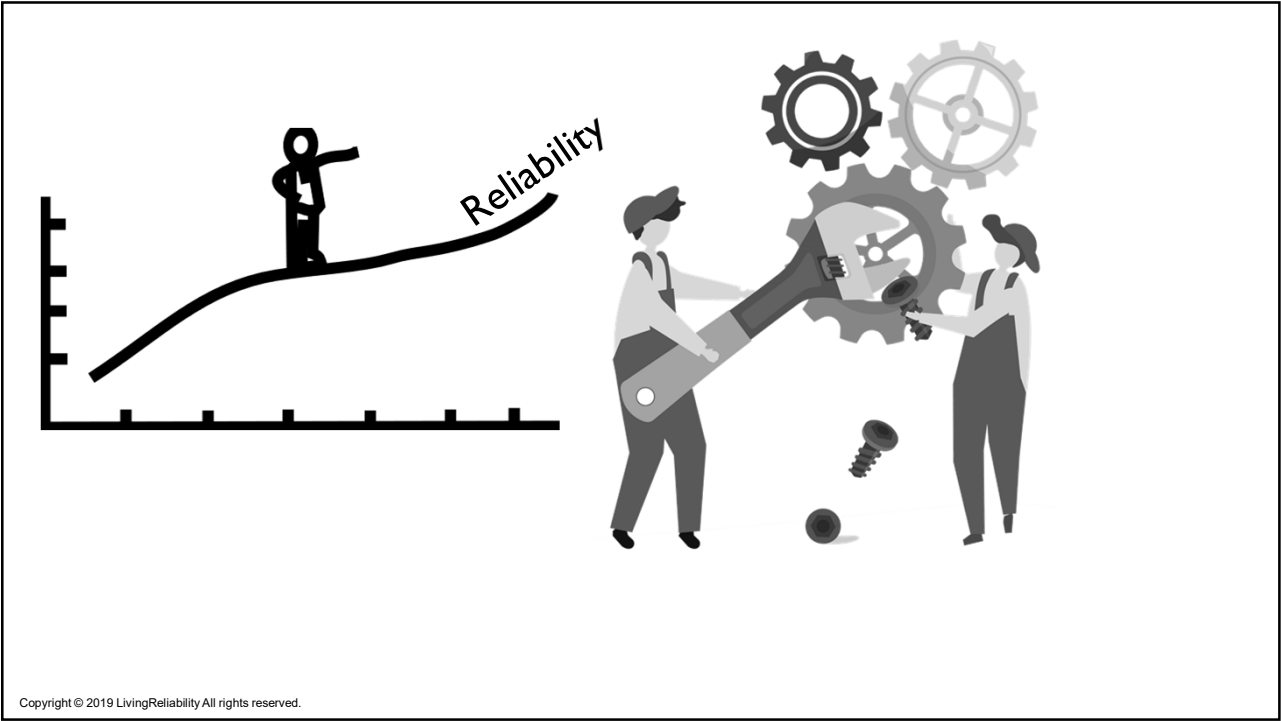


ACHIEVING RELIABILITY FROM DATA

Module 1.2en

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1



2

effective

How can we increase equipment reliability?

^

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3

By capturing and then analyzing

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4

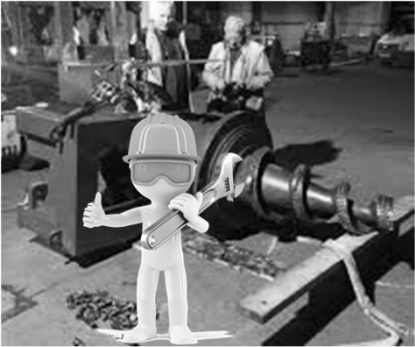
Copyright © 2019 LivingReliability All rights reserved.

6

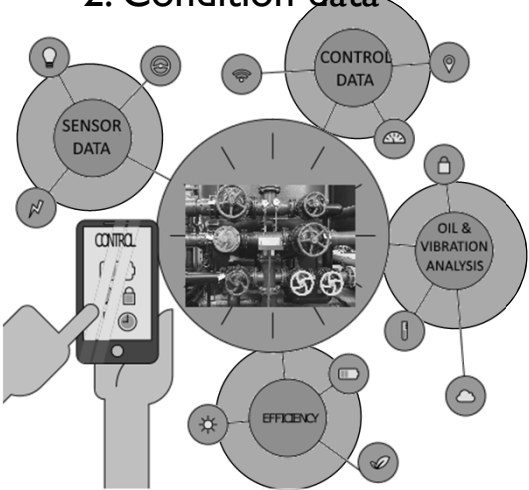


Reliability analysis *requires* ...

I. Maintenance Event History?




2. Condition data



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7



History

Descriptive

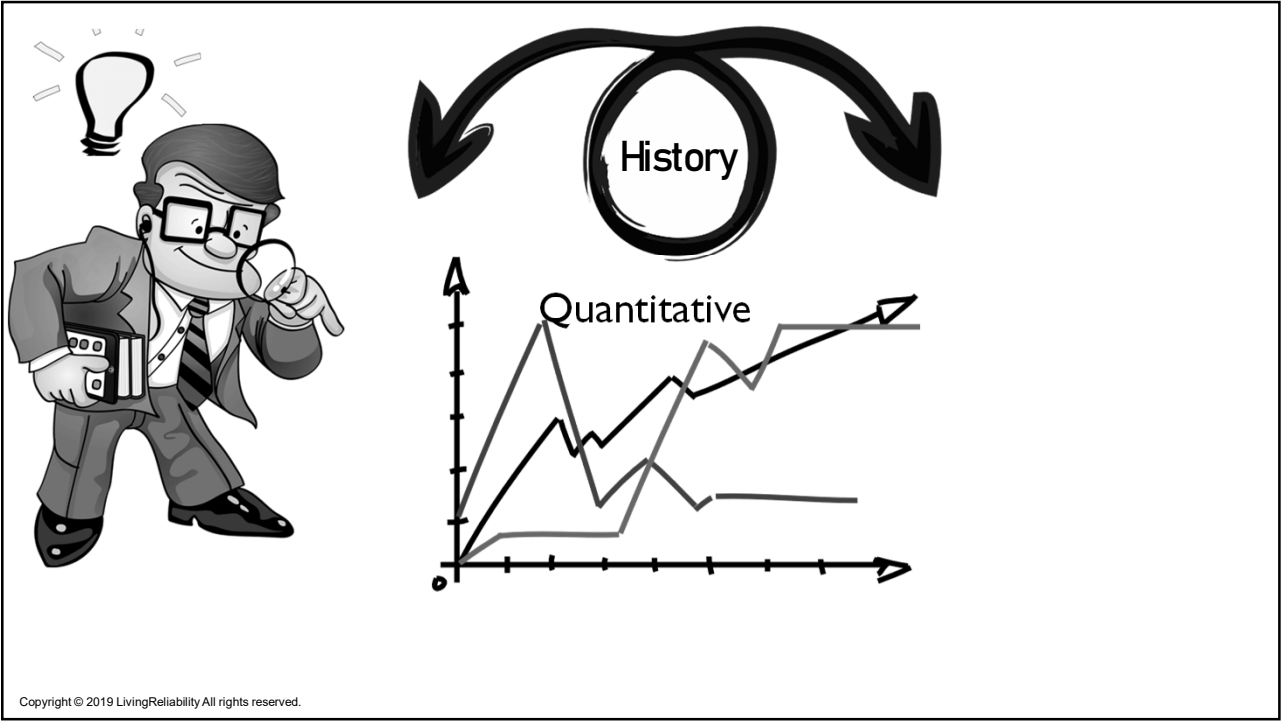
Quantitative

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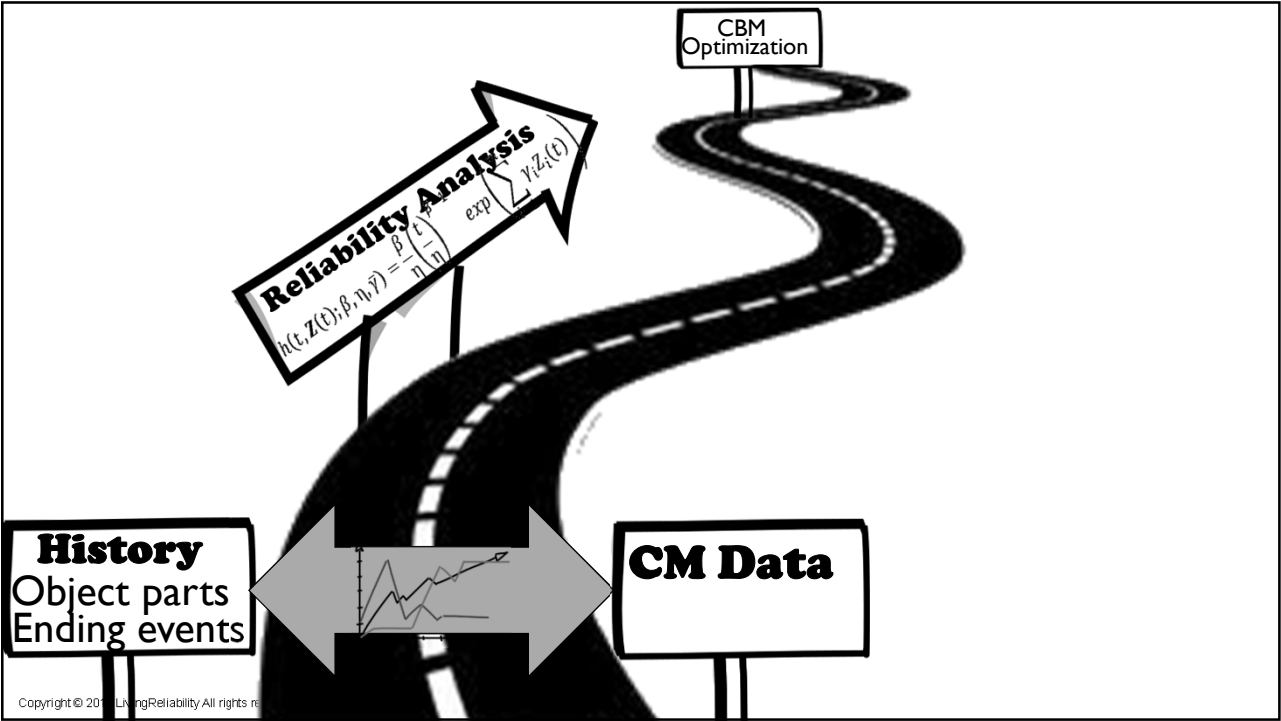
8

