



The 23rd International Asset Facility and Maintenance Management Conference



The Reliability requirement definition based on RAM Analysis and FMEA:

The basis for railway equipment future high performance

Dr.Eduardo Calixto, ECC CEO.

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Riyadh, KSA

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INTRODUCTION

- Dr. Eduardo Calixto is the ECC CEO & Founder, CRP (Certified Reliability Professional), CFSE (Certified Functional Safety Expert) AFSP (Automotive Functional Safety Professional), IBM Machine Learning in Python Certification, Microsoft Azure Machine Learning for Data Science , MatLab Machine Learning, Master data Science in R.
- 25 years experience indifferent Project for Oil and Gas, Railway, Aerospace for diferente organization across the globe.



INTRODUCTION



who we are? _____

ECC is an Engineering Consultant company

established in Europe since 2015

which provide Reliability, Maintenance and Safety engineering consultant service as well as Asset management solution for Oil and Gas, Railway, Military, Aerospace and Defense industries around the globe based on following programs:

**Asset Integrity
Reliability & Maintenance
Integrated Logistic Support**

what we do? _____

**Asset Management
performance optimization
based on:**

- LDA (Lifetime Data Analysis);
- RAM (Reliability, Availability and Maintainability Analysis);
- FRACAS (Failure Report and Correction Action System);
- WA (Warranty Analysis);
- FMEA (Failure Mode and Effect Analysis);
- RCM (Reliability Centred Maintenance);
- RBI (Risk Based Inspection);
- APO (Asset Performance Optimization);
- ORT (Optimum Replace Time);
- Asset management based on SaaS solution (Integrity PRO).

**Asset Integrity
Management based on:**

- Risk Management;
- Risk analysis (HAZOP, PHA, HAZID, SIL, LOPA, FTA, ETA, BOW TIE, Consequence and Effect Analysis);
- Human Reliability analysis (THERP, OAT, HEART, SHERPA, STAH-R, SPAR-H, Slim-Maud, BBN);
- Reliability engineering (FMEA, RBI, RAM);
- Asset Integrity management based on SaaS solution (Integrity PRO).

**Integrated Logistic Support
based on:**

- Spare optimization based on modelling;
- Inspection and preventive maintenance optimization based on modeling;
- Life Cycle cost optimization;
- Asse performance optimization.

**Safety Engineering
based on:**

- Functional Safety Analysis;
- Hazard Log Analysis;
- SIL analysis (assignment, verification and validation);
- Occupational risk assessment;
- Risk Management (hazard identification, risk analysis, risk evaluation, risk mitigation, risk communication, risk monitoring);
- Safety and Occupational Health Management;
- Safety System Audit based on ISO 18001 standard series;

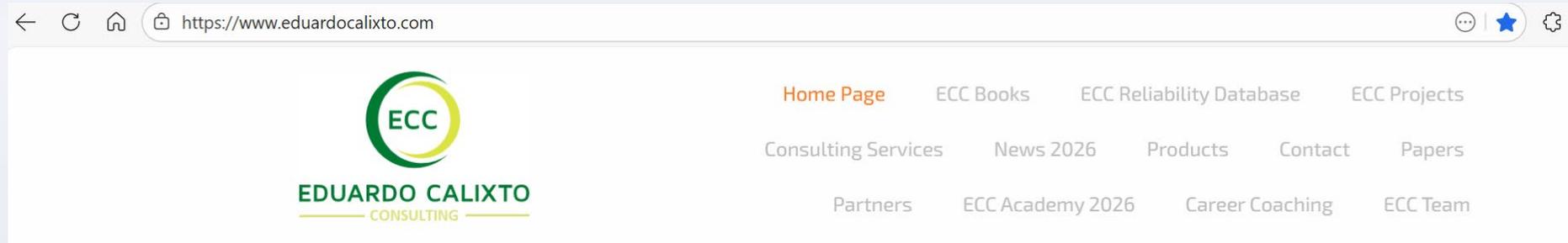
Partners



INTRODUCTION



<http://www.eduardocalixto.com>



Asset Management and RAMS Performance Optimization



What We Do:

We support and teach our client to achieve and maintain their physical assets high performance based on effective Reliability, maintenance or Safety programs and A.I Technology implementation.

