

Achieving Reliability from Data

☒

Decisions in maintenance

☒

Historical roots of RCM

☒

RCM Functional analysis

☒

RCM Failures, Modes, Effects analysis (FMEA)

☒

RCM Consequences analysis

☒

RCM Failure Management Policies

☐

Initial RCM Workshop

☐

Living RCM

☐

Reliability analysis in 2 dimensions

☐

Reliability analysis in >2 dimensions

(Initial) RCM Workshop

Module 2.6en


Functions (Q1)

FMEA (Q2-Q4)

Consequences (Q5)

Policies (Q6-Q7)

RCM Dashboard





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1

Hitachi EX3600
Shovel



2

"Hybrid"
structure

(LEVEL of Analysis)

DM TestFleet v1.10

1. Function 1

1. Fails to provide smooth ride

2. System1

1. Subsystem1.1

2. Subsystem1.2

1. Component1.2.1

2. Component1.2.2

1. Function 1.2.2.1

1. FunctionalFailure1.2.2.1.1

1. FailureMode1 Damage1 caused by Cause1

2. Part2 Damage2 caused by Cause2

2. FunctionalFailure1.2.2.1.2

2. Function1.2.2.2

3. Subsystem1.3

4. To hold back the evil creatures from the underworld

3. System2

1. Subsystem1.2

1. Component 2.1.4

2. Component1.2.2

1. Function 1.2.2.1

2. Function1.2.2.2

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"Hybrid" structure

(LEVEL of Analysis)

