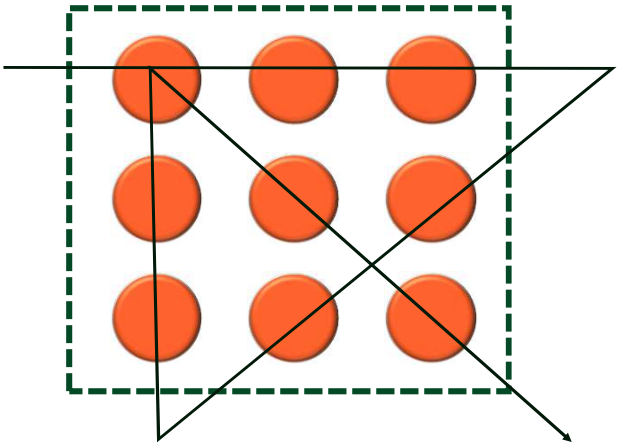
9-Dot Game



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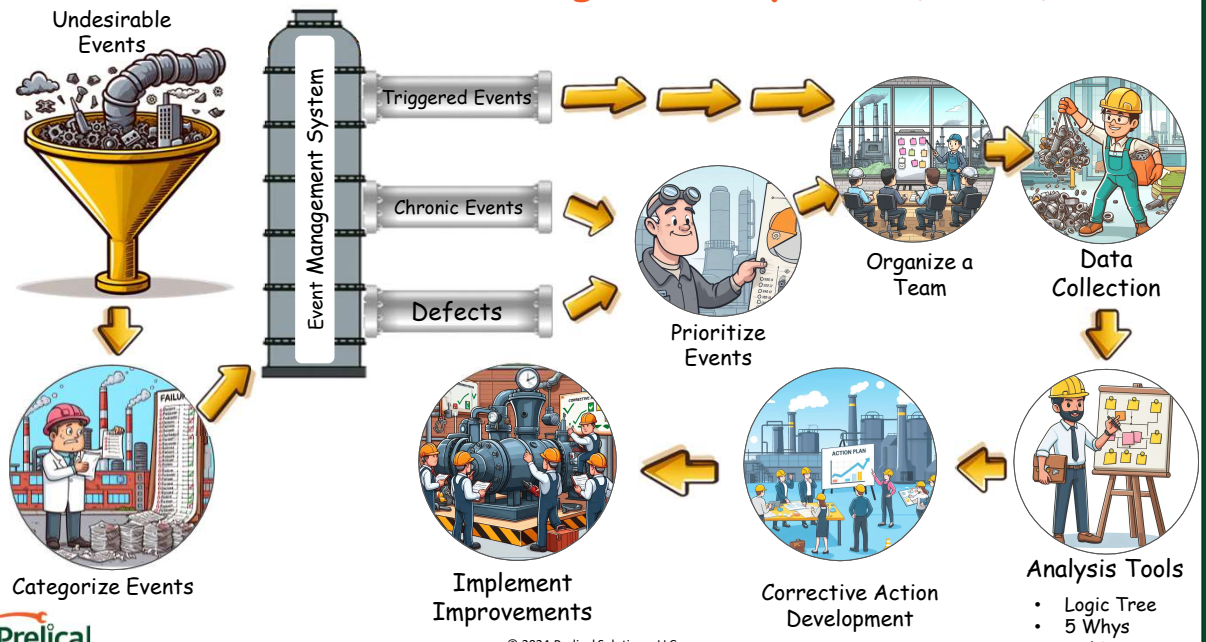
Prelical Event Management System (PEMS)



- Logic Tree
- 5 Whys
- Fishbone

9

Prelical Solutions, LLC.

Root Cause Analysis (RCA) Self-Assessment Tool

Likert Rating Scale
1 = Strongly Disagree
2 = Disagree
3 = Undecided
4 = Agree
5 = Strongly Agree

Root Cause Analysis (RCA) Self-Assessment Tool	Tot. Poss.	Likert Rating Scale	Total Rating By Category/ Rating	Category Score (%)
1. Fundamentals			15	
The Term 'RCA' is Clearly Defined by Leadership		1 2 3 4 5	0	
An Effective RCA Procedure is in Place & Easily Accessible		1 2 3 4 5	0	
RCA Lead Analysts are Formally Trained in the RCA Procedure		1 2 3 4 5	0	
Total Category Rating			0	0%
2. Quantifying/Qualifying Candidates for RCA			15	
Risk Assessment Tools (i.e. - FMEA) are Used to Quantify and Qualify RCA Candidates		1 2 3 4 5	0	
RCA is Routinely Applied to Chronic Failures (Not Just Triggered RCAs)		1 2 3 4 5	0	
Business Cases (ROI) are Made to Justify Conducting RCA's		1 2 3 4 5	0	
Total Category Rating			0	0%
3. Preserving Event Data			15	
Disciplined Data Collection Prior to Conducting an RCA is a Requirement & a Priority		1 2 3 4 5	0	
Data		1 2 3 4 5	0	
Metallurgists)		1 2 3 4 5	0	
Total Category Rating			0	0%
4. Ordering the Analysis Team			15	

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Important to Keep in Mind:
"We are Shooting for Practicality…Not Perfection!"

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The Role of RCA in Reliability

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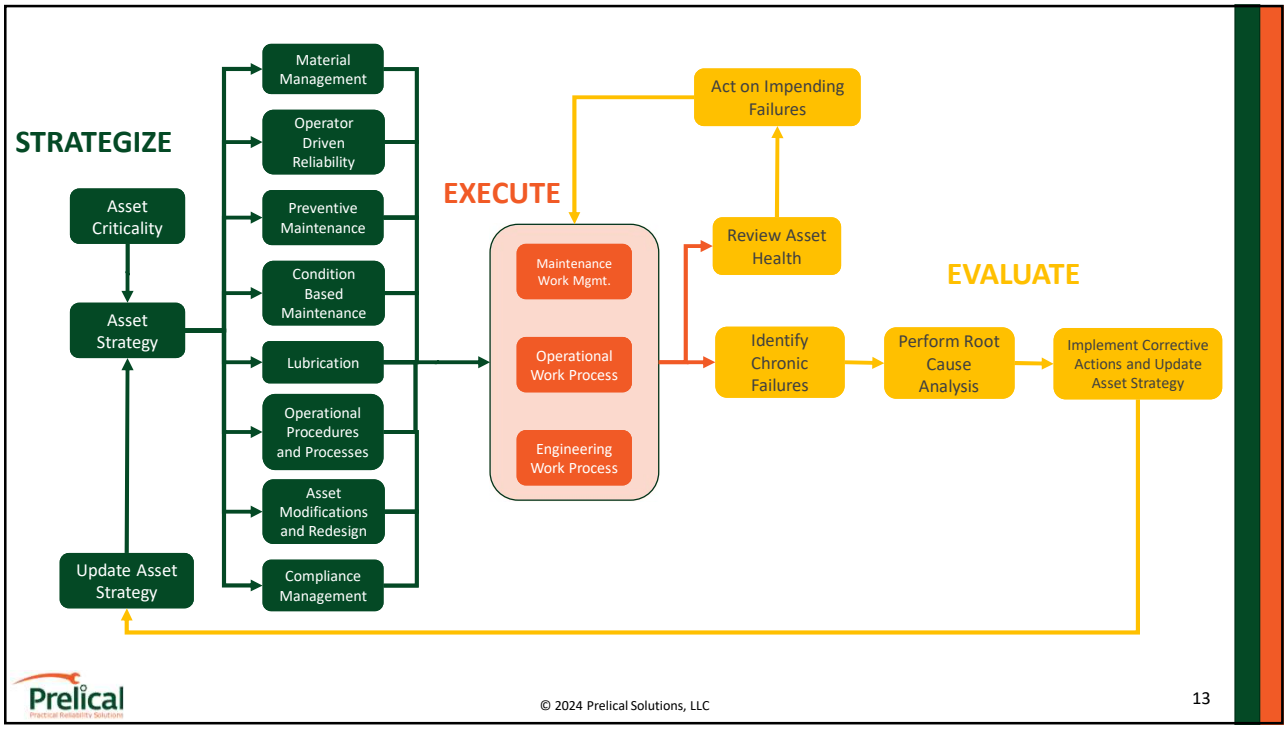