LivingReliability

4



9



10

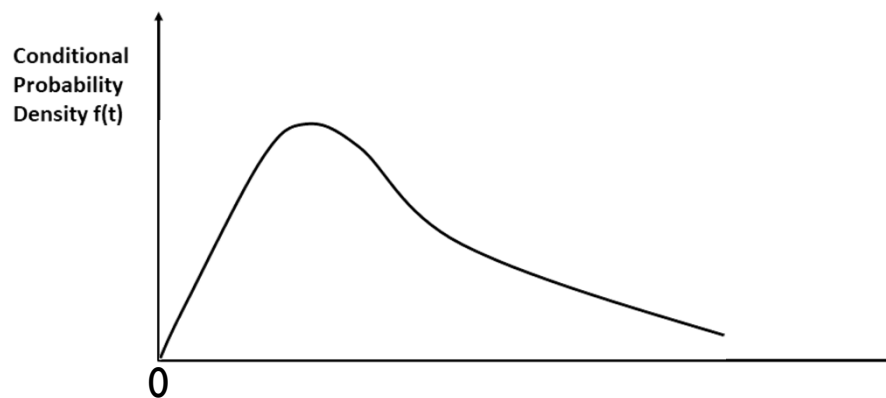
1. Predictive capability of CM data?
2. Which monitored variables?
3. Remaining useful life?
4. Predictive confidence?
5. ROI?
6. Predictive performance



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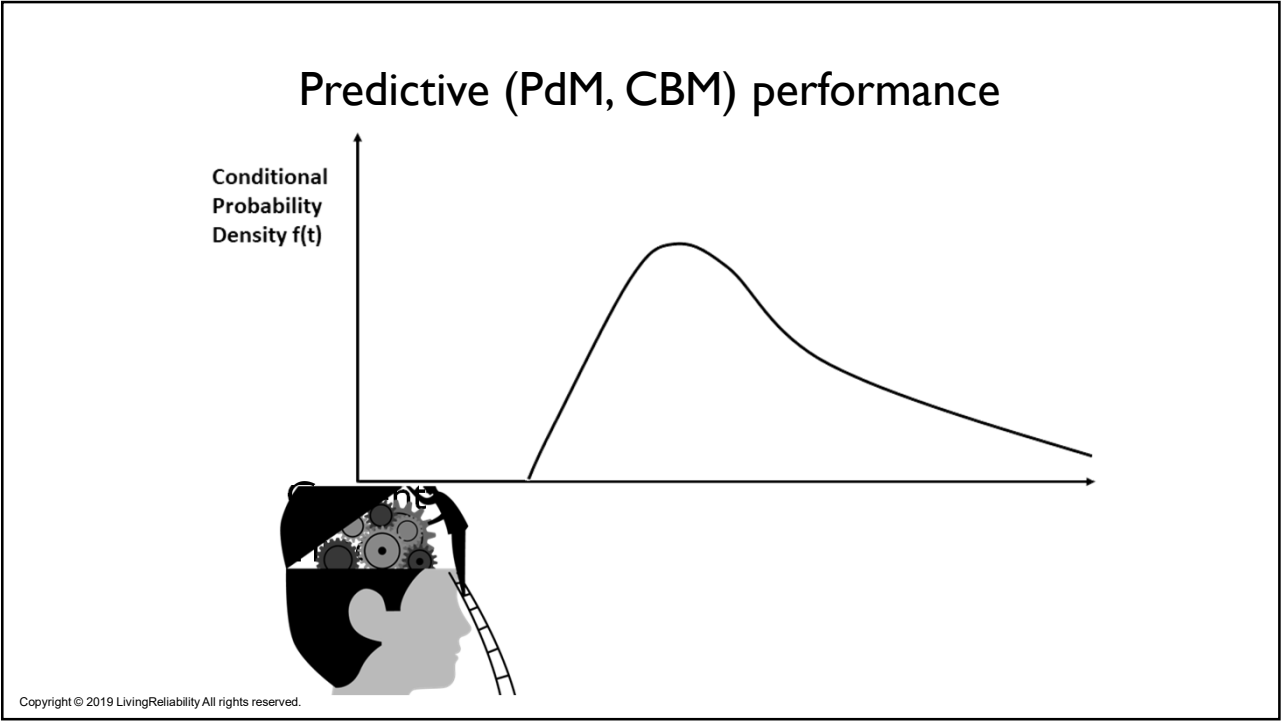
11

### Predictive (PdM, CBM) performance

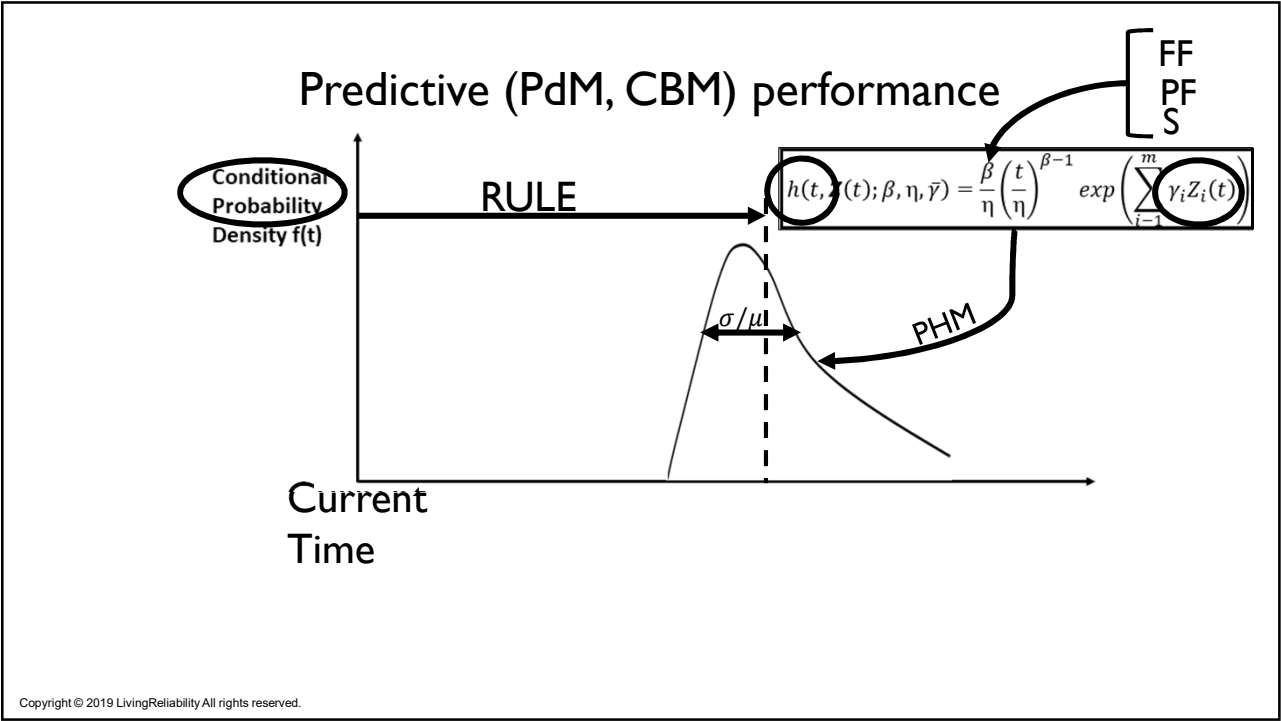


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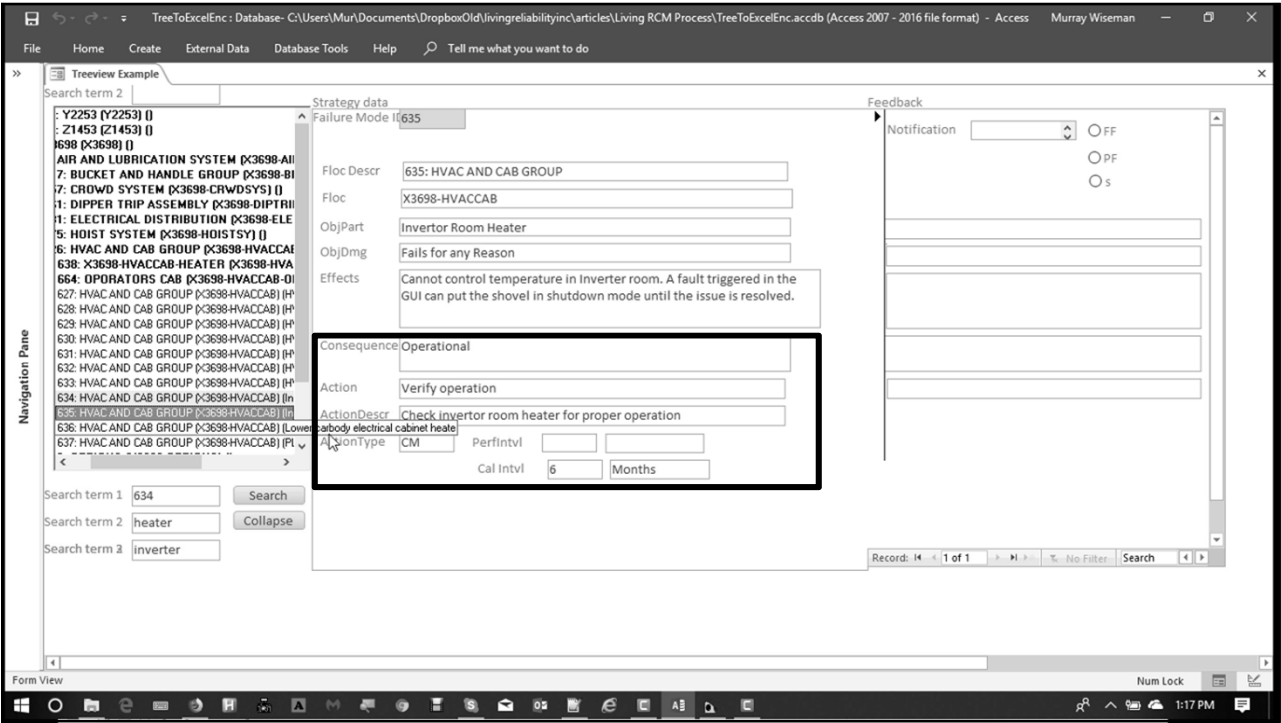
12