The implementation steps are the following:

Part 1 - Opportunities and Problems identification:

Workshop Outline

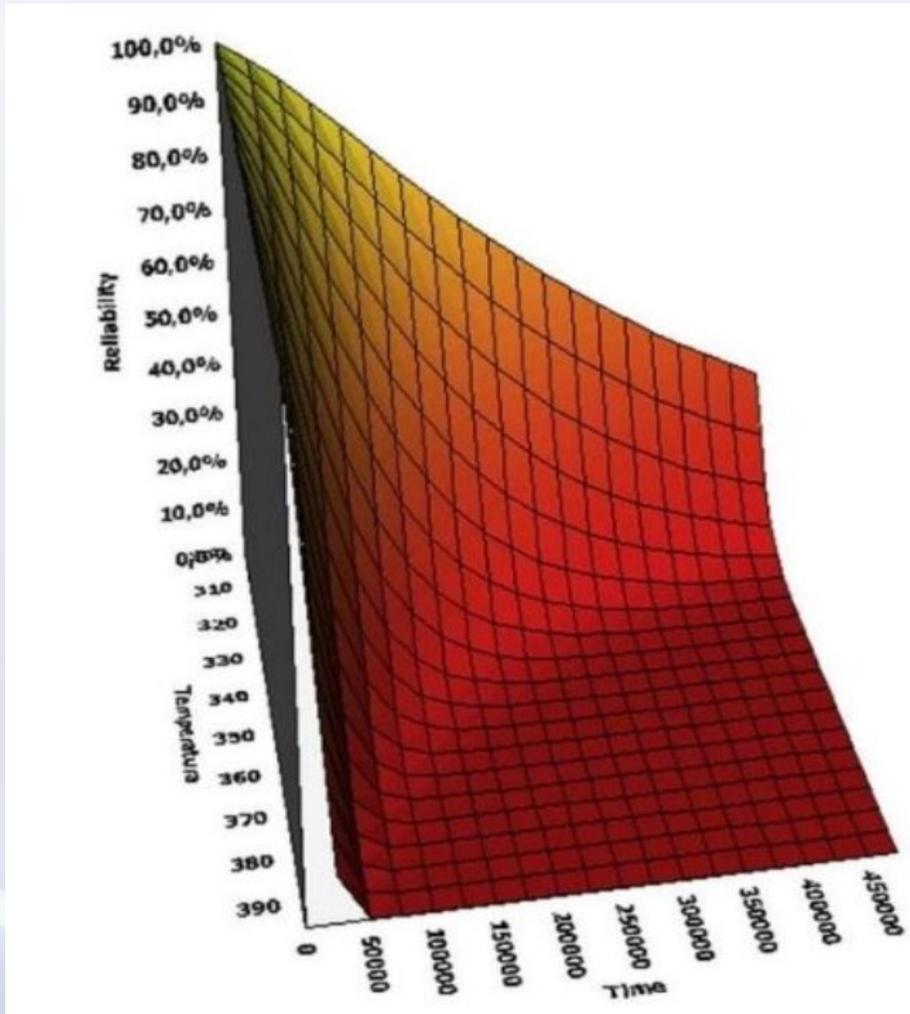
- 01 Introduction.
- 02 RAM Analysis Methodology.
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Glossary



- ❖ *Operational Availability: Uptime/total time.*
- ❖ **Reliability:** The chance of equipment to operate under defined operation condition until an specific period of time.
- ❖ $\beta\%$: percentage of total number of equipment that will fail untin a specific period of time.
- ❖ **MTTF:** Mean time To failure.
- ❖ **MTTR:** Mean Time to Repair/Replace.
- ❖ **MTBF:** Mena time Between Failure (MTBF=MTTF+MTTR)
- ❖ **MTBCF:** Mean Time Between Critical Failure.
- ❖ **MTBD:** Mean Time Between Distance.
- ❖ **RI:** Percentage of subsystem or equipment reliability impact impact on system reliability
- ❖ *FCI: Percentage of equipment or component of system total number failure .*
- ❖ *DECI: Percentage of equipment or component number of system shutdowns.*
- ❖ *DTCI: Percentage of equipment or component number of system downtime*

Reliability Concept



- **Reliability** is the probability that a system operates during a specific period of time under specific environmental conditions without failure.
- **Robustness** is the ability of a system to withstand to environment overstress condition without degrade the reliability in short period of time.
- **Durability** is the ability of a system to withstand to environment overstress conditions without degrade the reliability.