Hydraulic shovel Hitachi EX3600 - RCM G1 v3.5

Hydraulic shovel Hitachi EX3600 - RCM G1 v3.5

1. Accessories

2. Engine system

3. Hydraulic System

4. Electrical system

5. Structure

6. Monitoring and control system

1. Accessories

1. Hydraulic system main staircase

1. To allow raising or lowering the main staircase.

1. Cannot raise or lower main staircase.

1. Fuses ladder circuit Fails open caused by n/a

2. Wiring ladder circuit Fails open caused by n/a

3. Switch for activating ladder Fails open caused by n/a

4. Safety limit switch Fails closed caused by n/a

5. Solenoid valve for lowering ladder Stuck caused by n/a

6. Emergency shut off switch Fails open caused by n/a

Fleet

System

Subsystem

Component

Function

Functional Failure

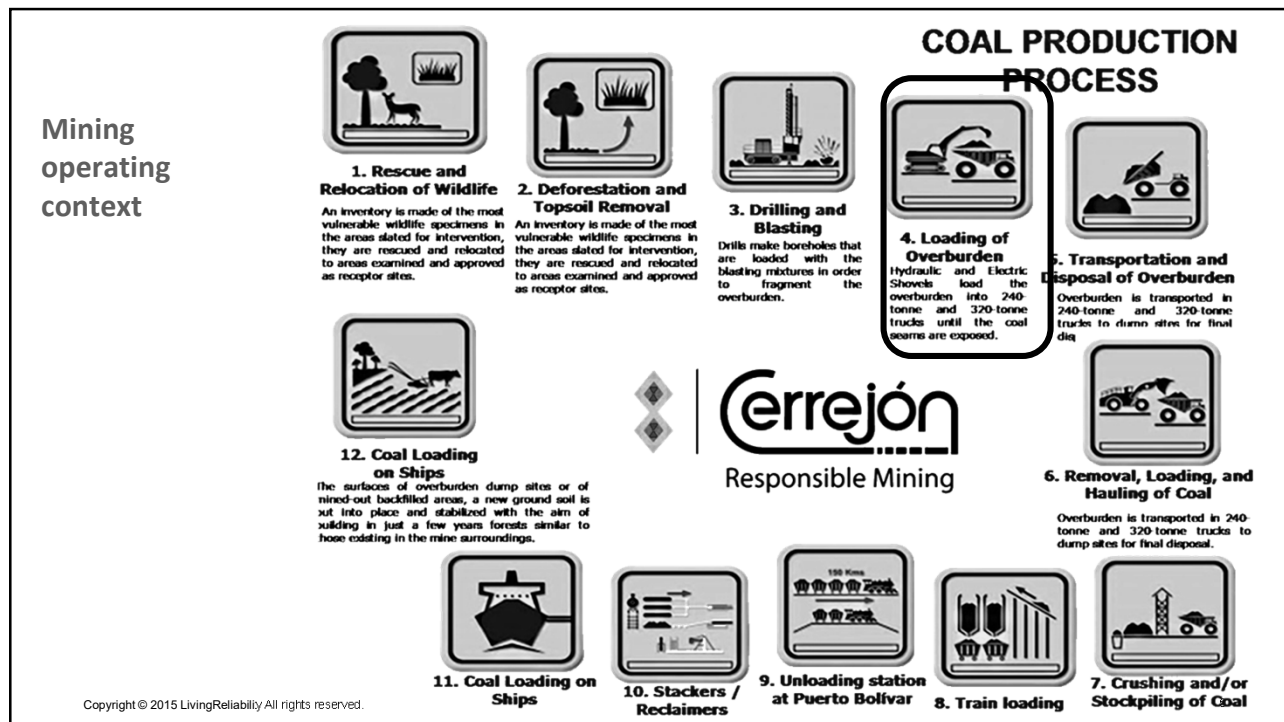
Failure Mode

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Mining operating context



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Operating context

1. Role of the asset in the organization?
2. What are the implications if the asset is unavailable?
3. What are the different operating phases?
4. What spares stocking policy applies to this asset?
5. Relevant shift arrangements?
6. Safety issues and past incidents?
7. Backup equipment, redundancies and built-in test equipment?
8. ...



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[illegible]

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Hydraulic shovel Hitachi EX3600 v22.22

1. Accessories

2. Engine system

3. Hydraulic System

4. Electrical system

5. Structure

6. Monitoring and control system

Fleet

System

Subsystem

Component

Function

Functional Failure

Failure Mode

Hydraulic shovel Hitachi EX3600 v22.22

1. Accessories

2. Engine system

3. Hydraulic System

1. Suction, supply and return system

2. Lift system

3. Push system

4. Bucket system

5. Swing system

6. Travel system

7. Cooling system

4. Electrical system

5. Structure

6. Monitoring and control system

Level of Analysis

Requirements - hydraulic return and supply system

The supply and return is responsible for supplying hydraulic oil to the four groups of axial piston pumps in tandem (eight pumps in total). Hydraulic oil is supplied at a flow rate of 4000lpm (8 * 500lpm) and a pressure of 300 bars (29.4MPa) to the functions: front attachment, swing, and travel. This system also ensures oil containment and must prevent particles larger than 177 microns from remaining in the hydraulic system. The hydraulic oil tank must be kept free of air pressure and oil should be kept clean meeting an ISO cleanliness code of 16/14/11.