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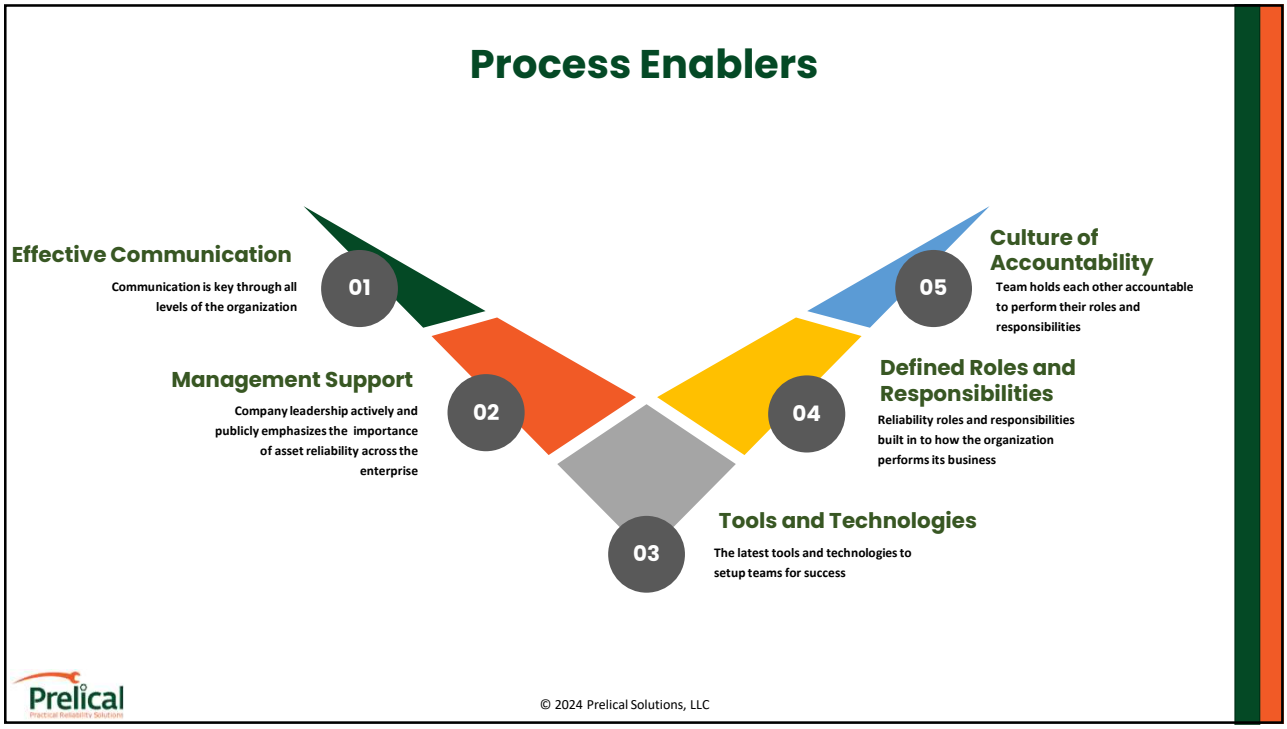

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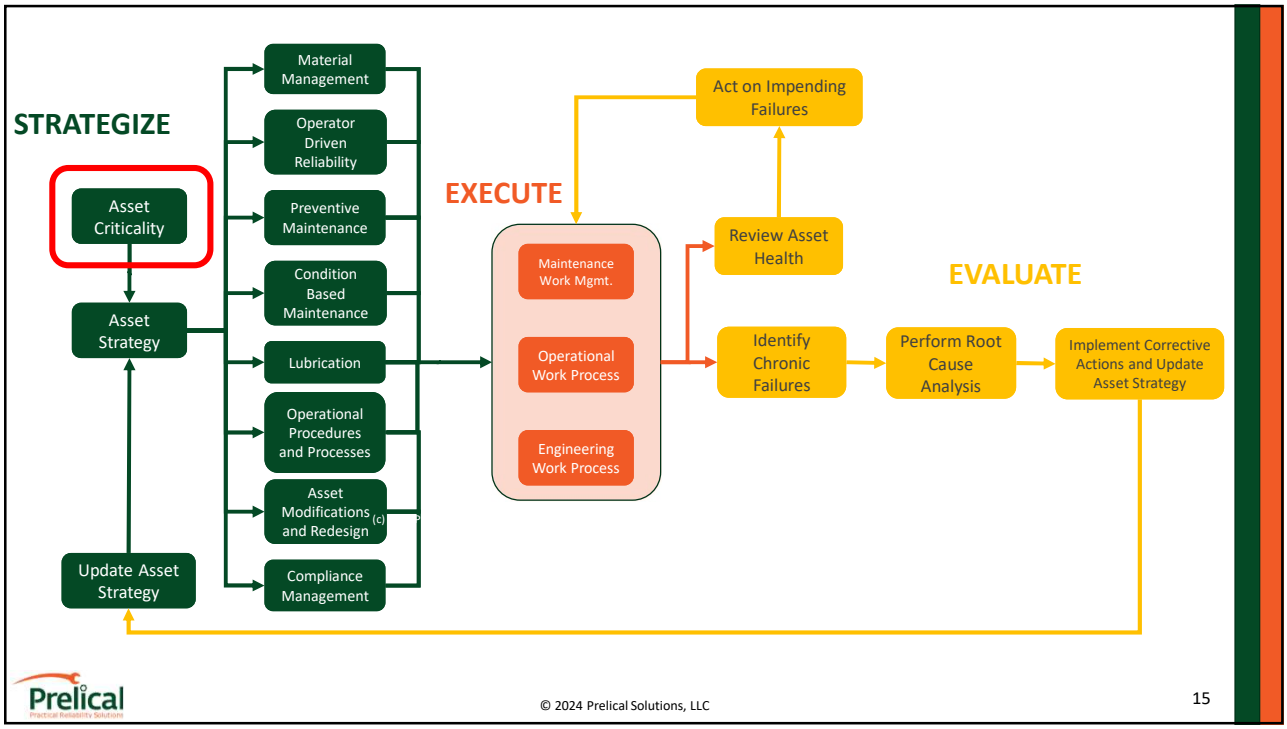

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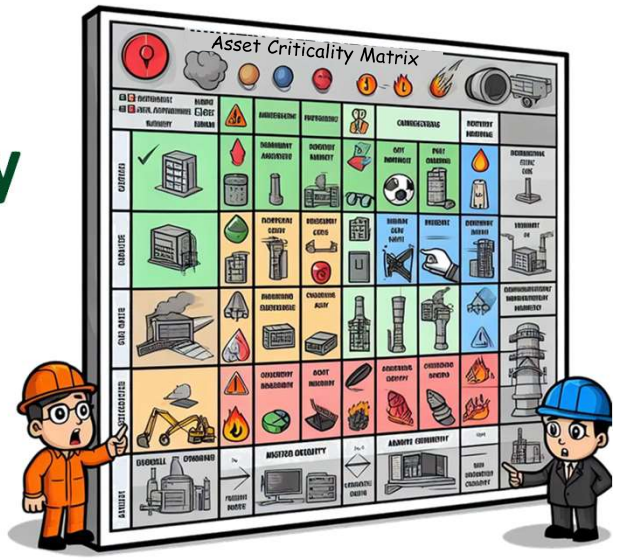
Asset Criticality Analysis



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Asset Criticality

- Asset Criticality
- Why is Criticality important?
- Elements of Criticality analysis (Safety, Environmental, Production and Cost)
- Typical criticality methodologies
- Typical distributions of Criticality
- Example of a risk matrix
- Demonstrate how to create one with a spreadsheet

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Why is Criticality Important?

Determines what level of asset strategy is required to mitigate failures

Helps to determine stocking levels of materials in the storeroom

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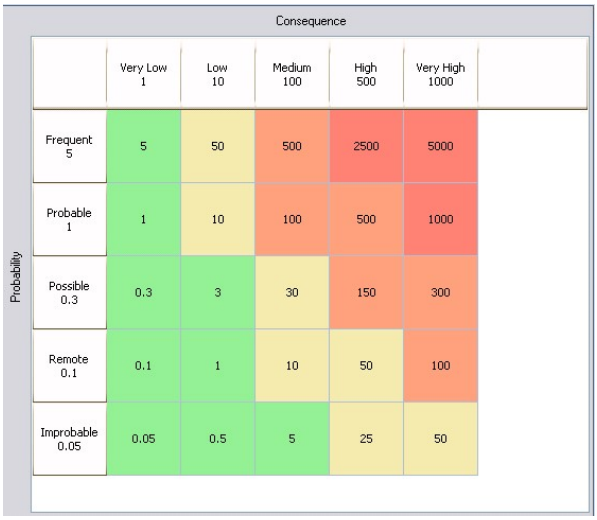
Risk Variables

- Safety
- Environmental
- Operations
- Financial



Probability	Very Low 1	Low 10	Medium 100	High 500	Very High 1000
Frequent 5	5	50	500	2500	5000
Probable 1	1	10	100	500	1000
Possible 0.3	0.3	3	30	150	300
Remote 0.1	0.1	1	10	50	100
Improbable 0.05	0.05	0.5	5	25	50

Consequence

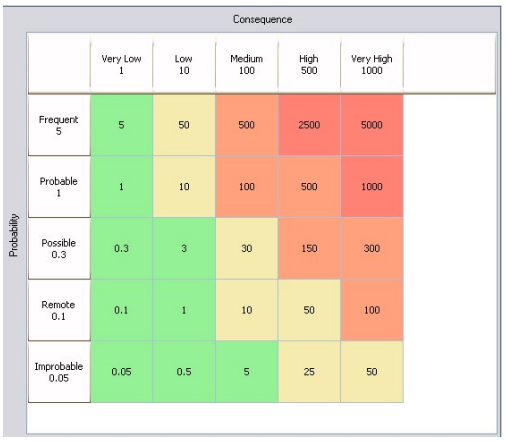
Mission Time

Mission time refers to the length of time during which an asset or system is expected to operate under normal operating conditions.