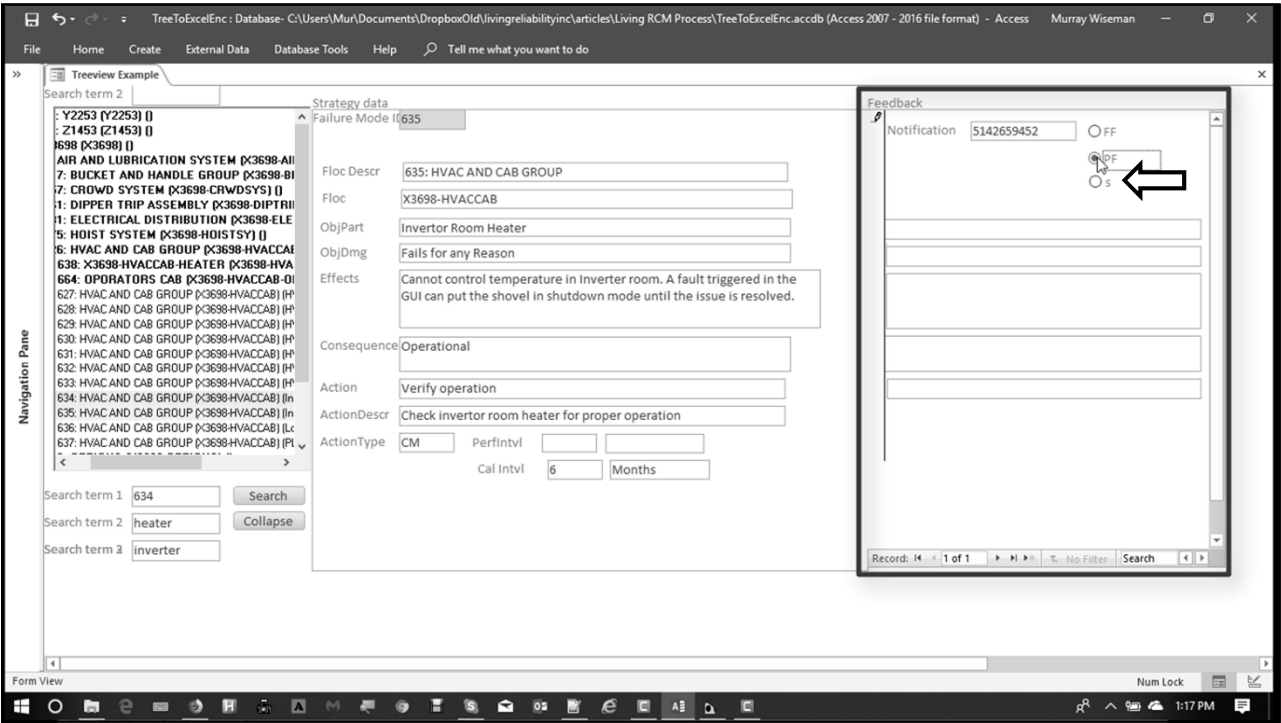
13



14




15




16





Object part?  
Ending event:  
PF?  
FF?  
S? ←



Analysis

Requires precision

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17

Treeview Example

Search term 2

Y2253 (Y2253) ()

Z1453 (Z1453) ()

6398 (X3698) ()

AIR AND LUBRICATION SYSTEM (X3698-AIR)

7: BUCKET AND HANDLE GROUP (X3698-BU)

7: CROWD SYSTEM (X3698-CRWDSYS) ()

1: DIPPER TRIP ASSEMBLY (X3698-DIPTRI)

1: ELECTRICAL DISTRIBUTION (X3698-ELE)

5: HOIST SYSTEM (X3698-HOISTSYS) ()

6: HVAC AND CAB GROUP (X3698-HVACCA)

638: X3698-HVACCA-HEATER (X3698-HVA

664: OPERATORS CAB (X3698-HVACCA-OI

627: HVAC AND CAB GROUP (X3698-HVACCA)

628: HVAC AND CAB GROUP (X3698-HVACCA)

629: HVAC AND CAB GROUP (X3698-HVACCA)

630: HVAC AND CAB GROUP (X3698-HVACCA)

631: HVAC AND CAB GROUP (X3698-HVACCA)

632: HVAC AND CAB GROUP (X3698-HVACCA)

633: HVAC AND CAB GROUP (X3698-HVACCA)

634: HVAC AND CAB GROUP (X3698-HVACCA)

635: HVAC AND CAB GROUP (X3698-HVACCA)

636: HVAC AND CAB GROUP (X3698-HVACCA)

637: HVAC AND CAB GROUP (X3698-HVACCA)

Search term 1: 634 Search

Search term 2: heater Collapse

Search term 3: inverter

Strategy data

Failure Mode I (635)

Floc Descr: 635: HVAC AND CAB GROUP

Floc: X3698-HVACCA

ObjPart: Invertor Room Heater

ObjDmg: Fails for any Reason

Effects: Cannot control temperature in Invertor room. A fault trigger... GUI can put the shovel in shutdown mode until the issue... is resolved.