RAM analysis Methodology

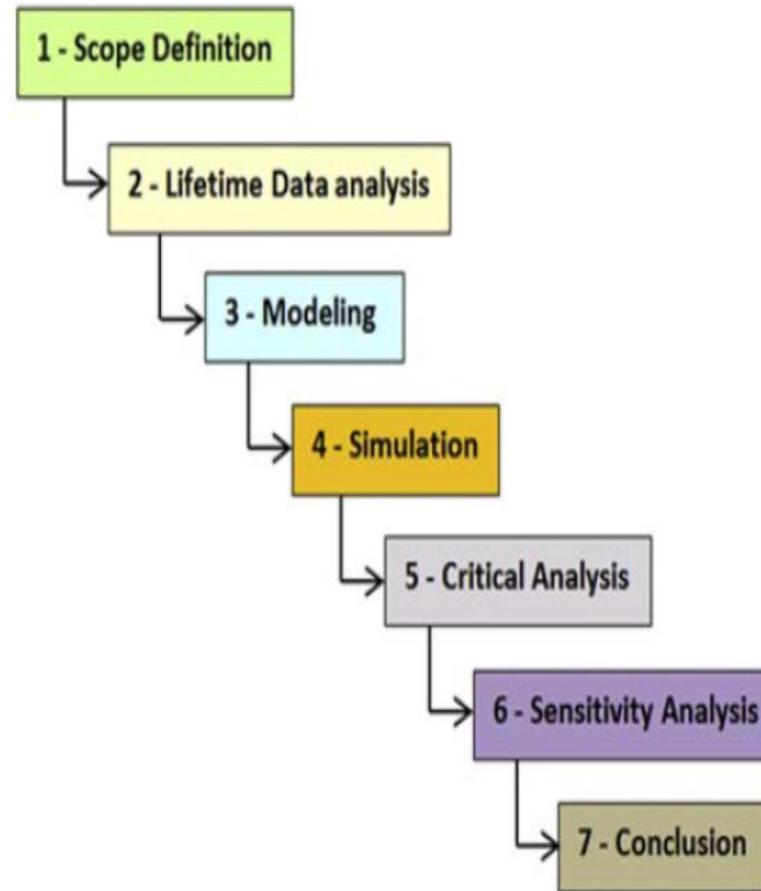


FIGURE 4.1

RAM analysis methodology steps.

RBD Modeling

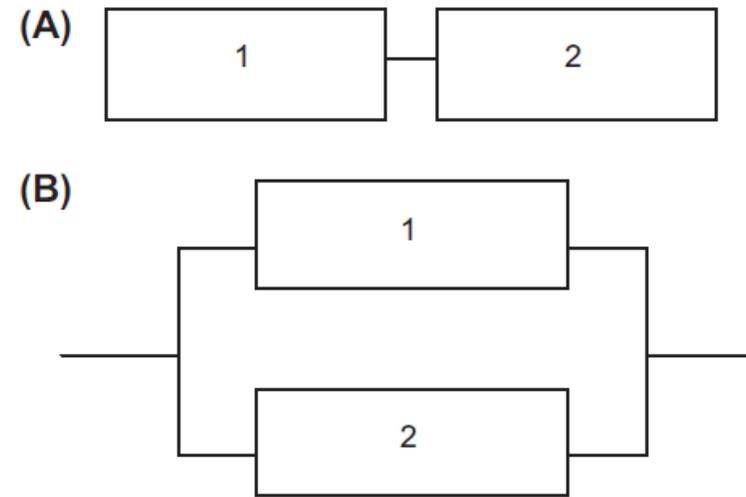


FIGURE 4.3

System block diagram (different equipment).