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Functional analysis

2. Hydraulic System

1. Suction, supply and return system

1. To supply 4000 lpm of hydraulic oil at 300 bar (29.4MPa) to front attachment, swing and travel func

2. To prevent particles larger than 177 microns to remain in the hydraulic system

3. To contain the hydraulic oil

4. To indicate the level of oil in the hydraulic oil tank

5. To relieve internal air pressure in the hydraulic tank to 0.5 bar.

6. Able to release air pressure from hydraulic tank

7. To prevent particles greater than 95 microns to pass into the main valves and actuators.

8. To direct the flow of hydraulic oil to each of the actuators

9. To keep the hydraulic system oil at a cleanliness level of ISO 16/14/11.

10. To prevent particles larger than 10 microns pass into the hydraulic tank.

11. To prevent particles larger than 5 microns in the oil passing from the main valve into the tank

1. Log into <https://206.189.168.145:8181/mesh/> GroupN, livingrcm1 (N=1,2,3, or 4)

2. Fleet Administration tab. Name filter: rcm

3. Hyd .. RCM Gn, Actions: Build knowledge icon

4. Hydraulic System, unfold

5. Button Start Edit

6. Suction, supply and return system, Right click, Append, Function

7. Start typing: "To supply ..." Wait a few seconds. Pick a choice. (hydraulic oil at 300...). Hit Accept.

8. Repeat 7 and 8 for each new function to be added. (Refer to operational context on previous slide. Hit Save.

Actions

Build Knowledge

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2.6.1 Quiz 1 Initial RCM Workshop

<https://forms.gle/rYWWL73tf67D5o4F6>

1. Complex assets may be broken down into convenient systems, subsystems, and components for RCM analysis. If one wishes to perform the analysis for a particular component, one should: *

1. List function statements below the branch representing that component.

2. Skip the functional analysis altogether and list the failure modes for the component.

3. both of the above

4. none of the above.

2. Each leaf of the RCM knowledge tree represents a failure mode. A failure mode can be copied and reused elsewhere in the asset hierarchy or even in another asset's analysis. True or false? *

True

False

3. It would be inappropriate to simplify the analysis and reduce the list of functions by: *

1. Representing some functions deep down in the asset as failure modes of a higher level function.

2. Including multiple performance standards in a single function statement as long as it is clear and concise.

3. Omitting some secondary functions.

4. All of the above.

5. None of the above.

4. The operating context *

1. should be documented before the analysis begins

2. should be referred to during the analysis.

3. should include relevant information such as whether and to what extent the asset is backed up in case of its failure.

4. should mention the various operating phases of the asset.

5. should explain the role of the asset in the organization.

6. all of the above.

7. none of the above.

5. It necessary to include quantitative standards such as range and accuracy in functions that involve a measurement because: *

1. RCM style always demands quantitative standards of some kind.

2. We are thinking ahead to question 2, the failed state, where the range of the measurement function can drift and accuracy can widen.

3. both of the above

4. none of the above.

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1. Session start

Username: *

Password: *

Log In

Language: English | Spanish

2. Fleet Administration

rcm

Hydraulic shovel Hitachi EX3600 - RCM G1

Hydraulic shovel Hitachi EX3600 - LRCM G1

3. Actions

Build Knowledge

4. Hydraulic shovel Hitachi EX3600 - RCM G1 v10.0

1. Accessories

2. Engine system

3. Hydraulic System

4. Bucket system

5. Swing system

5. Knowledge

Start Edit

Hydraulic shov

1. Accesss

6. 3. Hydraulic System

1. Suction, supply and

2. Lift system

3. Push system

4. Bucket system

5. Swing system

Append

Modify

Remove

Function

7. Append new function

Function:

To supply

To supply hot water at a rate of up to 60 liters/minute immediately upstream of

To supply hot water with a temperature between 50C and 55C to all taps within capability.

To supply hydraulic oil at 300 bar (Group3)

To supply hydraulic oil at 300 bar at a flow rate of 4000 lpm to front attachment

To supply oil to bearings and gbx at a minimum of 25 psi on start-up

To supply water to the hot water tap in the sink with sufficient pressure to clear minute

To supply water to the shower with sufficient pressure/flow rate to be comforta

Append new function

Function:

To supply hydraulic oil at 300 bar at a flow rate of 4000 lpm to front attachm

Accept

Cancel

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Functions

2. Hydraulic System

1. Suction, supply and return system

1. To supply 4000 lpm of hydraulic oil at 300 bar (29.4MPa) to front attachment, swing and travel func

2. To prevent particles larger than 177 microns to remain in the hydraulic system

3. To contain the hyraulic oil

4. To indicate the level of oil in the hydraulic oil tank

5. To relieve internal air pressure in the hydraulic tank to 0.5 bar.

6. Able to release air pressure from hydraulic tank

7. To prevent particles greater than 95 microns to pass into the main valves and actuators.

8. To direct the flow of hydraulic oil to each of the actuators

9. To keep the hydraulic system oil at a cleanliness level of ISO 16/14/11.

10. To prevent particles larger than 10 microns pass into the hydraulic tank.

11. To prevent particles larger than 5 microns in the oil passing from the main valve into the tank

Multiple standards

Absolute standard

What's missing?