Safety

Probability	Description
5	Likely to occur more often than mission time
1	Likely to occur the same as mission time
0.3	Likely to occur less frequent than the mission time
0.1	Likely to occur much less frequent than the mission time
0.05	Unlikely to occur

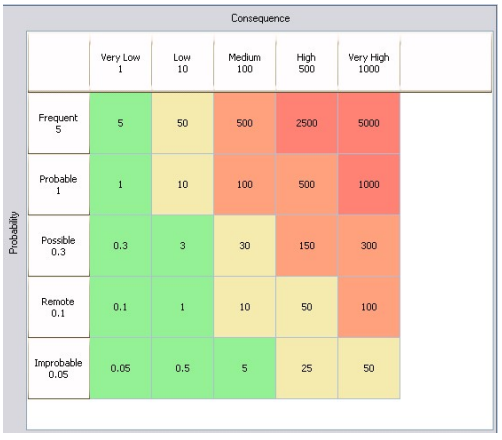
Safety Consequence	Description
1000	Fatality, litigation, business jeopardy
500	Permanent disability and potential litigation
100	Hospitilization and/or temporary disability
10	Lost Time Injury
1	None to minor first-aid



Environmental

Probability	Description
5	Likely to occur more often than mission time
1	Likely to occur the same as mission time
0.3	Likely to occur less frequent than the mission time
0.1	Likely to occur much less frequent than the mission time
0.05	Unlikely to occur

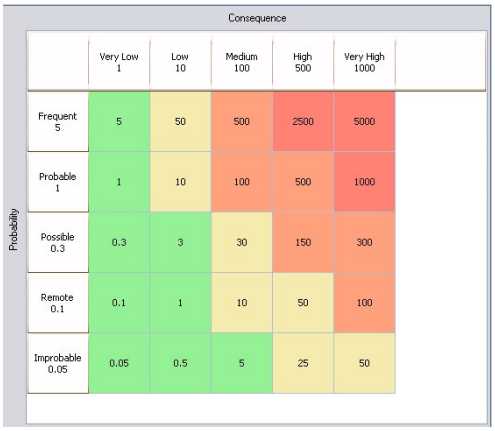
Environmental Consequence	Description
1000	World Issue, litigation and business jeopardy
500	National regulatory issue, fine or litigation
100	Local regulatory Issue, Fine, reputation damage
10	DEQ Recordable Issue
1	None to minor cleanup required



Operational

Probability	Description
5	Likely to occur more often than mission time
1	Likely to occur the same as mission time
0.3	Likely to occur less frequent than the mission time
0.1	Likely to occur much less frequent than the mission time
0.05	Unlikely to occur

Operational Consequence	
1000	Plant outage and $MM Loss
500	Area outage and $M loss
100	Subarea outage and $k loss
10	Asset outage with moderate repair cost
1	Minor repair or adjustment required



Financial

Probability	Description
5	Likely to occur more often than mission time
1	Likely to occur the same as mission time
0.3	Likely to occur less frequent than the mission time
0.1	Likely to occur much less frequent than the mission time
0.05	Unlikely to occur

Production Loss $

X **+** **=** **Consequence $**

Maintenance Cost $

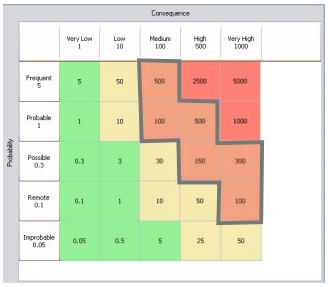
Overall Rating

Safety Probability X Safety Consequence + **Environmental Probability X Environmental Consequence** + **Operational Probability X Operational Consequence**

Overall Rating

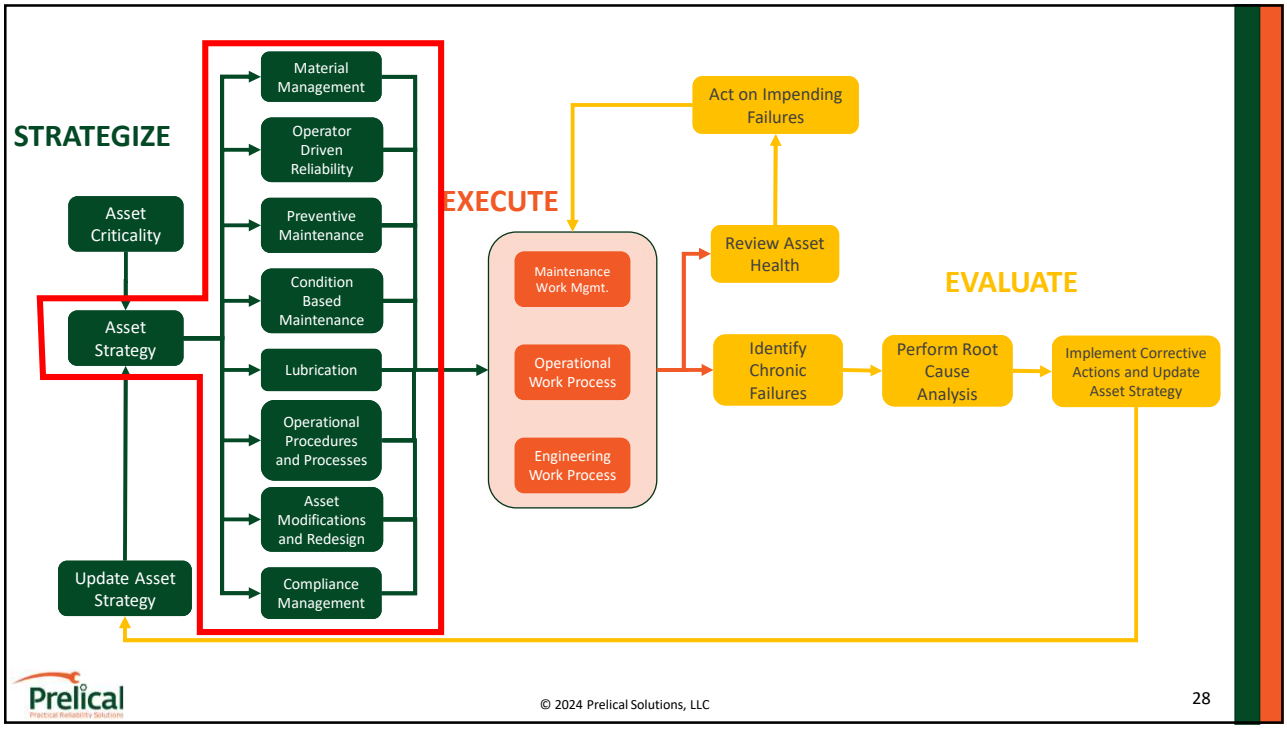
Safety 1 x 10 = 10 + **Environmental** 1 x 100 = 100 + **Operational** 1 x 100 = 10 = **120 (B)**

Rating	Range
A	>= 1000
B	>=100 and <1000
C	>5 and <100
D	<=5



Asset Criticality Distribution

High Criticality (A)	Medium Criticality (B)	Low Criticality (C/D)
• 5-10% of Assets • Consider robust asset strategies development	• 20-30% of Assets • Manufacturer Recommendations • Asset Specific Templates	• 60-75% of Assets • Basic Care • Run to Failure



Asset Strategy Development

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Failure Phases

Phase of Failure	Effect	Mitigating Action
Primary Failure	Initial indication of an impending failure	Condition Monitoring
Secondary Failure	Inability to perform intended function	Root Cause Analysis (RCA)

Primary	Secondary
Process temperature too hot →	Off-spec product
High vibration of bearing →	Pump fails
Pipe thinning →	Steam leak

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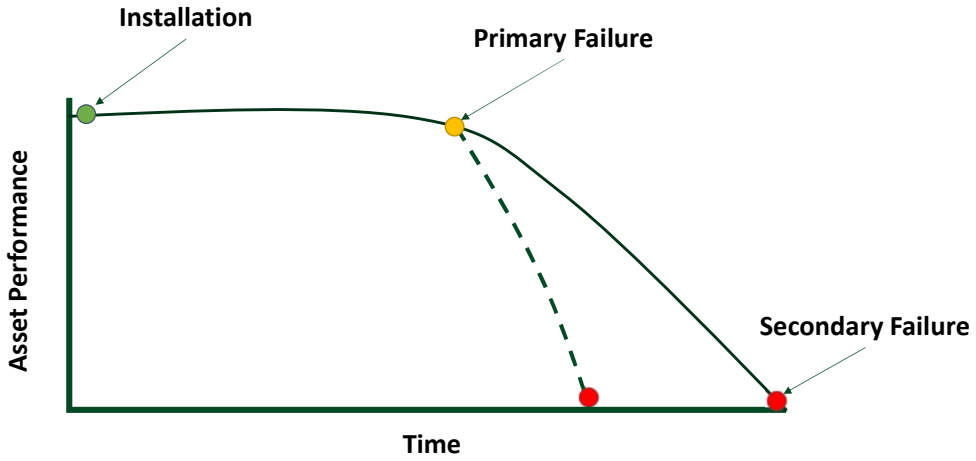
30