Consequence: Operational

Action: Verify operation

ActionDescr: Check invertor room heater for proper operation

ActionType: CM Perflntvl Cal Intv Mont

Feedback

Notification: 5142659452

☐ FF

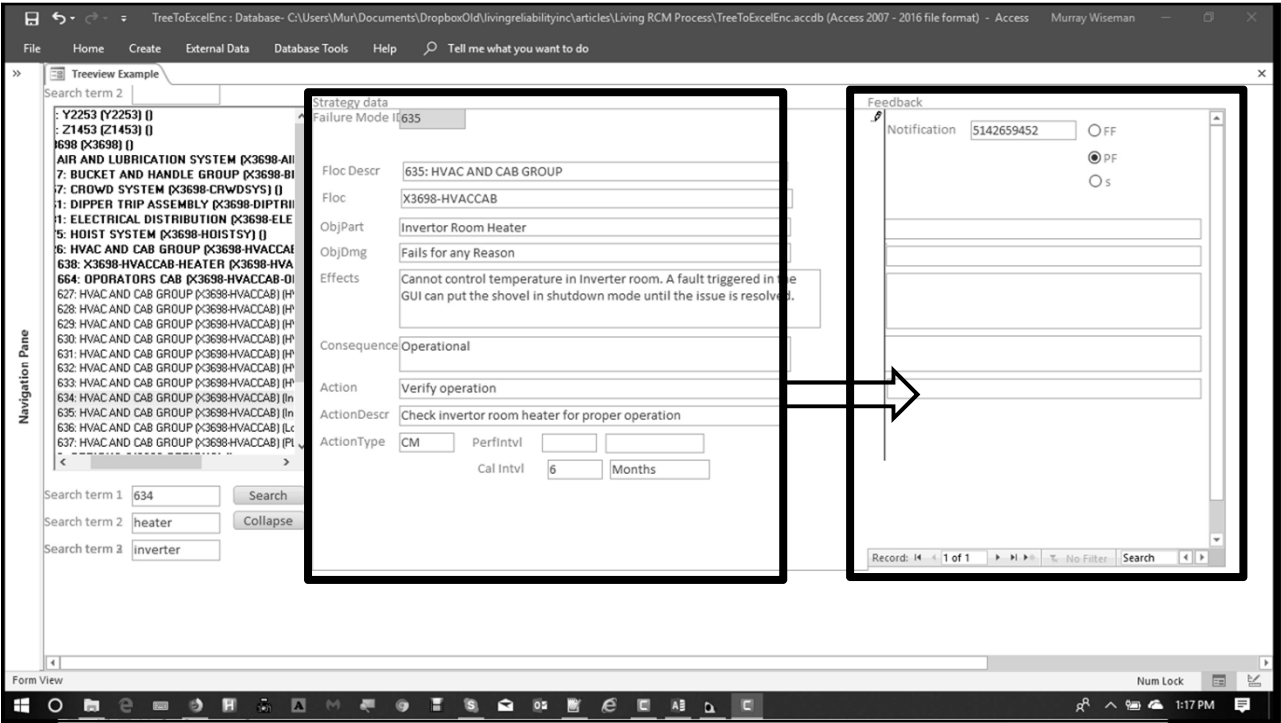
☒ PF

☐ S

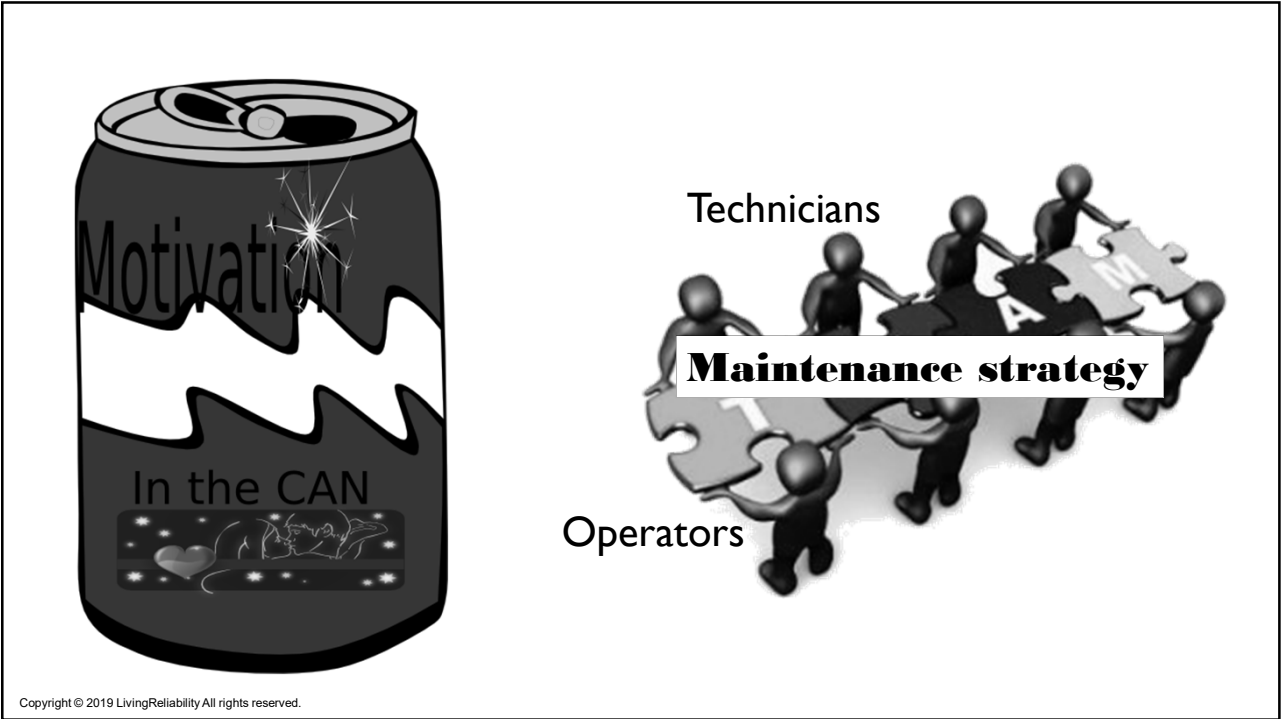
Record: 14 1 of 1 No Filter Search

Form View Num Lock 1:17 PM

18



19



20

Feedback

Notification 

FF

PF

S

Strategy data

Failure Mode ID635

Floc Descr635: HVAC AND CAB GROUP

FlocX3698-HVACCAB

ObjPartInverter Room Heater

ObjDmgFails for any Reason

EffectsCannot control temperature in Inverter room. A fault triggered in the GUI can put the shovel in shutdown mode until the issue is resolved.

ConsequenceOperational

ActionVerify operation

ActionDescrCheck inverter room heater for proper operation

ActionTypeCMPerfIntvlCal Intvl6Months

Life Ending Event?

Potential Failure

Functional Failure

Context dependent

>1 l/mo

Suspension

21

TreeToExcelEnc : Database- C:\Users\Mur\Documents\DropboxOld\livingreliability\nc\articles\Living RCM Process\TreeToExcelEnc.acddb (Access 2007 - 2016 file format) - Access Murray Wiseman

FileHomeCreateExternal DataDatabase ToolsHelpTell me what you want to do

Treeview Example

Search term 2

Y2253 (Y2253) ()

Z1453 (Z1453) ()

H698 (H698) ()

AIR AND LUBRICATION SYSTEM (P3698-AIR)

7: BUCKET AND HANDLE GROUP (P3698-BU)

7: CROWD SYSTEM (P3698-CROWDSYS) ()

1: DIPPER TRIP ASSEMBLY (P3698-DIPTRI)

1: ELECTRICAL DISTRIBUTION (P3698-ELE)

5: HOIST SYSTEM (P3698-HOISTSYS) ()

6: HVAC AND CAB GROUP (P3698-HVACCAB)

638: X3698-HVACCAB-HEATER (P3698-HVA)

664: OPERATORS CAB (P3698-HVACCAB-OI)

627: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

628: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

629: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

630: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

631: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

632: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

633: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

634: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

635: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

636: HVAC AND CAB GROUP (P3698-HVACCAB) (Lower cabody electrical cabinet heater)

637: HVAC AND CAB GROUP (P3698-HVACCAB) (P)

Strategy data

Failure Mode ID635

Floc Descr635: HVAC AND CAB GROUP

FlocX3698-HVACCAB

ObjPartInverter Room Heater

ObjDmgFails for any Reason

EffectsCannot control temperature in Inverter room. A fault triggered in the GUI can put the shovel in shutdown mode until the issue is resolved.

ConsequenceOperational

ActionVerify operation

ActionDescrCheck inverter room heater for proper operation

ActionTypeCMPerfIntvlCal Intvl6Months

Feedback

Notification 

FF

PF

S

Search term 1634Search

Search term 2heaterCollapse

Search term 3inverter

Form View

Microsoft Office

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22

LivingReliability

11

One-to-one Relationship

APMS

APMS

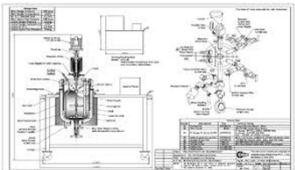
ID

ObjectPart

1 Left Front Idler Roller Assembly

2 Right Front Idler Roller Assembly

OEM Engineering



EAM

EAM

ID

ObjectPart

1 Adjuster Bolting

2 Bushing

3 Cap

4 Idler

5 Pivot Shaft Bearing

6 Roller

7 Seal

8 Shaft

9 Track

10 Bogie Major

11 Bogie Minor

12 Crawler Shoe

13 Drive Tumbler

14 Equalizer Bar

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23

One-to-one Relationship

APMS

APMS


ID

ObjectPart

1 Left Front Idler Roller Assembly

2 Right Front Idler Roller Assembly

OEM Manuals



EAM

EAM

ID

ObjectPart

1 Adjuster Bolting

2 Bushing

3 Cap

4 Idler

5 Pivot Shaft Bearing

6 Roller

7 Seal

8 Shaft

9 Track

10 Bogie Major

11 Bogie Minor

12 Crawler Shoe

13 Drive Tumbler

14 Equalizer Bar

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One-to-one Relationship

APMS

ID	ObjectPart
1	Left Front Idler Roller Assembly
2	Right Front Idler Roller Assembly

EAM

ID	ObjectPart
1	Adjuster Bolting
2	Bushing
3	Cap
4	Idler
5	Pivot Shaft Bearing
6	Roller
7	Seal
8	Shaft
9	Track
10	Bogie Major
11	Bogie Minor
12	Crawler Shoe
13	Drive Tumbler
14	Equalizer Bar

OEM

BOMs

Stock Item Record

Equipment Record

Equipment List

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One-to-one Relationship


APMS

ID	ObjectPart
1	Left Front Idler Roller Assembly
2	Right Front Idler Roller Assembly

EAM

ID	ObjectPart
1	Adjuster Bolting
2	Bushing
3	Cap
4	Idler
5	Pivot Shaft Bearing
6	Roller
7	Seal
8	Shaft
9	Track
10	Bogie Major
11	Bogie Minor
12	Crawler Shoe
13	Drive Tumbler
14	Equalizer Bar

Roller Seal Kit



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One-to-one Relationship

APMS

ID	ObjectPart
1	Left Front Idler Roller Assembly
2	Right Front Idler Roller Assembly

EAM

ID	ObjectPart
1	Adjuster Bolting
2	Bushing
3	Cap
4	Idler
5	Pivot Shaft Bearing
6	Roller
7	Seal
8	Shaft
9	Track
10	Bogie Major
11	Bogie Minor
12	Crawler Shoe
13	Drive Tumbler
14	Equalizer Bar



MATCH?

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27


One-to-one Relationship

APMS

ID	ObjectPart
1	Left Front Idler Roller Assembly
2	Right Front Idler Roller Assembly

EAM

ID	ObjectPart
1	Adjuster Bolting
2	Bushing
3	Cap
4	Idler
5	Pivot Shaft Bearing
6	Roller
7	Seal
8	Shaft
9	Track
10	Bogie Major
11	Bogie Minor
12	Crawler Shoe
13	Drive Tumbler
14	Equalizer Bar



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28

One-to-one Relationship

APMS

ID

ObjectPart

1 Left Front Idler Roller Assembly

2 Right Front Idler Roller Assembly

EAM

ID

ObjectPart

1 Adjuster Bolting

2 Bushing

3 Cap

4 Idler

5 Pivot Shaft Bearing

6 Roller

7 Seal

8 Shaft

9 Track

10 Bogie Major

11 Bogie Minor

12 Crawler Shoe

13 Drive Tumbler

14 Equalizer Bar

Function

Failure

Failure

Obj Part

Obj Part

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29

One-to-one Relationship

APMS

ID

ObjectPart

Strategy data

Failure Mode ID 634

Floc Descr 634: HVAC AND CAB GROUP

Floc X3698-HVACCAB

ObjPart Inverter Cabinet Heater

ObjDmg Fails for any Reason

Effects Inverter cabinet heater fails to operate. Fault triggered in GUI which might put the shovel in shutdown mode until the issue has been resolved