What's missing?

Quantitative standard

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Failures

Hydraulic shovel Hitachi EX3600 v1.4

1. Drive train

2. Hydraulic System

1. Suction, supply and return system

1. To supply hydraulic oil at 300 bar (4000 rpm) to front attachment, swing and travel functions.

1. Supplies no oil

2. Supplies less than 4000 lpm

3. Supplies more than 4000 lpm

4. Supplies at less than 300 bar

5. Supplies at more than 300 bar

2. To contain the hyraulic oil

1. Does not contain

Total failure

Partial failures related to flow

Partial failure related to pressure

Absolute (total or partial)

1. Button Start Edit

2. To supply hydraulic oil at 300 ..., Right click, Append, Functional Failure

3. Start typing words ifor example: "oil" Wait a few seconds for the choices. Pick a choice. (Does not provide hydraulic oil), Hit Accept.

4. Repeat 2 and 3 for each new failure to be added.

5. Hit the Save button.

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Hydraulic shovel Hitachi EX3600 v1.33

1. Drive train

2. Hydraulic System

1. Suction, supply and return system

1. To supply hydraulic oil at 300 bar (4000 rpm) to front attachment, swing and travel functions.

2. To contain the hydraulic oil

1. Does not contain

1. Suction hoses, tubes, couplings on main pumps Leak caused by n/a

2. Suction hose Broken caused by Crystallization

3. Suction hose Broken caused by Over pressure

4. Suction hoses, tubes, couplings on main pumps Broken caused by External force

5. Oil tank Cracked caused by External force

6. Oil subtank Cracked caused by External force

7. Oil temperature sensor Seals crystallized caused by External force

8. Oil temperature sensor Leaks caused by Incorrectly installed

9. Oil level sensor Leaks caused by Crystallization

10. Oil level sensor Leaks caused by Incorrectly installed

Failure modes

1. Button Start Edit

2. Fails to contain oil, Right click, Append, Failure Mode

3. Start typing words in Part: "oil level" Wait a few seconds for the choices. Pick a choice. (Oil level sensor), Hit Accept.

4. Repeat similar actions for Damage and Cause.

5. Continue with Effects, Consequences, and Mitigation tasks. (See next slide)

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5. Oil tank Cracked caused by External force

6. Oil subtank Cracked caused by External force

7. Oil temperature sensor Seals crystallized caused by External force

8. Oil temperature sensor Leaks caused by Incorrectly installed

9. Oil level sensor Leaks caused by Crystallization

10. Oil level sensor Leaks caused by Incorrectly installed

11. Sight glass Broken caused by External force

12. Sight glass Broken caused by External force

12. Sight glass Seals crystallized caused by n/a

Effects, Consequences, Mitigation tasks

Failure Mode

Oil level sensor Leaks caused by Crystallization

(From RCMCost):

Effects

Oil appears on outside surface of the tank. Drops eventually fall. If the oil level in the tank reaches 281 gln sound and light alarm in the control panel. The engine slows to its minimum speed. 800 RPM. The equipment is stopped. If the tank loses all the oil the main pumps are damaged. Time to change seal and add oil and place into operation 4 hours. (The availability of the lube truck affects the downtime of the equipment.) This failure mode is considered unlikely.