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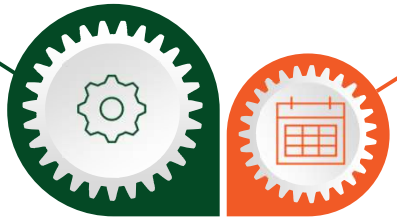
Asset Strategies



Reactive

Acting after a secondary failure has occurred

e.g., Repairing pump after it fails to function

Preventive

Performing maintenance on equipment on a fixed time interval

e.g., Changing oil on a fixed time interval

Predictive

Analyzing the condition of the equipment and acting when equipment health dictates

e.g., Oil Analysis

Proactive

Analyzing secondary failures and determining Root Causes and recommendations and analyzing unacceptable risks.

e.g., RCA, Reliability in design. FMEA

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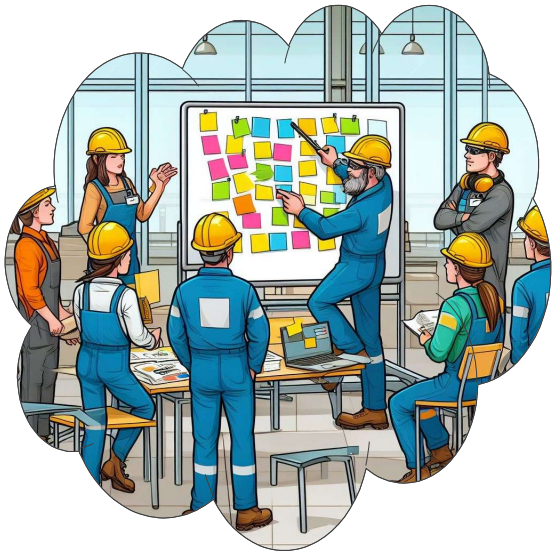
Group Exercise

What is your maintenance strategy ratio?



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Reactive	_____%
Preventive	_____%
Predictive	_____%
Proactive	_____%

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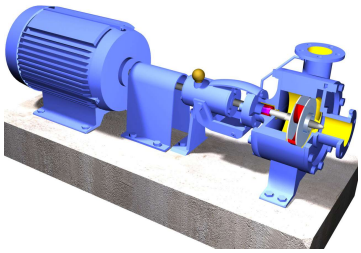
Risks (Failure Modes)

- Bearing Failures
- Seal / Packing Failure
- Coupling Failures
- Performance Issue



Mitigating Actions

- Vibration Analysis
- Visual Coupling Inspection
- Maintenance Rounds
- Operator Rounds
- Alignment Check
- Routine Oil Sampling
- Evaluate pump performance curve and system curve
- Stock materials in storeroom

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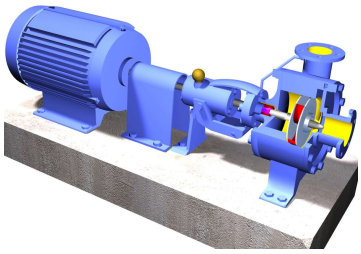
Risks (Failure Modes)

- Bearing Failures



Mitigating Actions

- Vibration Analysis
- Visual Coupling Inspection
- Maintenance Rounds
- Operator Rounds
- Alignment Check
- Routine Oil Sampling
- Evaluate pump performance curve and system curve
- Stock materials in the storeroom

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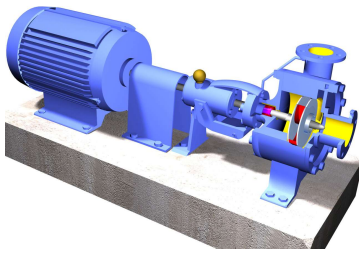
Risks (Failure Modes)

- Bearing Failures

Mitigating Actions

- Vibration Analysis



Task Properties

Interval:
1/month
Cost:
$25/check
Recommended Resources:
Vibration Analysis

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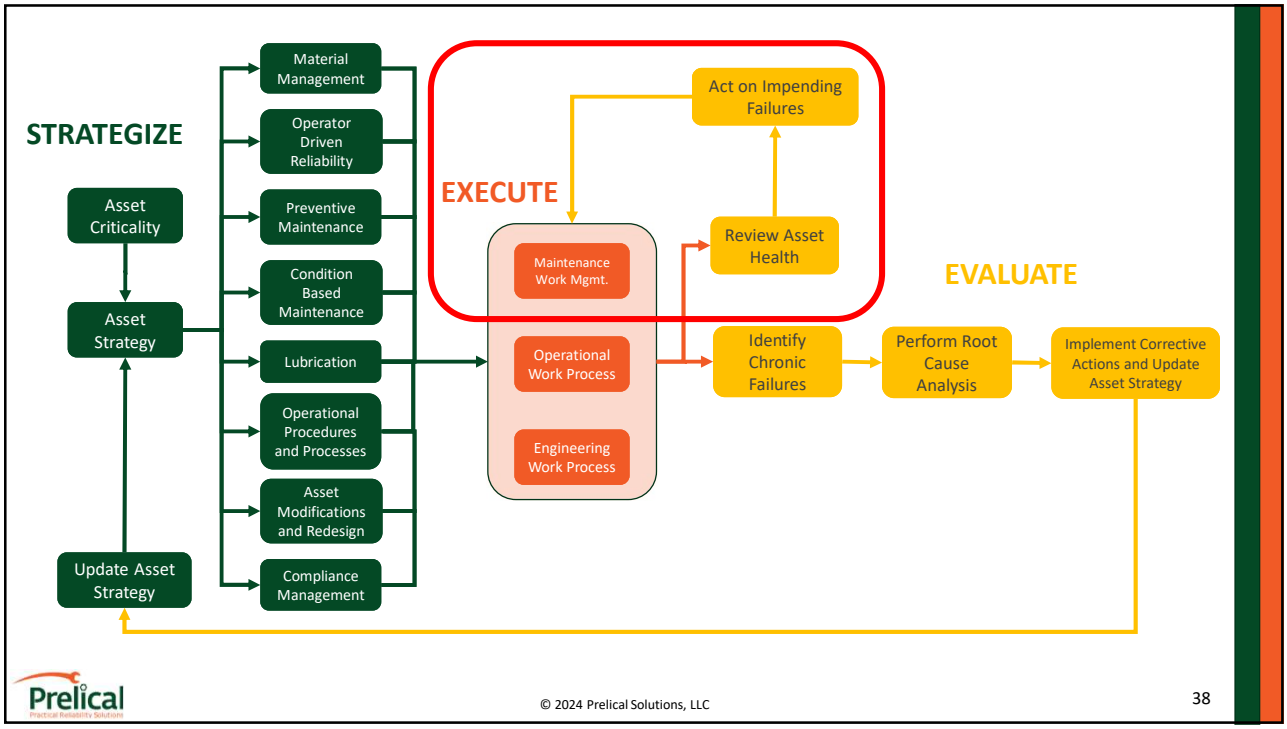

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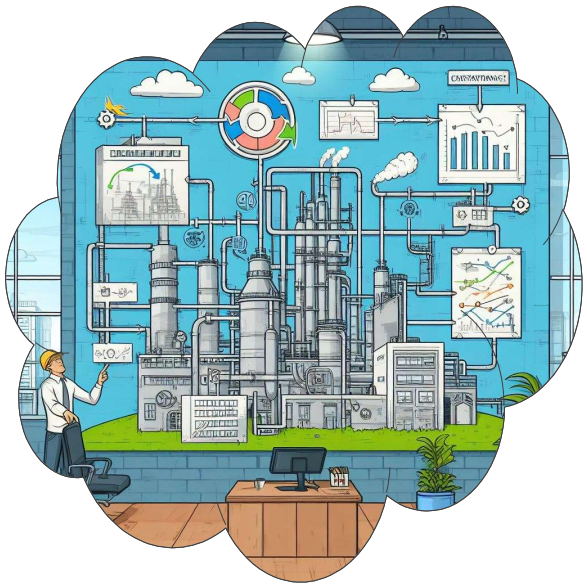
Maintenance Work Execution



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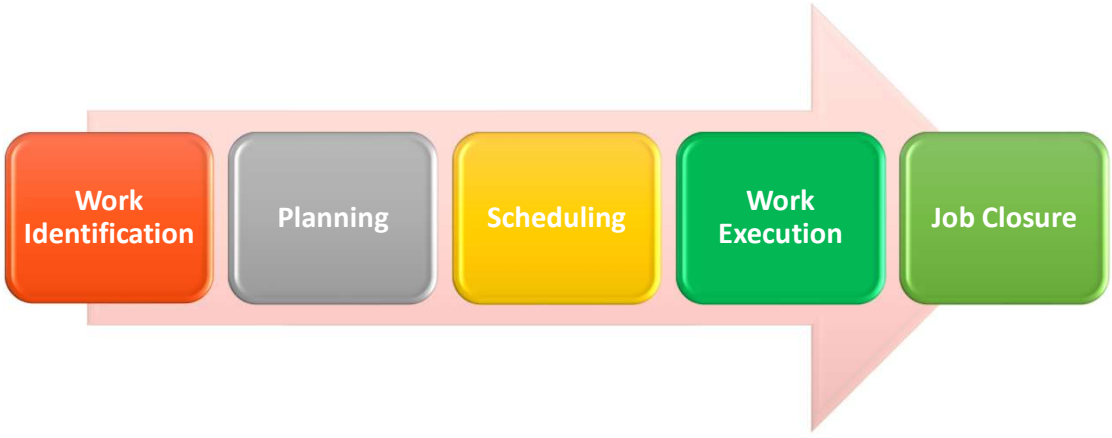
Typical Maintenance Work Management System