Consequence Operational

Action Check semi-annually

ActionDescr Check inverter cabinet heater for proper operation

ActionType CM

PerfIntvl

Cal Intvl 6 Months

EAM

ID

ObjectPart

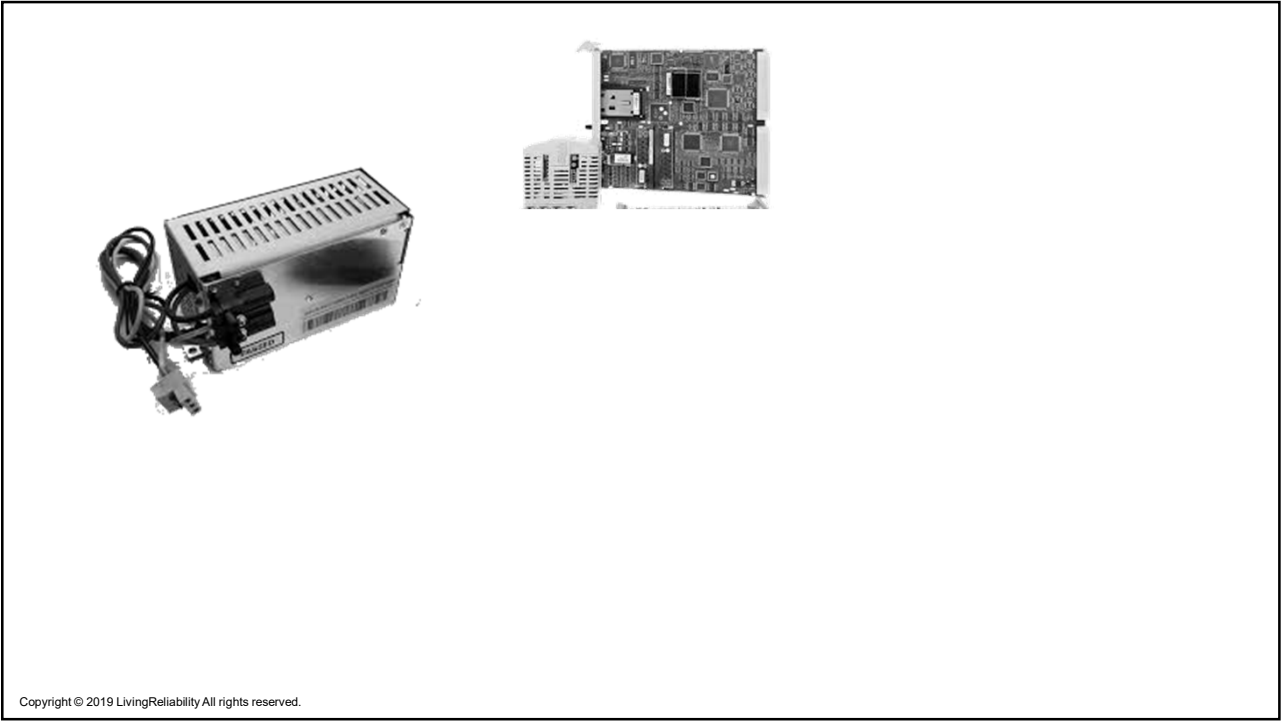
Notification

FF

PF

S

30



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31

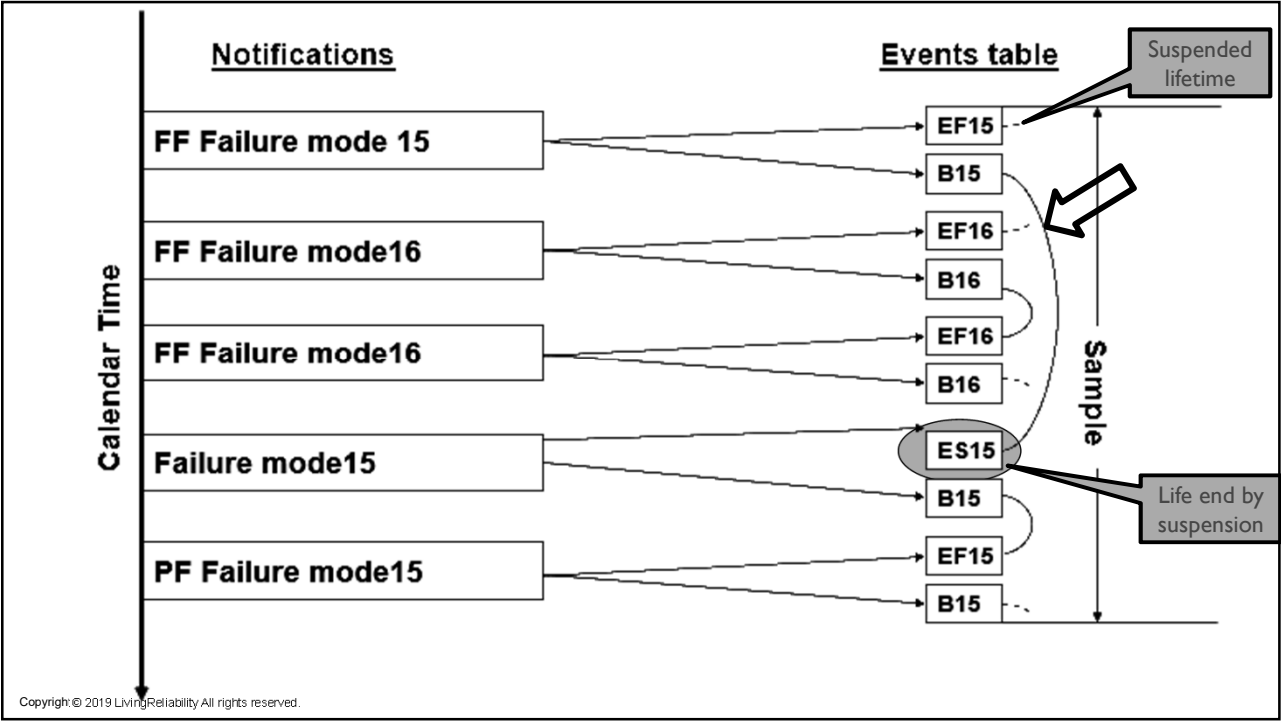
Ident	Date	WorkingAge	HN	edence	Event	Iron	Lead	Calcium
17-66	9/26/94	6030	1	1	OC	0	0	5000
17-66	10/24/94	6693	1	0	*	14	2	5895
17-66	11/21/94	7319	1	0	*	11	1	4827
17-66	11/21/94	7319	1	1	OC	0	0	5000
17-66	12/19/94	7902	1	0	*	5	0	5313
17-66	1/16/95	8474	1	0	*	8	4	5138
17-66	1/16/95	8474	1	1	OC	0	0	5000
17-66	2/13/95	9108	1	0	*	8	2	5039
17-66	3/13/95	9732	1	0	*	18	5	4050
17-66	3/13/95	9732	1	1	OC	0	0	5000
17-66	4/10/95	10320	1	0	*	25	3	5576
17-66	4/23/95	10524	1	2	EF	25	3	5576
17-66	4/24/95	10524	2	4	B	0	0	5000
17-66	5/08/95	10886	2	0	*	12	0	4584
17-66	5/08/95	10886	2	1	OC	0	0	5000

Captured  
Events

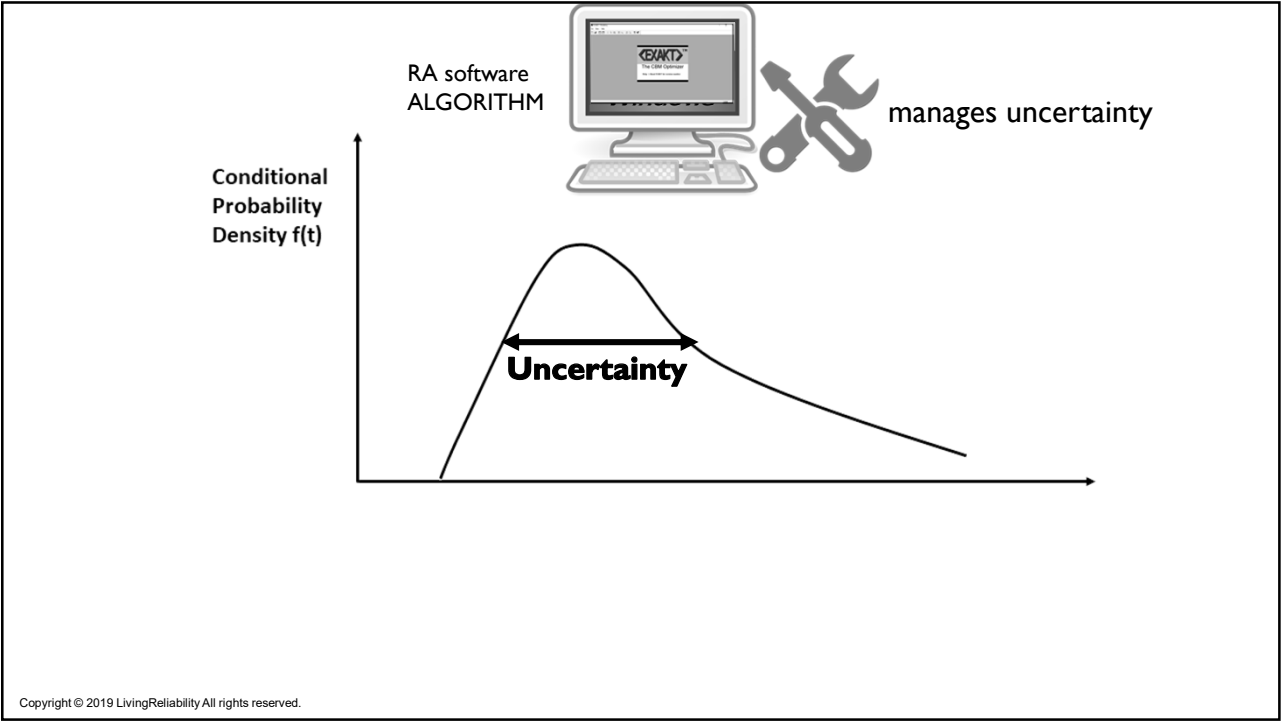
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32