Summary:

Corrective Task: n/a

Skills: Inspector

Est. Downtime(h): 4

Consequence

Operational

Mitigation Tasks

Type	Description	Interval	Skills	Time
Condition based	Inspect seal on hydraulic oil level sensor in tank. If leakage present schedule change of element	3000 h	Inspector	3

1. Add text for Effects.

2. Enter text for Corrective task

3. Select a skill

4. Enter Estimated downtime

5. Select a consequence

6. Tab – Mitigation Tasks

7. Hit +

8. Type: Select

9. Description: Enter text

10. Interval: Enter number and unit

11. Skill: Select

12. Time: Enter duration of task.

13. Save, Accept

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2.6.1 Quiz 2 Initial RCM Workshop

https://forms.gle/yaC98tL6pFZ1aSZSA

1. To avoid the technician having to parse unnecessary menu items in the failure catalogs when documenting the work order the failure mode should sometimes:
*

☐

1. use "fails" in segment 2 of the failure mode if the mechanism (object damage) is not relevant in view of the consequences of failure.

☐

2. use "n/a" in segment three if the cause is not relevant given the consequences (severity and probability) of failure.

☐

3. both of the above.

☐

4. none of the above.

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RCM Process Dashboard

Gro up	Username	Password
1	Groupxx1	liviNGrcm1
2	Groupxx2	liviNGrcm1
3	Groupxx3	liviNGrcm1
4	Groupxx4	liviNGrcm1

1. [www.qlikcloud.com](#). Log in with Groupxxn and Password

2. Murray Wiseman

3. RCM Dashboard

4. RCM Progress

5. Table RCM Analyses: Select an asset that has been analyzed (GG Lube and Hydraulic oil System)

6. Notice a filter has appeared in the black bar above the sheet.

7. Read the answer to Question 1 in the table (42).

8. Dropdown list at top right: Select Failure Mode Detail

9. Hit Equipment Type filter at left side of sheet.

10. Deselect "GG Lube and Hydraulic oil System" and select "Power Gas Sysem". Hit ✓.

11. In Pie Chart place cursor over Hidden. Read number of hidden failures for Question 2.

12. Dropdown list at top right: Select "Mitigation Task Detail"

13. Fleet_NAME filter: Deselect "Power Gas System" and Select "Gas Generator". Hit ✓.

14. In the "Tasks Grouped by Frequency" barchart hover over the first bar (to see that the gas generator has 77 yearly tasks). Select it and note 2 more filters added. Hit ✓.

15. In the Tasks grouped by Skill barchart hover over the second (orange) bar (to see that it is mechanic). Select it. Hit ✓.

16. See the 31 tasks in the Mitigating tasks table to answer Question 3.

Dashboard exercise questions:

1. How many failure modes have been listed for the GG Lube and Hydraulic oil System?

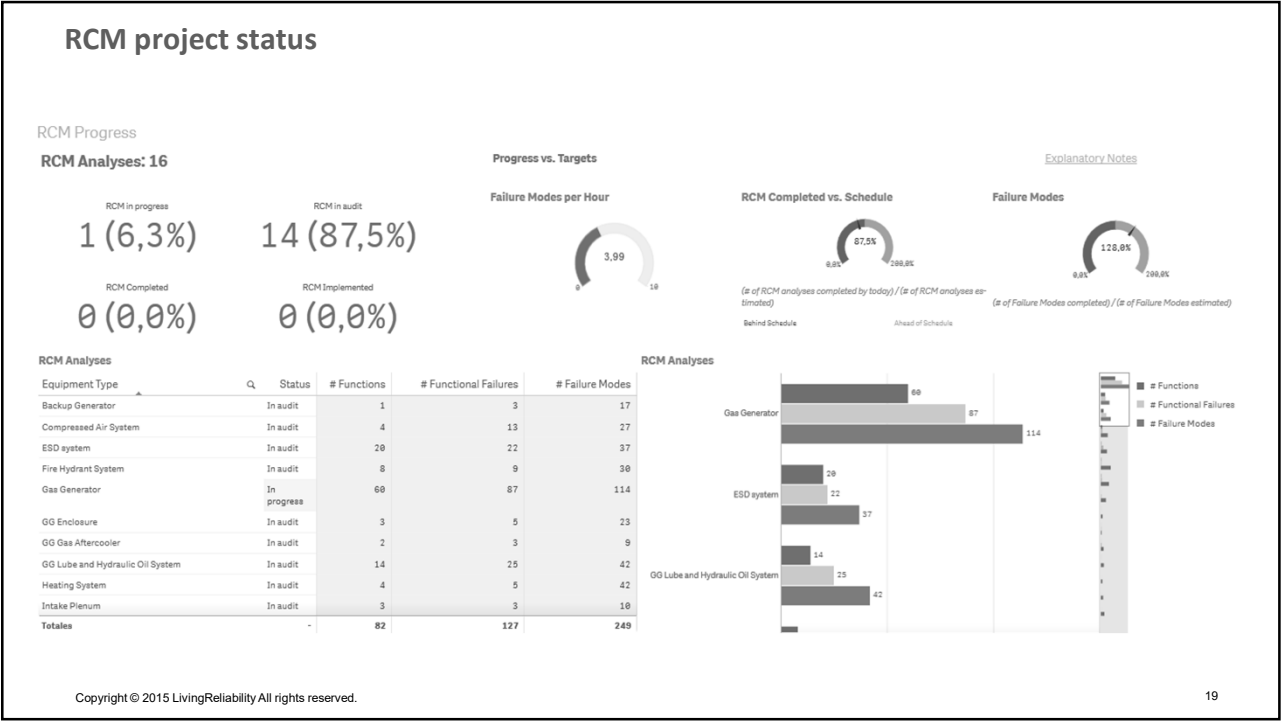
2. How many hidden failures are there in the Power Gas System?