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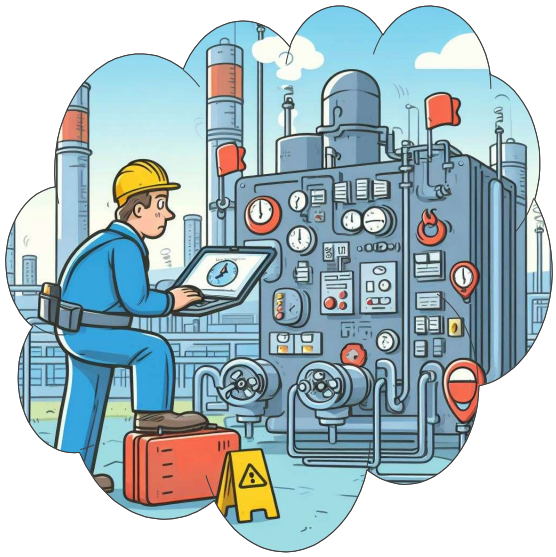
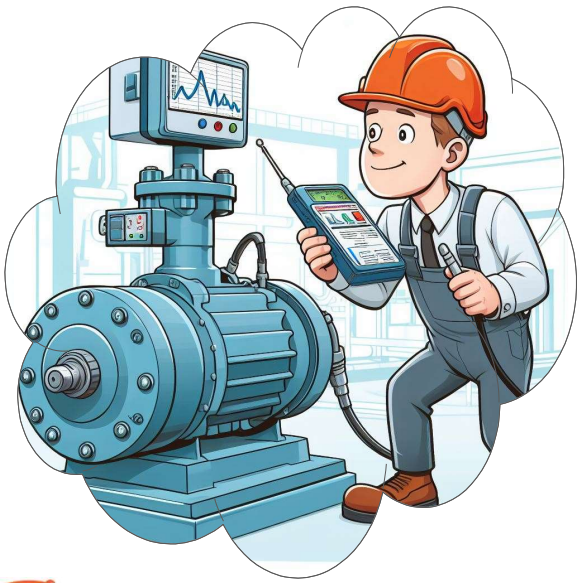
Work Identification

How is work identified in the facility?



Work Identification



- Operator/Maintenance Routes
- Preventive and Predictive (PM/PdM) Maintenance Routes
- Root Cause Analysis (RCA) action Items
- Tank Integrity
- Safety and Environmental Audits
- Employee Ownership and Awareness
- Engineering and/or Capital Initiatives

Rounds (Operator/Maintenance)

- Early detection of equipment defects
- Use of operator/craftsman senses and basic diagnostic tools
- Supplements more advance inspections performed by Predictive Maintenance Group (e.g. vibration, infrared)
- Allows identified defects to be planned and scheduled
  - Will reduce unplanned equipment downtime and related maintenance repair cost
  - Reduces the probability of safety and environmental issues
- Creates a feeling of ownership of the equipment

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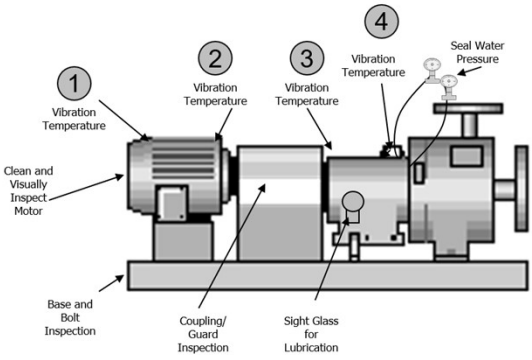
Pump / Motor Data Collection Points



Centrifugal Pump

- Check Bearing Temperatures (inboard/outboard)
- Check Bearing Overall Vibration (ips) (inboard/outboard)
- Check Seal Water Pressure
- Inspect Coupling RPM (if safe to do so)
- Inspect for loose, short or missing bolts on base and flanges
- Check oil level
- Check oil quality (visual inspection)

Electric Motor

- Check Bearing Temperatures (inboard/outboard)
- Check Bearing Overall Vibration (ips) (inboard/outboard)
- Ensure airflow on fins and back, and clean debris from back of motor
- Inspect for loose, short or missing bolts on base
- Ensure all cables are in working order

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Backlog Management

- Work is coming in faster than we can process it
- Prioritization is critical to managing the backlog of work
- Priority should be based on the level of risk
- Backlog review and prioritization should be an ongoing activity
- Every work order should have an accurate priority code

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Planning

- Detailed work instructions
- Supplemental documentation (e.g. procedures, drawings, etc.)
- Proper time allocation from internal resources
- Contract work if required:
  - Permits
  - Mill Entry Requirements
  - Pre-Job Requirements
- Spare parts procured (internal or external)
- Proper work order coding in CMMS

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Scheduling

- Maintenance Resource Optimization cannot be obtained without effective scheduling
- Operations and Maintenance are both responsible for work scheduling and coordination of work (Core Teams)
- Planned and ready to be scheduled (R2BS) work is essential for effective scheduling
- The backlog is used to prioritize, select and Schedule work
- Manpower availability must be established for effective scheduling
- Final manpower availability is established weekly by Operations/maintenance coordinator
- Weekly, daily & shutdown schedules are developed, distributed and posted

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Work Execution

- All safety precautions will be in place and reviewed prior to performing the work.
- Ensure that all tools, parts and service equipment (e.g. cranes) are available for the schedule start of work
- Ensure that the equipment is locked out ahead of work execution and the area is ready for maintenance to perform the required work
- Utilizing precision maintenance techniques and principles will be the expectation on every job effort.
- Good housekeeping practices
  - Identifies issues and assigns work to promote good housekeeping to extend equipment life and asset health.
  - Personally, assure that each job site is left in a neat and clean condition promoting equipment reliability and life, and that his/her area is kept in safe and clean condition for all employees

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Job Closure

- The crew should communicate with the Supervisor, Operation/Maintenance Coordinator or an appointed operations contact to properly return the equipment to service and the desired performance is obtained
- Maintenance works with operations to startup or “try” equipment, when possible, to insure it operates properly when work is complete
- Document the details of the job in CMMS
- Craft time confirmations are accurately entered CMMS
- Precision Maintenance forms are completed and returned to Supervisor as required by the job
- Spare parts / cores are properly tagged and returned to the storeroom
- Feedback provided to the planner for any corrections needed (e.g. wrong parts, time estimates incorrect, etc.)
- Work order is properly closed

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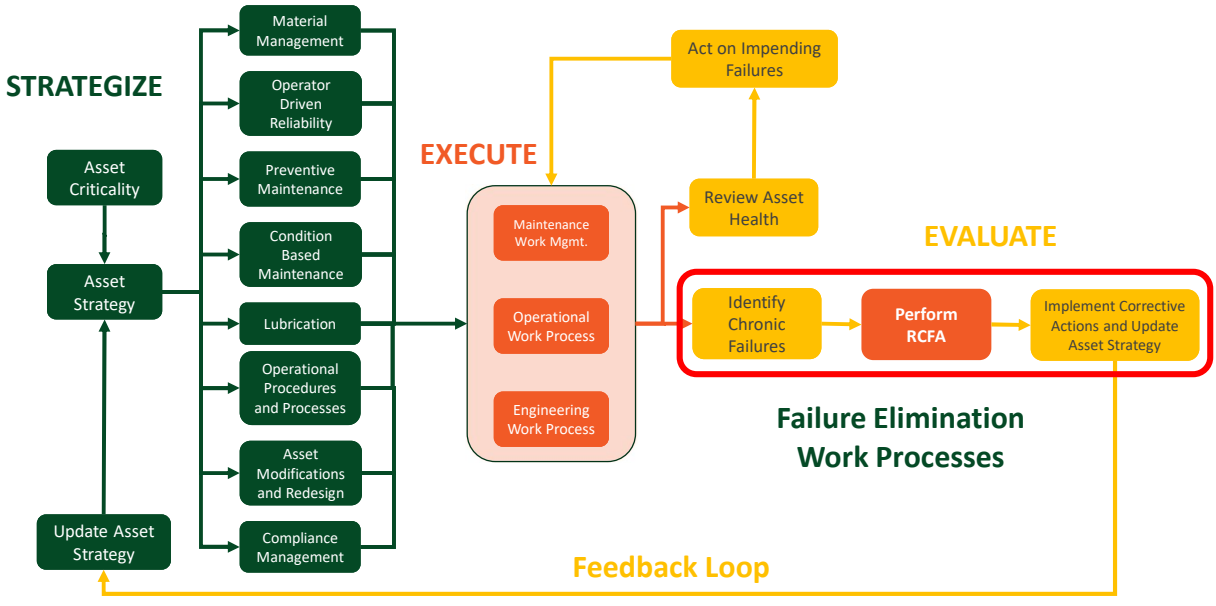