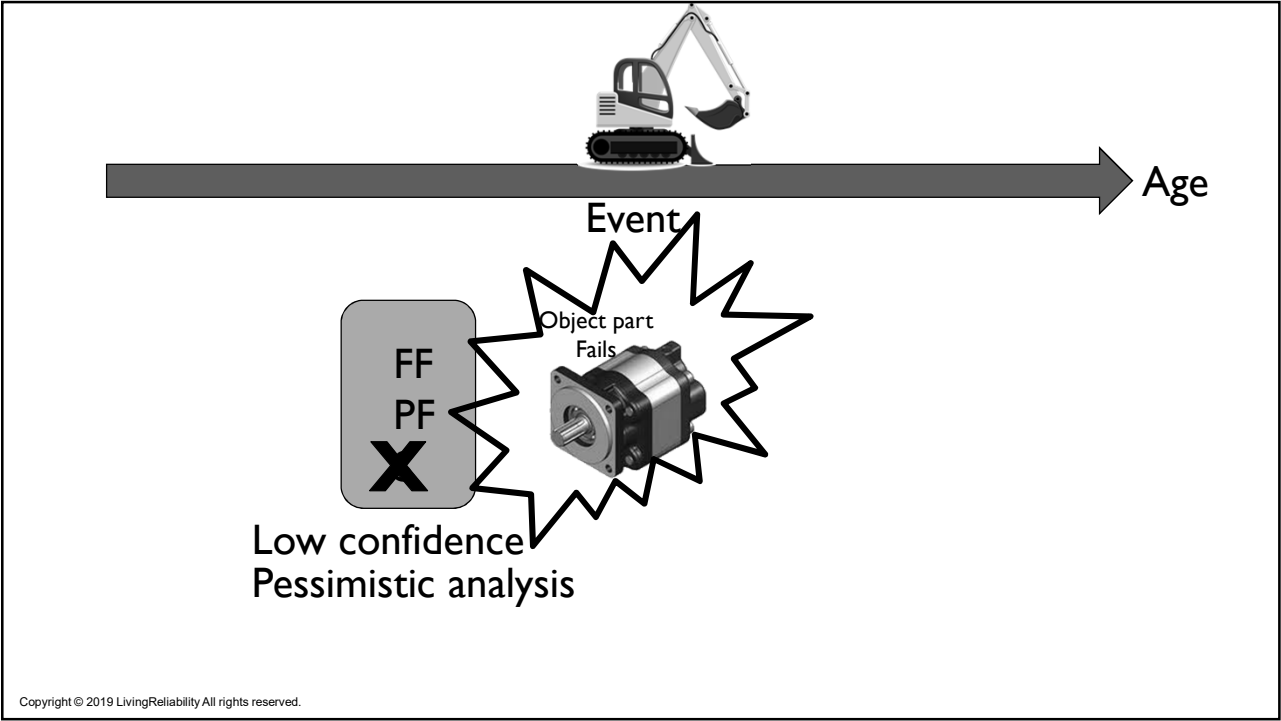




33



34



35

▼ 40 ton truck v4.1

▼ 1. To transfer up to 40 tons of material

▶ 1. Unable to transfer any material at all

▼ 2. Transfers less than 40T

▶ 1. *Transmission Fails* caused by n/a

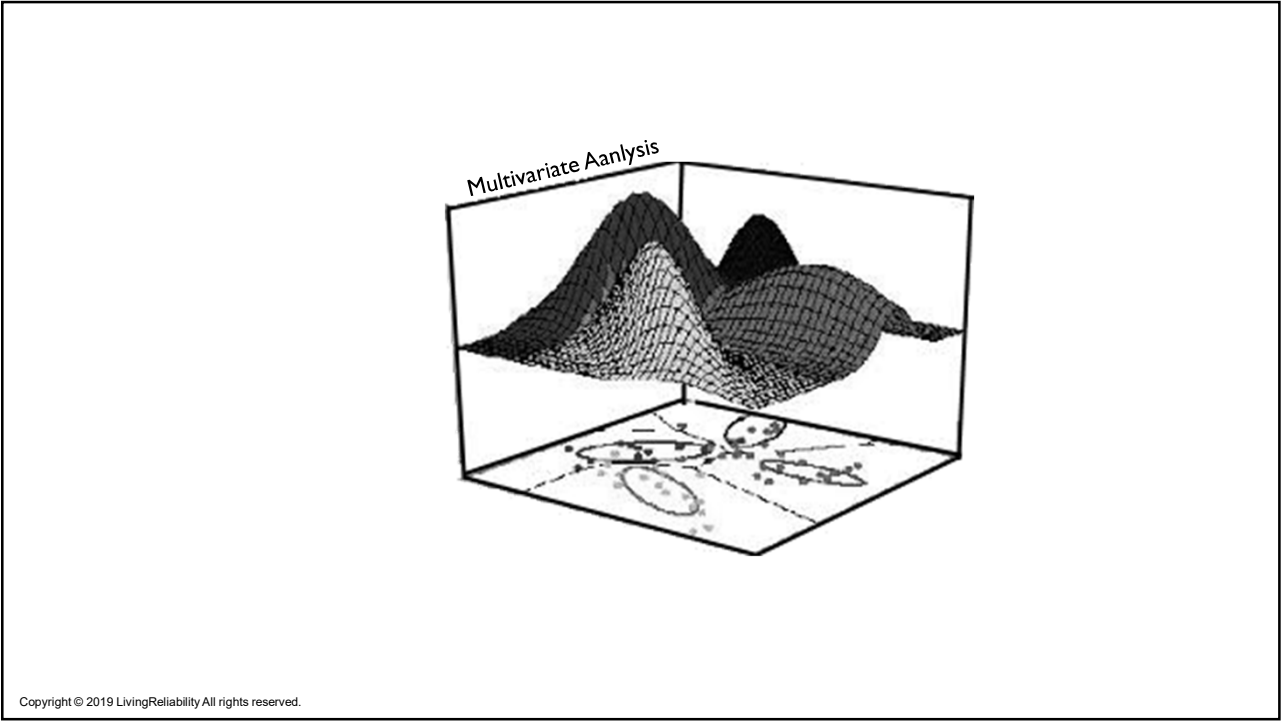
▶ 2. Braking system

▶ 3. Steering system

▶ 4. Cab

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36



37

EXAKT - Mooring

File View Help

EXAKT™

The CBM Optimizer

Help > About EXAKT for version number

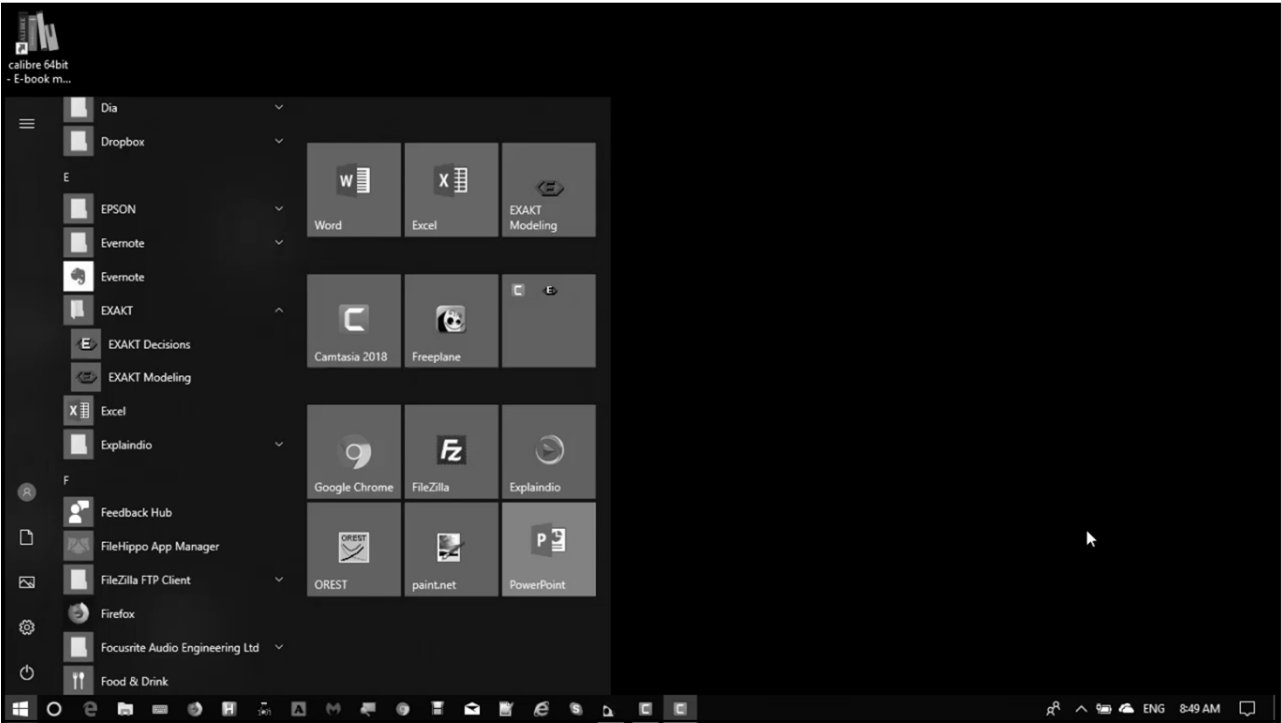
UNIVERSITY OF  
TORONTO

Centre for Maintenance  
Optimization and Reliability  
Engineering (C-MORE)

Andrew Jardine  
Dragan Banjevic

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38



39

EXAKT - Modeling - Cat340T\_WM0D.mdb

File Edit Modeling ModelDBase View Window Help

C\_Inspections

17-66

Ident	Date	WorkingAge	HN	Precedence	Event	Iron	Lead	Calcium	Magnesium
17-66	12/30/93	0	1		B	0	0	5000	
17-66	1/01/94	33	1		*	2	0	3759	
17-66	1/17/94	398	1		*	13	1	3822	
17-66	2/14/94	1028	1		*	11	0	3504	
17-66	2/14/94	1028	1		OC	0	0	5000	
17-66	3/14/94	1674	1		*	10	0	4603	
17-66	4/12/94	2600	1		*	14	2	5067	
17-66	4/12/94	2600	1		OC	0	0	5000	
17-66	5/09/94	2927	1		*	7	1	4619	
17-66	6/04/94	3522	1		*	14	0	4784	
17-66	6/04/94	3522	1		OC	0	0	5000	
17-66	7/04/94	4177	1		*	13	0	4517	
17-66	8/02/94	4786	1		*	9	1	4062	
17-66	8/02/94	4786	1		OC	0	0	5000	
17-66	8/29/94	5392	1		*	8	0	4562	
17-66	9/26/94	6030	1		*	9	3	4409	
17-66	9/26/94	6030	1		OC	0	0	5000	
17-66	10/24/94	6693	1		*	14	2	5895	
17-66	11/21/94	7319	1		*	11	1	4827	
17-66	11/21/94	7319	1		OC	0	0	5000	
17-66	12/19/94	7902	1		*	5	0	5313	
17-66	1/16/95	8474	1		*	8	4	5138	
17-66	1/16/95	8474	1		OC	0	0	5000	
17-66	2/13/95	9108	1		*	8	2	5039	
17-66	3/13/95	9732	1		*	18	5	4050	
17-66	3/13/95	9732	1		OC	0	0	5000	
17-66	4/10/95	10320	1		*	25	3	5576	
17-66	4/23/95	10524	1		EF	25	3	5576	
17-66	4/24/95	10524	2		*	0	0	5000	
17-66	5/08/95	10886	2		*	12	0	4594	
17-66	5/08/95	10886	2		OC	0	0	5000	
17-66	6/05/95	11457	2		*	14	1	5218	
17-66	7/03/95	12011	2		*	8	0	4955	
17-66	7/03/95	12011	2		OC	0	0	5000	
17-66	8/01/95	12670	2		*	10	1	4830	
17-66	8/28/95	13214	2		*	17	0	4787	