3. Display the yearly tasks for the mechanic on the Gas Generator

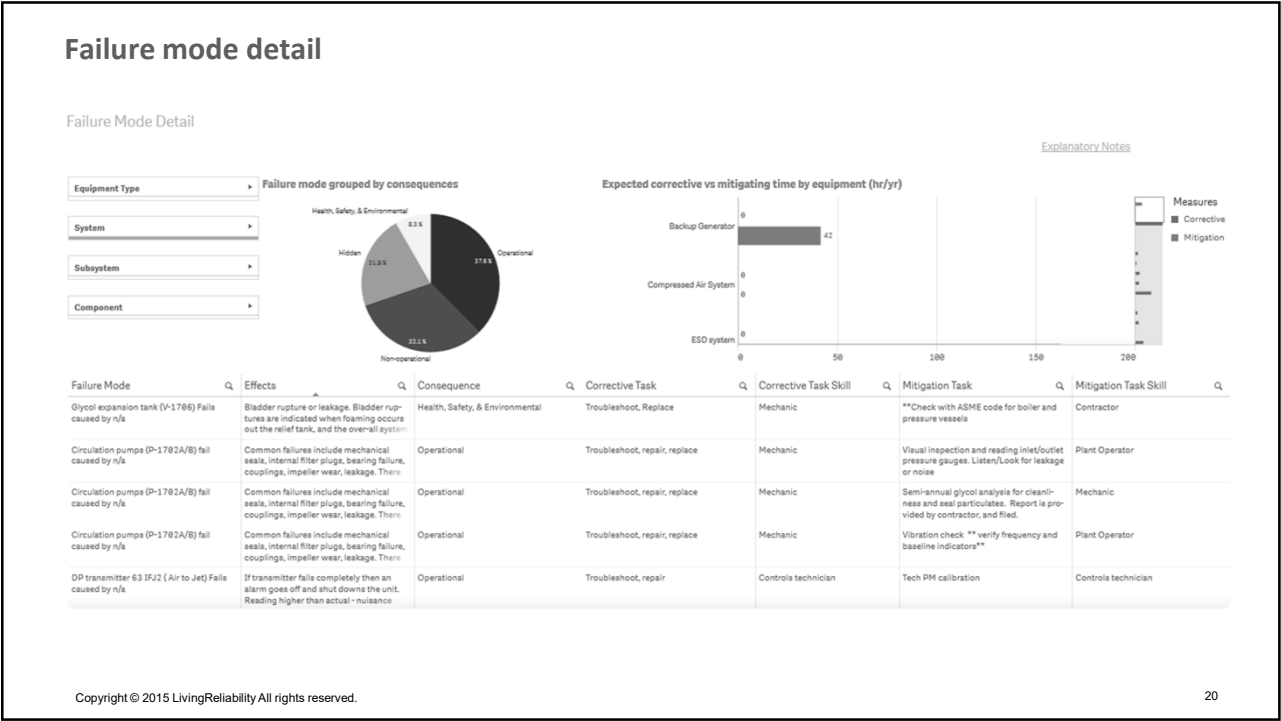
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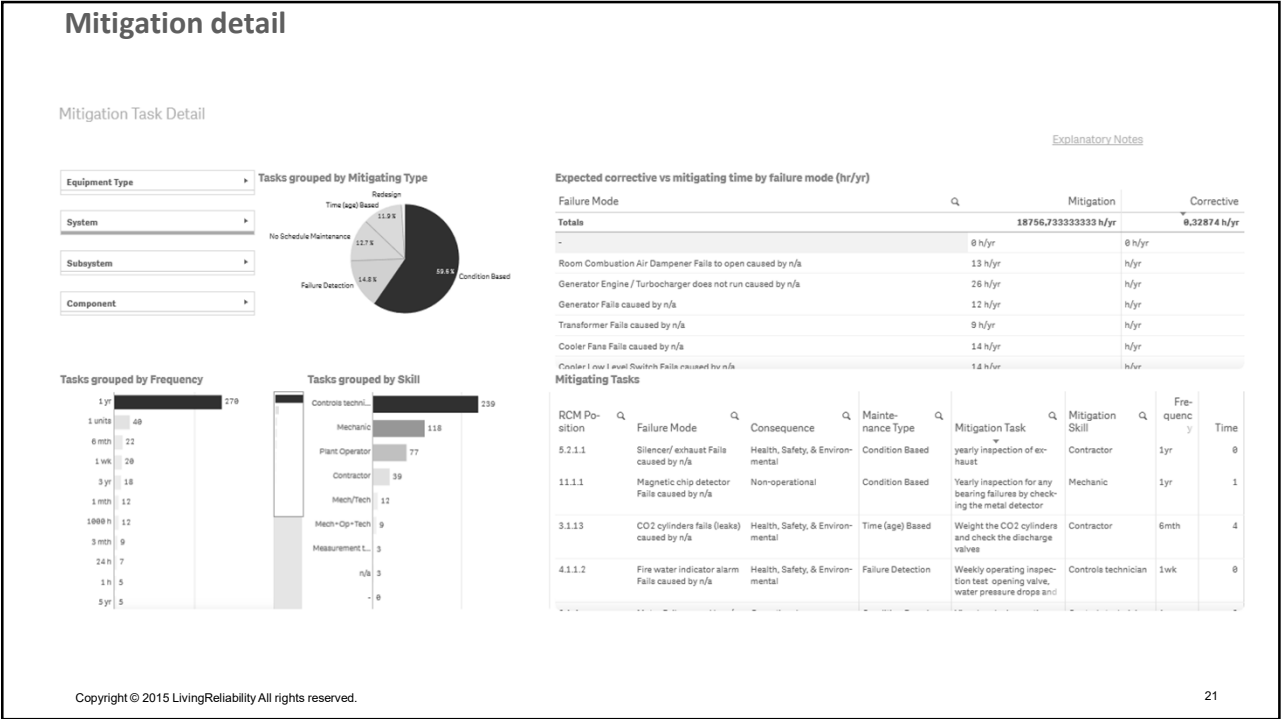
16