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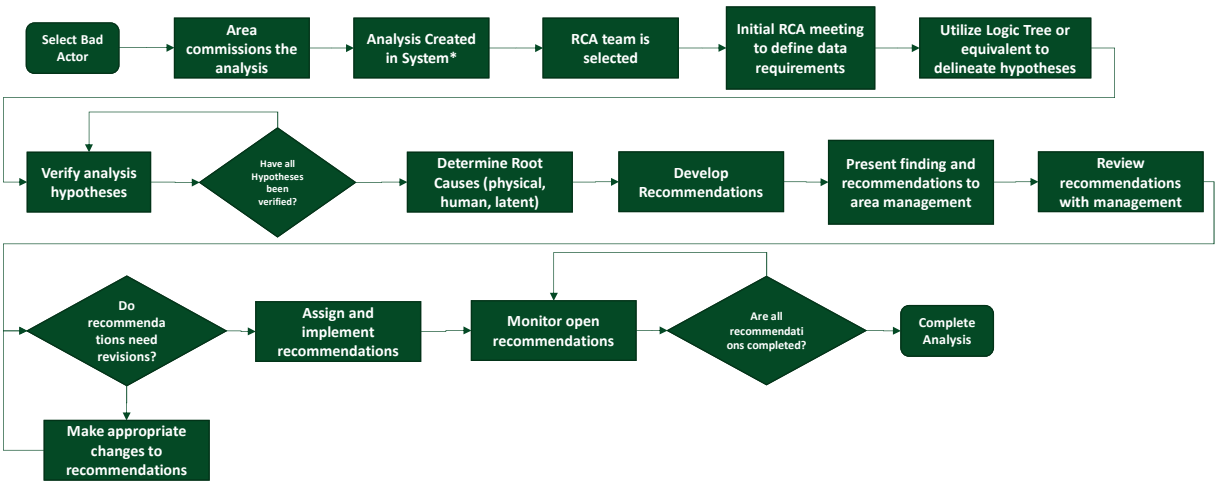
Simplified Failure Elimination Workflow (Chronic)



* System denotes the software solution where the RCA will be created.

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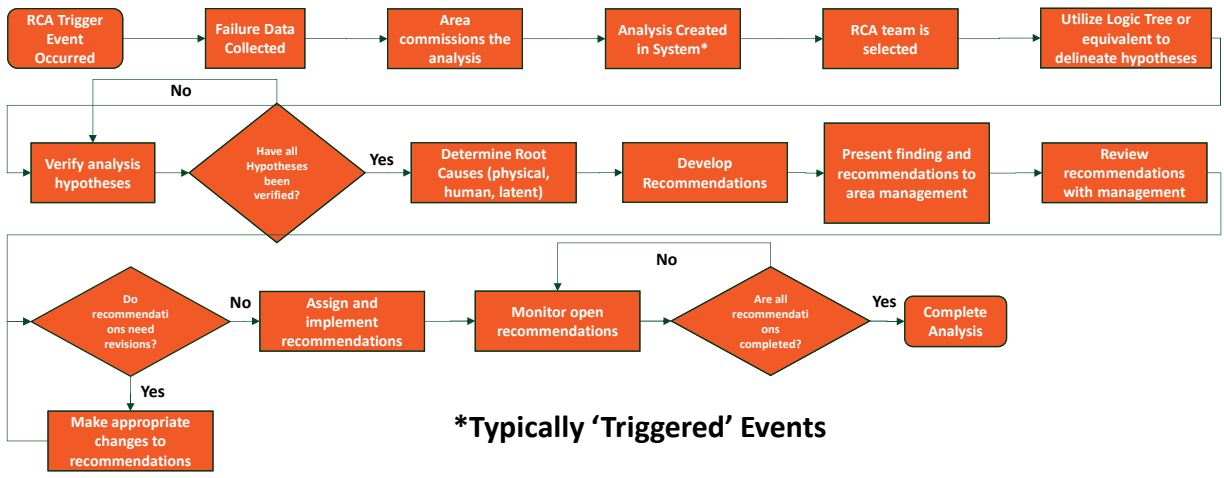
Simplified Failure Elimination Workflow (Sporadic)



***Typically 'Triggered' Events**

* System denotes the software solution where the RCA will be created.

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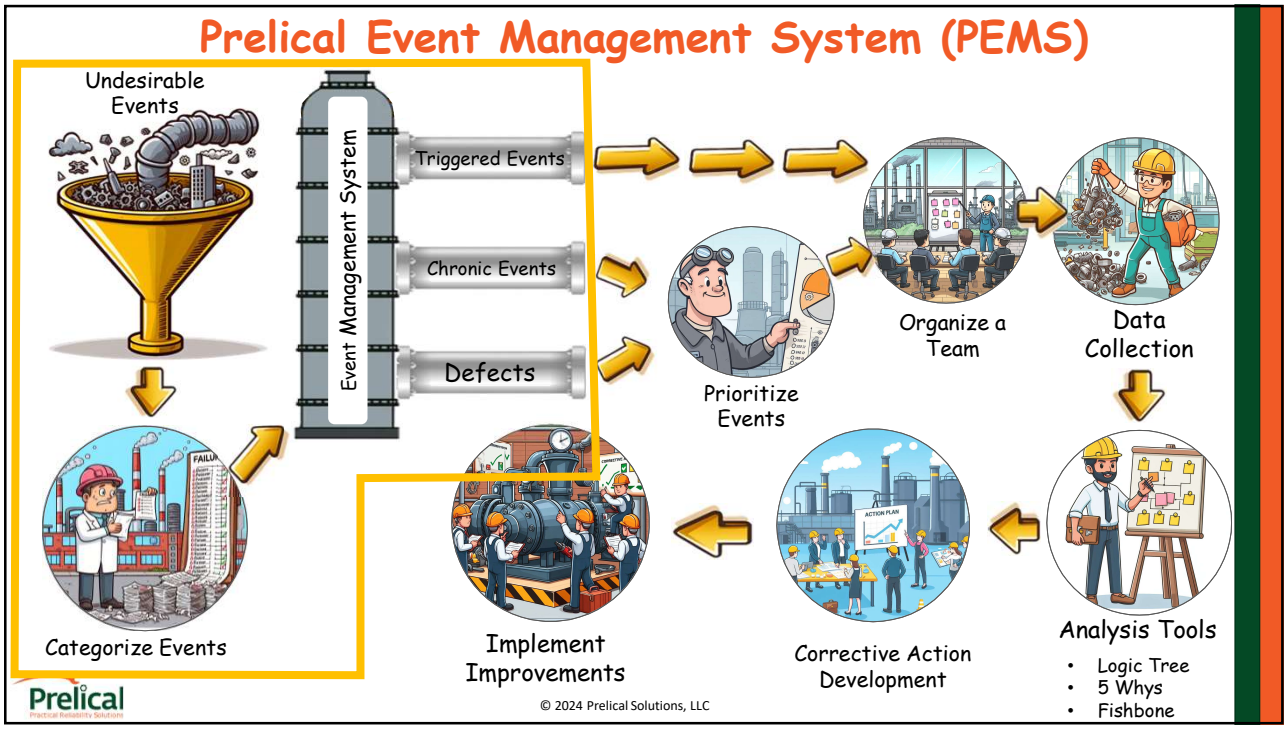

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Root Cause Analysis Case Study

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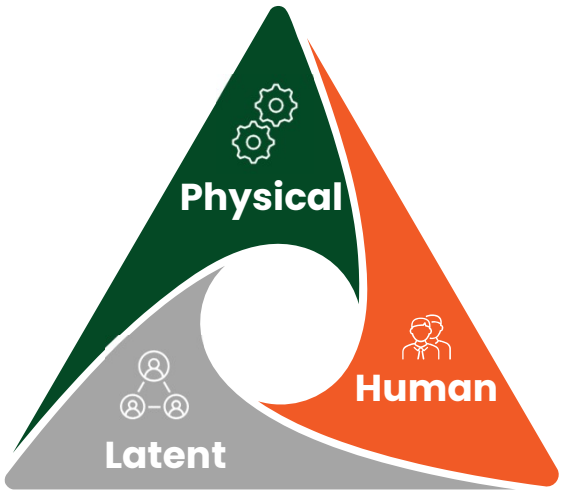
Levels of Root Cause



Physical

Physical root cause refers to the underlying, tangible, and typically material factor or condition responsible for a problem, failure, or issue in a system or process.

Human

Human root cause refers to the underlying factors or conditions related to human actions or decisions that contribute to a problem or incident.

Latent

Latent root causes are typically related to systemic weaknesses, process flaws, organizational culture, or other underlying factors that may have been contributing to the problem over an extended period.