NUM

40

EXAKT - Modeling - Cat340T\_WM0D.mdb

File Edit Modeling ModelDBase View Window Help

C\_Inspections

17-66

Ident	Date	WorkingAge	HN	Precedence	Event	Iron	Lead	Calcium	Magnesium
17-66	1/15/96	16037	2	0	*	4	0	5377	
17-66	2/12/96	16694	2	0	*	11	0	5441	
17-66	2/12/96	16694	2	1	OC	0	0	5000	
17-66	3/12/96	17134	2	0	*	4	0	5040	
17-66	4/09/96	17760	2	0	*	7	1	5349	
17-66	4/09/96	17760	2	1	OC	0	0	5000	
17-66	5/06/96	18377	2	0	*	9	0	3170	
17-66	5/10/96	18378	2	0	*	10	1	4385	
17-66	6/03/96	18914	2	0	*	11	0	3586	
17-66	6/03/96	18914	2	1	OC	0	0	5000	
17-66	7/01/96	19338	2	0	*	8	0	4885	
17-66	7/29/96	19876	2	0	*	16	0	4430	
17-66	7/29/96	19876	2	1	OC	0	0	5000	
17-66	8/26/96	20425	2	0	*	6	0	5249	
17-66	9/24/96	21034	2	0	*	10	0	4932	
17-66	9/24/96	21034	2	1	OC	0	0	5000	
17-66	10/21/96	21626	2	0	*	5	0	5070	
17-66	11/18/96	22266	2	0	*	3	0	5538	
17-66	11/18/96	22266	2	1	OC	0	0	5000	
17-66	12/09/96	22706	2	3	ES	3	0	5538	
17-66	12/10/96	22706	3	4	B	0	0	5000	
17-66	12/16/96	22862	3	0	*	4	0	4962	
17-66	1/13/97	23499	3	0	*	9	0	5593	
17-66	1/13/97	23499	3	1	OC	0	0	5000	
17-66	2/11/97	24084	3	0	*	11	0	5361	
17-66	3/09/97	24491	3	0	*	5	0	4916	
17-66	3/09/97	24491	3	1	OC	0	0	5000	
17-66	4/07/97	25053	3	0	*	8	1	4321	
17-66	5/05/97	25666	3	0	*	11	0	4316	
17-66	5/05/97	25666	3	1	OC	0	0	5000	
17-66	6/02/97	26289	3	0	*	6	0	5013	
17-66	6/29/97	26884	3	0	*	10	0	5293	
17-66	6/29/97	26884	3	1	OC	0	0	5000	
17-66	7/28/97	27519	3	0	*	7	0	4933	
17-66	8/25/97	28157	3	0	*	8	0	5648	
17-66	8/25/97	28157	3	1	OC	0	0	5000	

NUM

41

EXAKT - Modeling - Cat340T\_WM0D.mdb

File Edit Modeling ModelDBase View Window Help

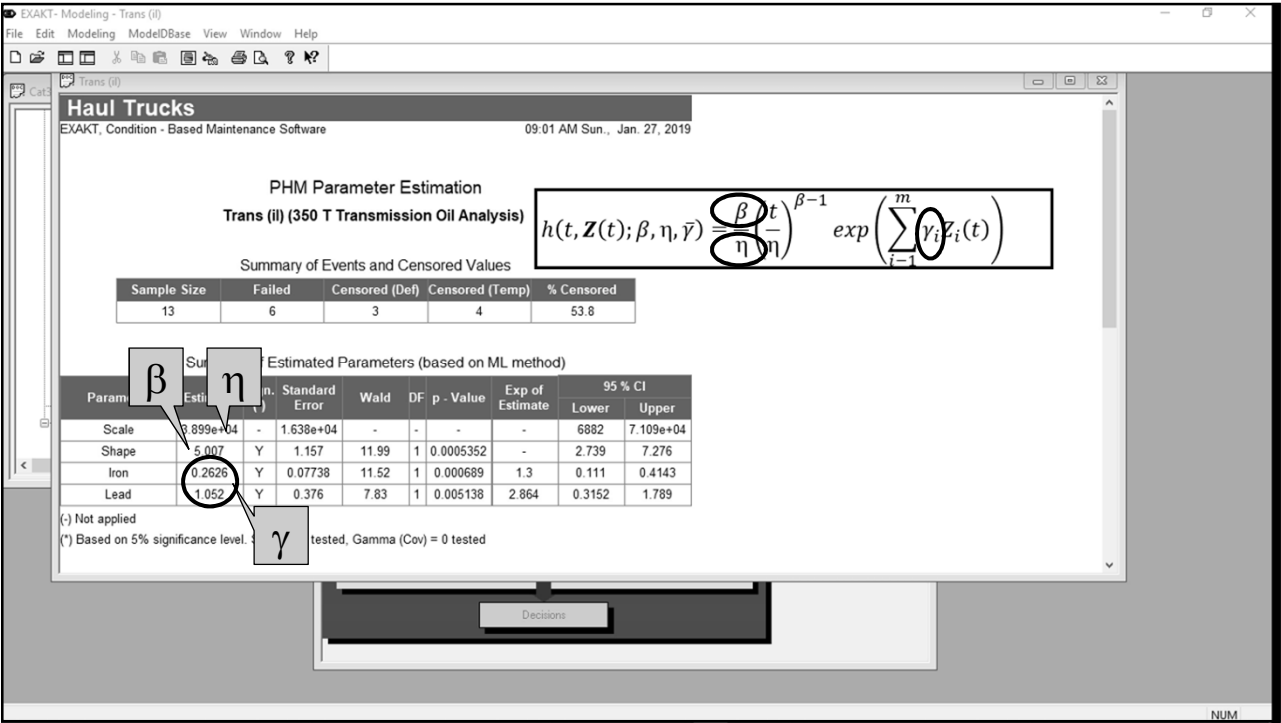
C\_Inspections

17-66

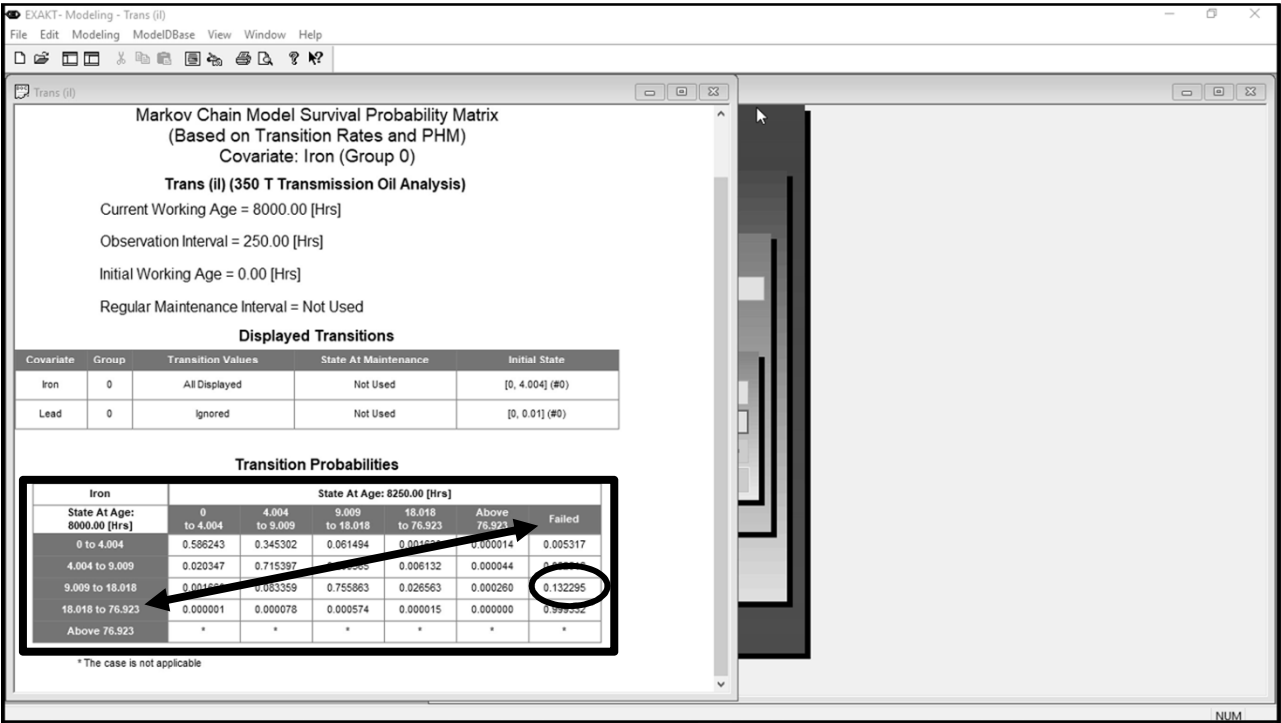
Ident	Date	WorkingAge	HN	Precedence	Event	Iron	Lead	Calcium	Magnesium
17-66	1/15/96	16037	2	0	*	4	0	5377	
17-66	2/12/96	16694	2	0	*	11	0	5441	
17-66	2/12/96	16694	2	1	OC	0	0	5000	
17-66	3/12/96	17134	2	0	*	4	0	5040	
17-66	4/09/96	17760	2	0	*	7	1	5349	
17-66	4/09/96	17760	2	1	OC	0	0	5000	
17-66	5/06/96	18377	2	0	*	9	0	3170	
17-66	5/10/96	18378	2	0	*	10	1	4385	
17-66	6/03/96	18914	2	0	*	11	0	3586	
17-66	6/03/96	18914	2	1	OC	0	0	5000	
17-66	7/01/96	19338	2	0	*	8	0	4885	
17-66	7/29/96	19876	2	0	*	16	0	4430	
17-66	7/29/96	19876	2	1	OC	0	0	5000	
17-66	8/26/96	20425	2	0	*	6	0	5249	
17-66	9/24/96	21034	2	0	*	10	0	4932	
17-66	9/24/96	21034	2	1	OC	0	0	5000	
17-66	10/21/96	21626	2	0	*	5	0	5070	
17-66	11/18/96	22266	2	0	*	3	0	5538	
17-66	11/18/96	22266	2	1	OC	0	0	5000	
17-66	12/09/96	22706	2	3	ES	3	0	5538	
17-66	12/10/96	22706	3	4	B	0	0	5000	
17-66	12/16/96	22862	3	0	*	4	0	4962	
17-66	1/13/97	23499	3	0	*	9	0	5593	
17-66	1/13/97	23499	3	1	OC	0	0	5000	
17-66	2/11/97	24084	3	0	*	11	0	5361	
17-66	3/09/97	24491	3	0	*	5	0	4916	
17-66	3/09/97	24491	3	1	OC	0	0	5000	
17-66	4/07/97	25053	3	0	*	8	1	4321	
17-66	5/05/97	25666	3	0	*	11	0	4316	
17-66	5/05/97	25666	3	1	OC	0	0	5000	
17-66	6/02/97	26289	3	0	*	6	0	5013	
17-66	6/29/97	26884	3	0	*	10	0	5293	
17-66	6/29/97	26884	3	1	OC	0	0	5000	
17-66	7/28/97	27519	3	0	*	7	0	4933	
17-66	8/25/97	28157	3	0	*	8	0	5648	
17-66	8/25/97	28157	3	1	OC	0	0	5000	