Case Study – Brake System

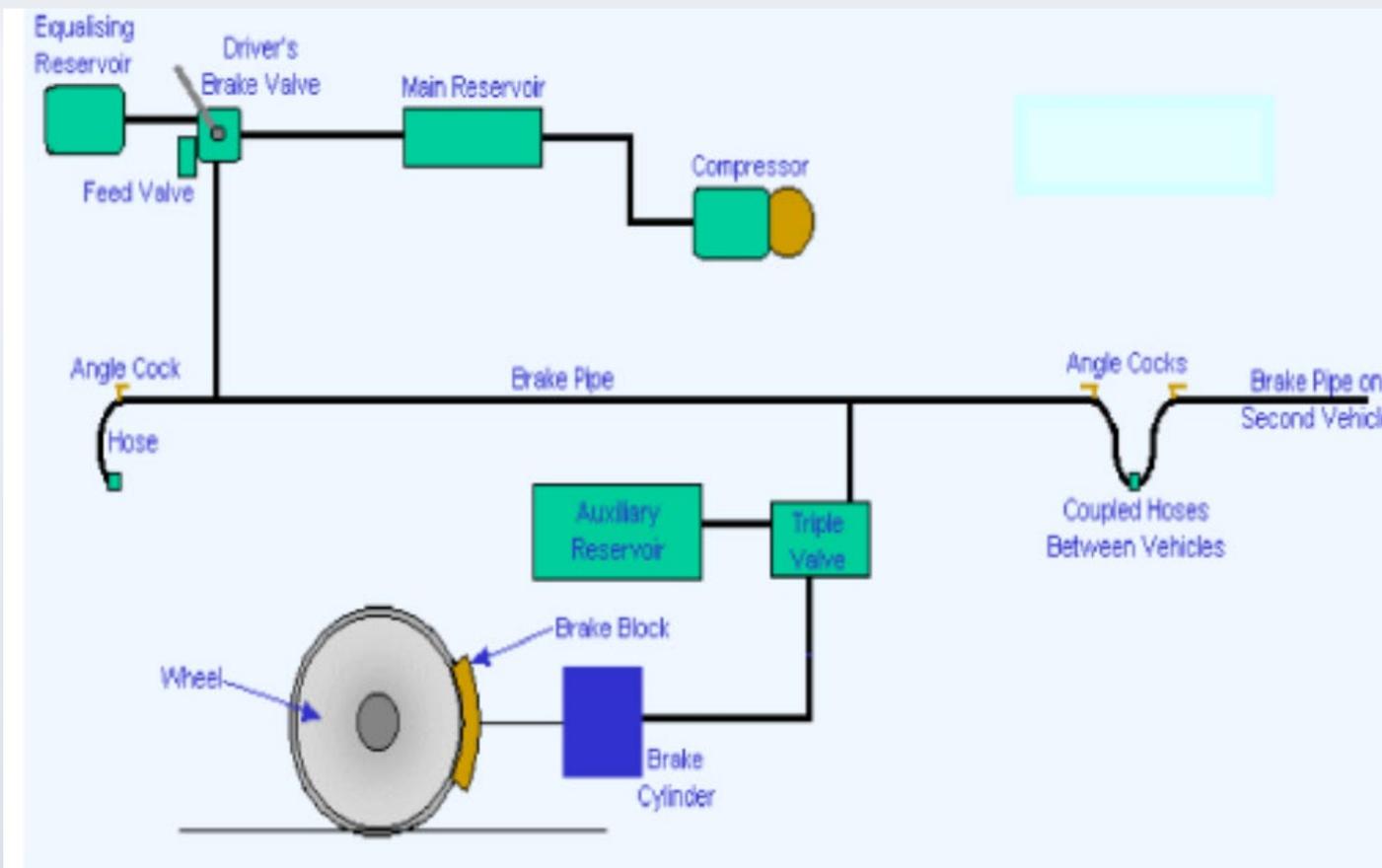


Figure 2-15 Brake System

Reliability and Maintainability input Data

Equipment	Failure (Year)			Repair (Hour)			PM 1 Interval (years)			PM2 Interval (years)			
	PDF	Parameter		PDF	Parameter		PDF	Task	Duration (Hour)	Schedule Time (Years)	PDF	Task	Duration (Hour)
Air Compressor	Gumbel												
Shaft	Gumbel	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		7	2		0.5	0.1		Overhaul	1	4		Insp NDT	1
Bearing	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		3	1		0.5	0.1		Overhaul	1	2		Insp NDT	1
Seal	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		3	0.5		0.5	0.1		Overhaul	1	2		Insp NDT	1
Coupling	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		5	1		0.5	0.1		Overhaul	1	4		Insp/ Test	1
Control	Exp	MTTF		Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10	2		0.5	0.1		N/A				Test	1
Pipes	Gumbel	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10	2		0.5	0.1		Overhaul	1	9		Insp NDT	1

Reliability and Maintainability input Data

Equipment	Failure (Year)			Repair (Hour)			PM 1 Interval (years)			PM2 Interval (years)			
	PDF	Parameter		PDF	Parameter		PDF	Task	Duration (Hour)	Schedule Time (Years)	PDF	Task	Duration (Hour)
Break System													
Reservoir vessel	Gumbel	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10	2		2	0.1		Overhaul	1	9		Insp NDT	1
Equalizing Reservoir vessel	Gumbel	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10	2		2	0.1		Overhaul	1	9		Insp NDT	1
Auxiliary Reservoir vessel	Gumbel	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10	2		2	0.1		Overhaul	1	9		Insp NDT	1
Driver brake Valve	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		5	0.5		1	0.1		Overhaul	1	4		Insp NDT	1
Brake control	Exp	MTTF		Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10			1	0.1		N/A				N/A	
Pressure Governor	Exp	MTTF		Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10			1	0.1		N/A				N/A	
Triple Valve	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		5	0.5		1	0.1		Overhaul	2	4		Insp NDT	1
Check Valve	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		5	0.5		1	0.1		Overhaul	1	4		Insp NDT	1
Safety Valve	Normal	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		5	0.5		1	0.1		Overhaul	1	4		Insp NDT	1
Pipes	Gumbel	μ	∂	Normal	μ	∂	Constant	Description	Time	Schedule Time	Constant	Description	Time
		10	2		0.5	0.1		Overhaul	1	9		Insp NDT	1