16

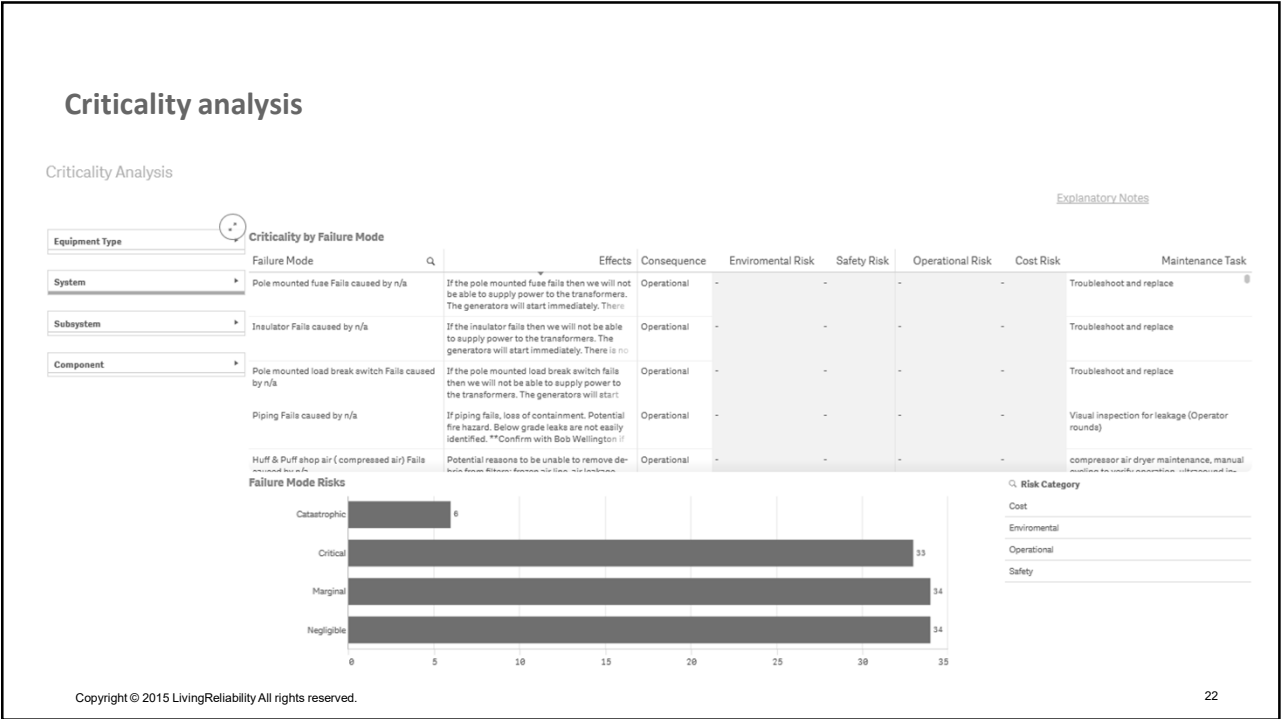


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2.6.1 Quiz 3 Initial RCM Workshop

<https://forms.gle/cpprQT4HDZmUo6bv6>

The RCM dashboards: *

1 point

- ☐ 1. Assist in RCM project management with indicators such RCM analysis in progress, in audit, and completed.
- ☐ 2. Use filters, such as equipment, consequence type, skills, frequency.
- ☐ 3. Display KPIs such as "Failure modes per hour", compliance with schedule, and knowledge feedback by month.
- ☐ 4. Allow risk versus cost comparison for each scheduled task (assuming criticality analysis was performed.)
- ☐ 5. Allow the creation of maintenance schedules for conversion and upload to the EAM system.
- ☐ 6. all of the above
- ☐ 7. none of the above

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