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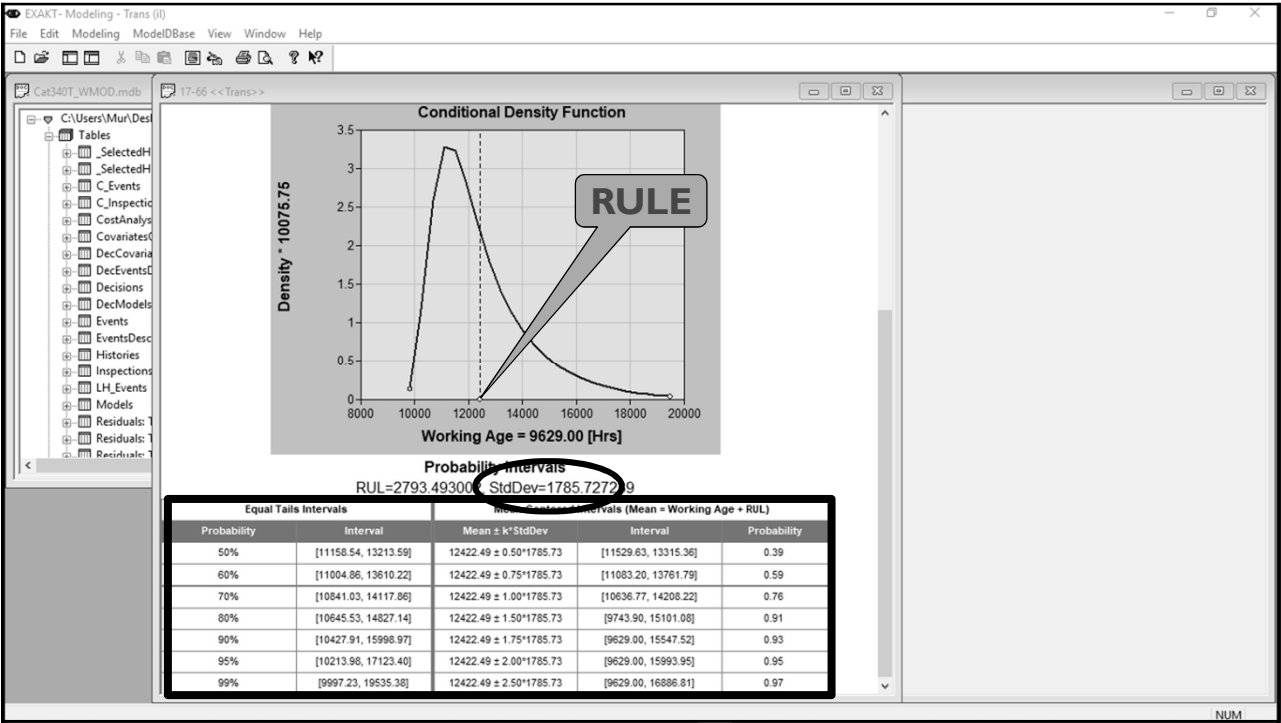
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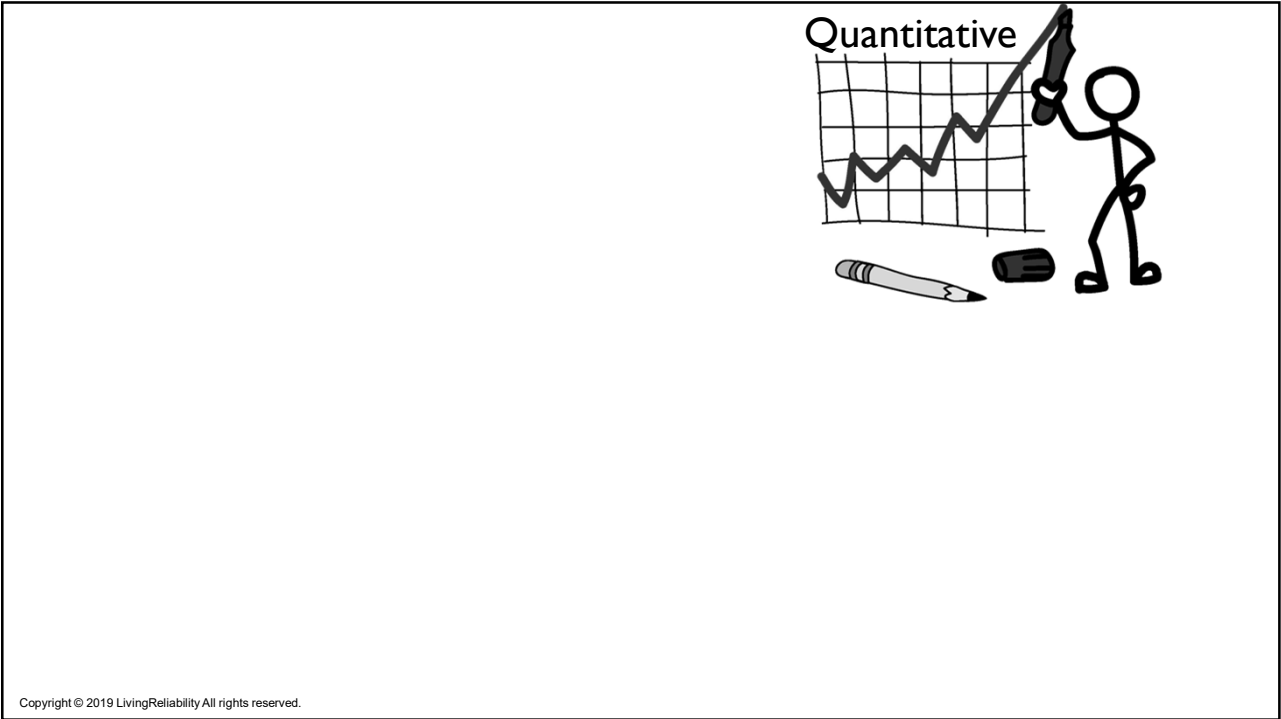
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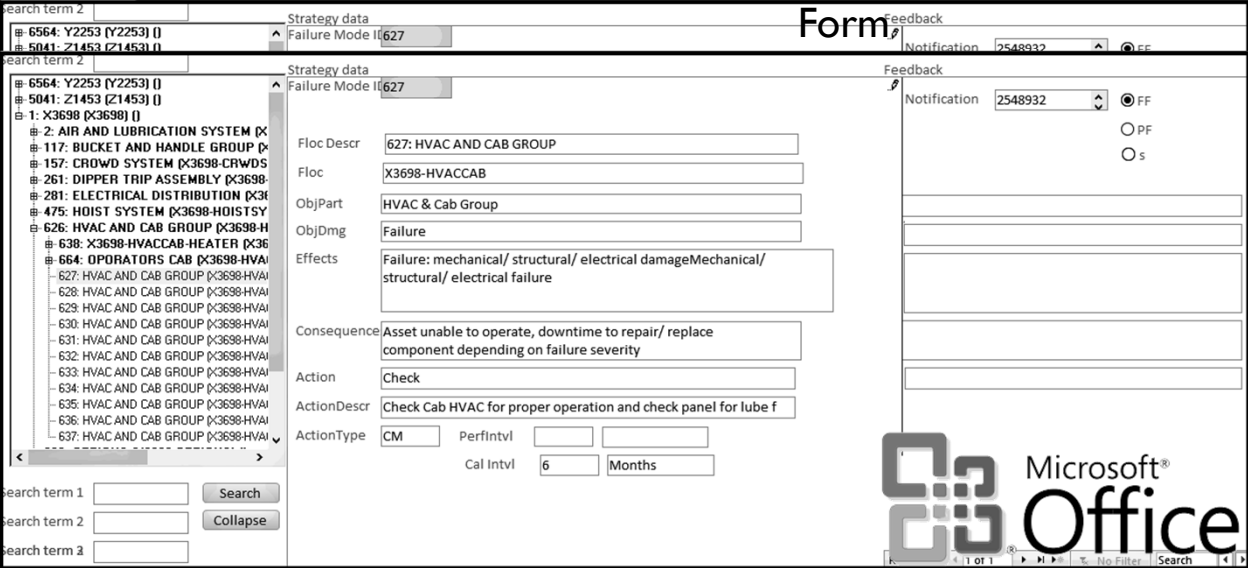
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Event data



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Event data  
Form



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