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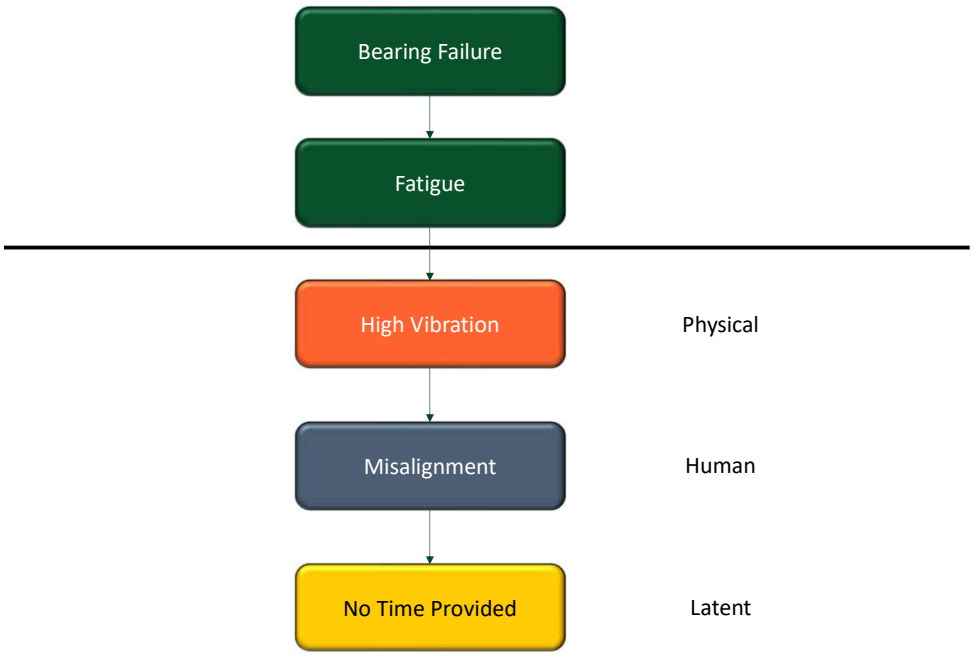

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Determining Candidates for Root Cause

Defined Triggers

"Root Cause Analysis Triggers" are specific events, incidents, or circumstances that initiate the need for a Root Cause Analysis (RCA) process. These triggers serve as signals or prompts for an organization to investigate and identify the underlying causes of a problem, failure, or undesired outcome.

Chronic Failures

Chronic or repetitive failures refer to a pattern of recurring and persistent issues, malfunctions, or breakdowns in a piece of machinery, equipment, or a system. These failures happen on a regular or frequent basis, and they typically occur over an extended period. Such failures are characterized by their repetitiveness and can be a significant source of disruption, cost, and operational inefficiency for an organization.

Defect

“Anything that erodes value, reduces production, compromises health, safety or environmental performance or creates waste”

Source: Frontline Solutions

Prelical

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	Triggered Events	Chronic Events	Defects
Requires Prioritization		●	●
Requires Extensive Data Collection	●	●	
Logic Tree	●	●	●
5 Whys			●
Fishbone Diagram			●
Corrective Action Development	●	●	●
Report and Presentation for Management	●	●	
Corrective Action Implementation	●	●	●

Prelical

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Examples of Triggers

More than 16 hours of downtime on a process (e.g., Paper Machine)

An unplanned repair that costs more that $150K in maintenance cost

Boiler Trip

Example Triggers for a Paper Mill

- Safety Recordable Injuries
- Environmental Excursions
- 8 hours unscheduled downtime on any major process area (C1, C2, C8, Power, Recovery, Fiberline)
- Unscheduled mechanical or electrical repair where costs exceed $100,000 in maintenance expense
- Rejects greater than 250 tons for a single event
- Boiler trip for Recovery Boilers (1 or 2) or Power Boilers (1 or 9)
- Manager invoked

What are your Triggers?

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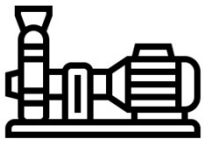
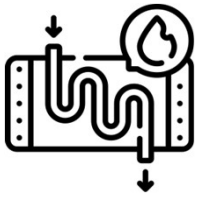
Examples of Chronic Failures



Pump 101 fails 4 times per year

Average 10 wet end breaks on PM-1



Heat Exchanger 101 experiences numerous tube leaks

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Examples of Defects

Arriving at a maintenance job and the equipment is not locked out

Assigned a maintenance job but the parts provided are incorrect

Operating a process when the instrumentation is not working or is providing incorrect information

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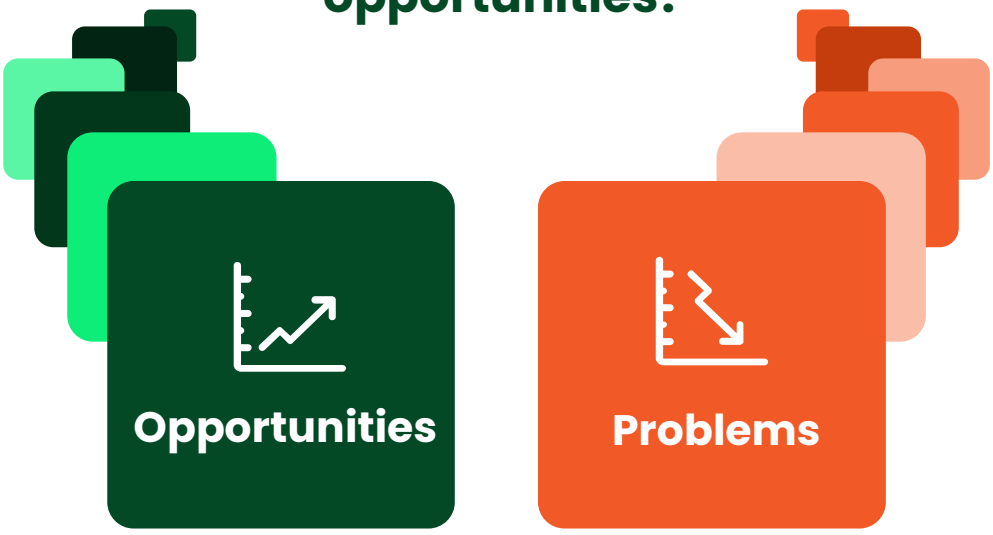
Are problems really opportunities?



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Are problems really opportunities?

Opportunities

An occasion or situation that makes it possible to do something to improve the current situation (status quo)

Problems

A matter or situation regarded as unwelcome or harmful and needing to be dealt with and overcome to get back to status quo.

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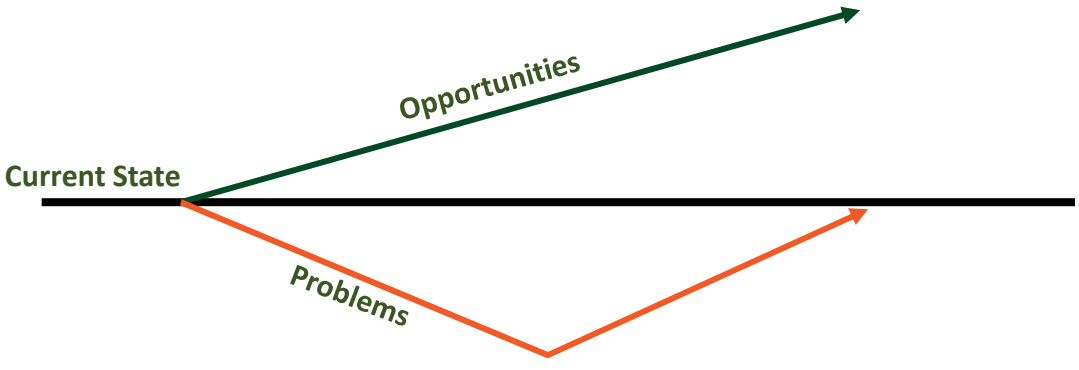

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If opportunities drive improvements, why do we focus so much on fixing problems?

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It is human nature for us to work on the 'urgent' versus the 'important'!!

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Triggered Event Characteristics

Urgent

These events are typically dramatic event that require immediate attention from the site

Infrequent

These events, by definition, do not occur very often

Time Consuming

These events take considerable time and attention away from the site to deal with the consequences of the event

Costly

These events require considerable financial resources to get back to steady state operations

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Triggered Event Examples

Conveyor Fracture

Dryer Bearing Failure

Gloss Calender Roll Failure

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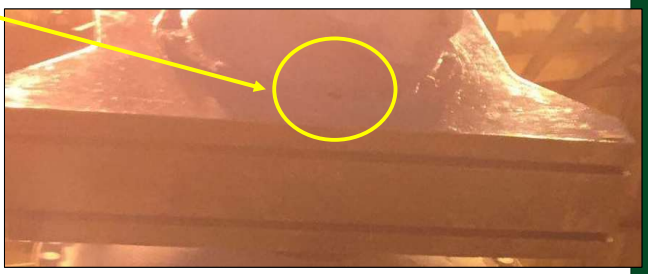

2nd Plug not easily visible inside the role (6" deeper than 1st plug).

Prelical

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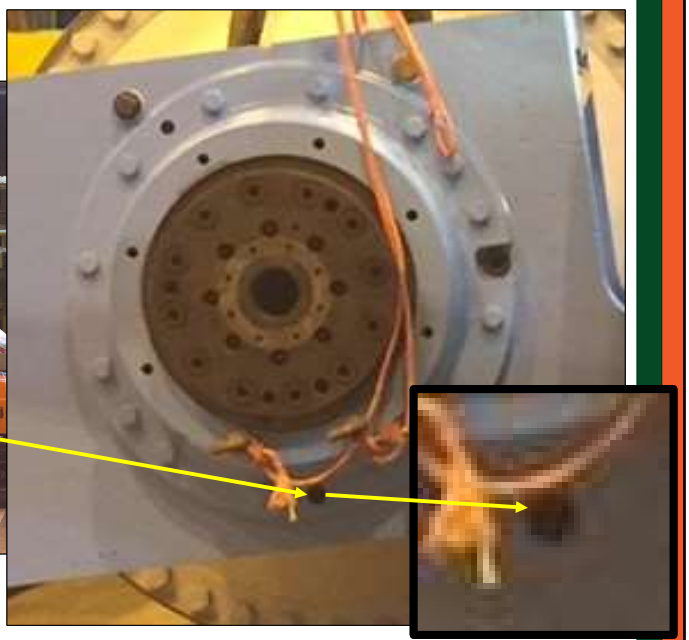

2nd Plug not easily visible inside the roll

Prelical

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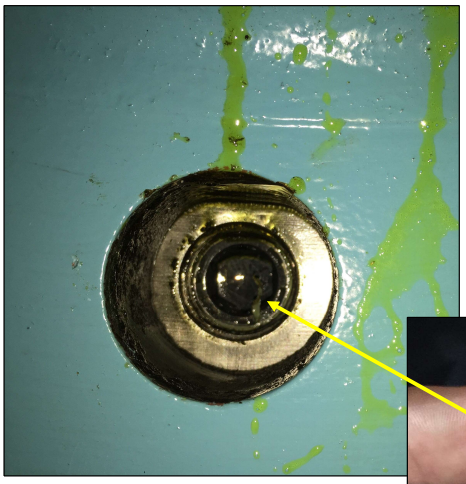
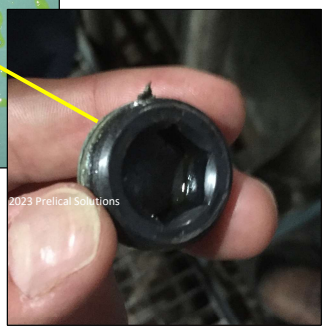


Front Side



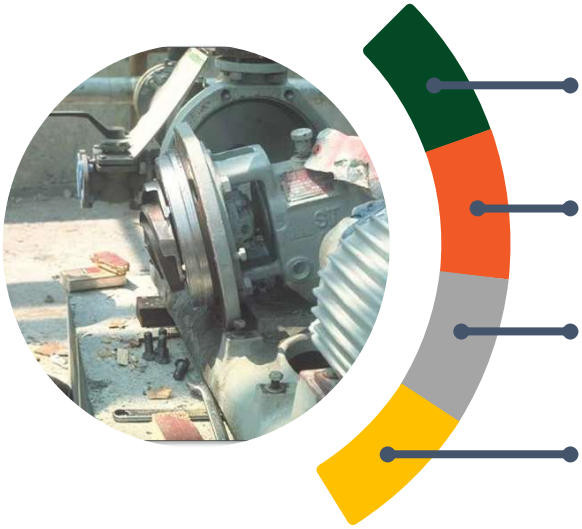
Back Side

Note: Practice was to hold roll being replaced before sending out for repairs, in case new roll had issues.

Team Exercise: Develop a List of Triggered Events

As a group, let's develop a list of significant failures that meets the definition of Sporadic (aka Triggered). Break the failures into the areas of the facility.

Chronic Failure Characteristics



Routine

These are events that happen so often, they are considered part of the status quo

Frequent Occurrence

These events, by definition, happen very frequently

Quick Fix

These events generally get resolved quickly. Mainly due to how often they occur

Not Individually Costly

Individual events do not cost very much when compared to sporadic failures. However, they are very costly if you multiple their impact by their frequency of occurrence.

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Chronic Effect

Fuel Oil Pumps

Trim Squirt Pumps

Thick Stock Pumps

Pulper Plugging

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Team Exercise: Develop a List of Chronic Events

As a group, let's develop a list of chronic failures that meets the definition of chronic. Break the failures into the areas of the facility.

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Defect Characteristics

Barriers to Work

Any barrier that prevents the worker from performing their intended task.

Low Cost to Correct

Must be a low-cost item to correct. Typically, it should be less that $5k to resolve.

Short Time to Resolve

Should not take longer than 60-90 days to resolve the defect

Does Not Require In-Depth Analysis

Does not require a lot of analysis and meetings to resolve. Can typically be resolved by one person or a small group.

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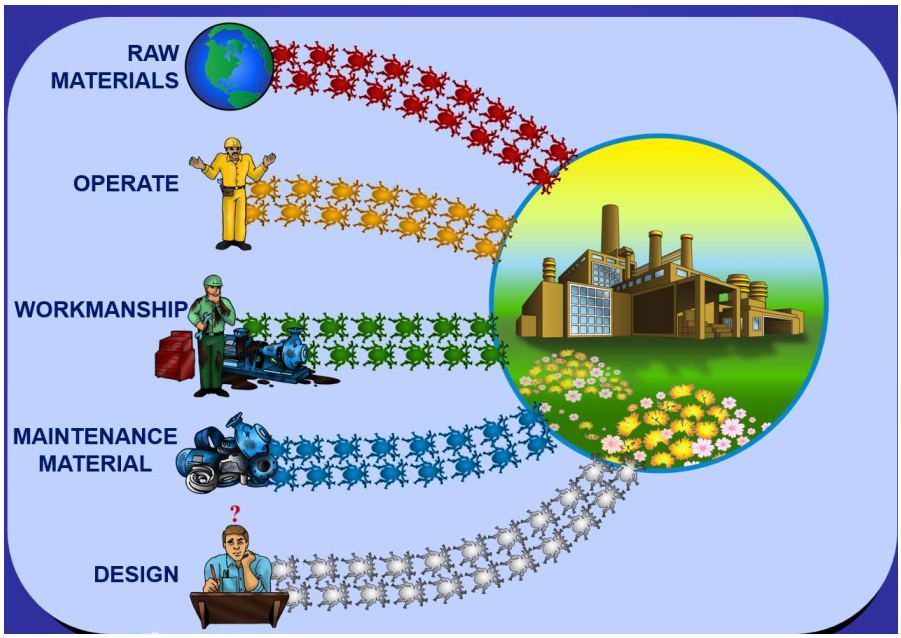

Source: The Manufacturing Game®

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Defect Example

Waiting on Operations to Start a Job

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Team Exercise: Develop a List of Defects

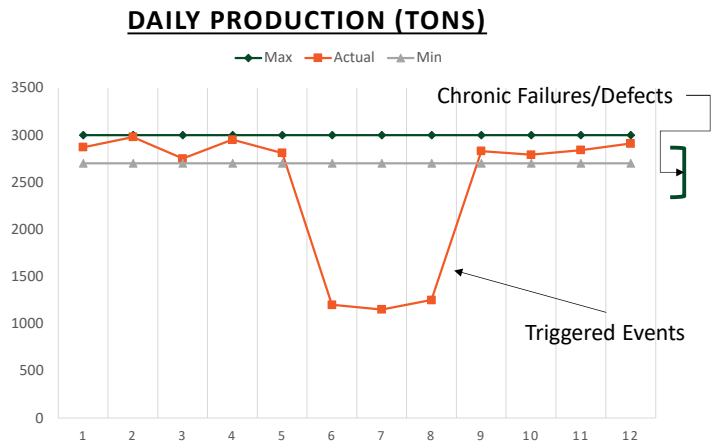
As a group, let's develop a list of defects that meets the definition of a defect. Break the defects into the area of the facility.

Chronic Failures are Built Into the Current State

Max Goal Production
Maximum Sustainable Production

Min Goal Production
Minimum Sustainable Production

Actual Production
Actual Daily Production

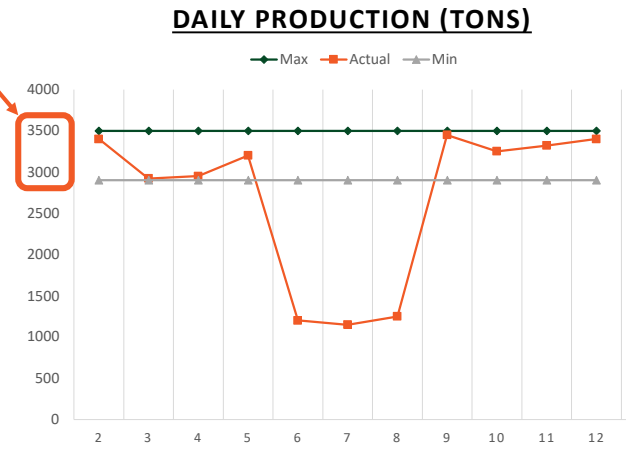


Focusing on Reducing Chronic Failures/Defects Increases the Status Quo

Max Goal Production
Maximum Sustainable Production

Min Goal Production
Minimum Sustainable Production

Actual Production
Actual Daily Production



Sustainable Improvement

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