ECC Reliability and Maintainability Database



“Reliability and Maintainability Database for Railway Industry”
 (Rail Infrastructure, Electric Power Supply, Signalling and Rolling Stock)



2025

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Preventive Maintenance effect on Reliability

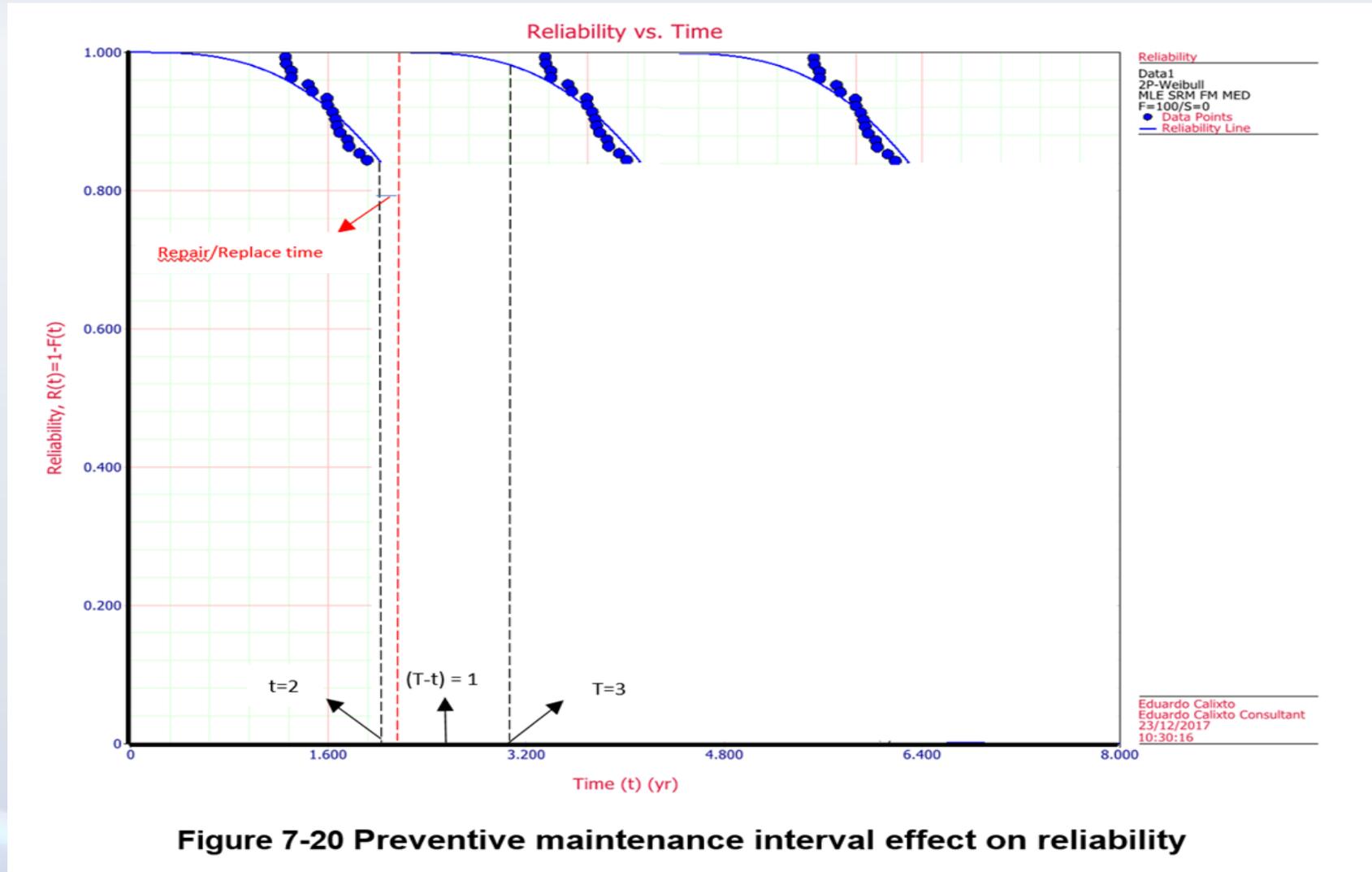


Figure 7-20 Preventive maintenance interval effect on reliability

Brake RBD (Reliability Block Diagram)

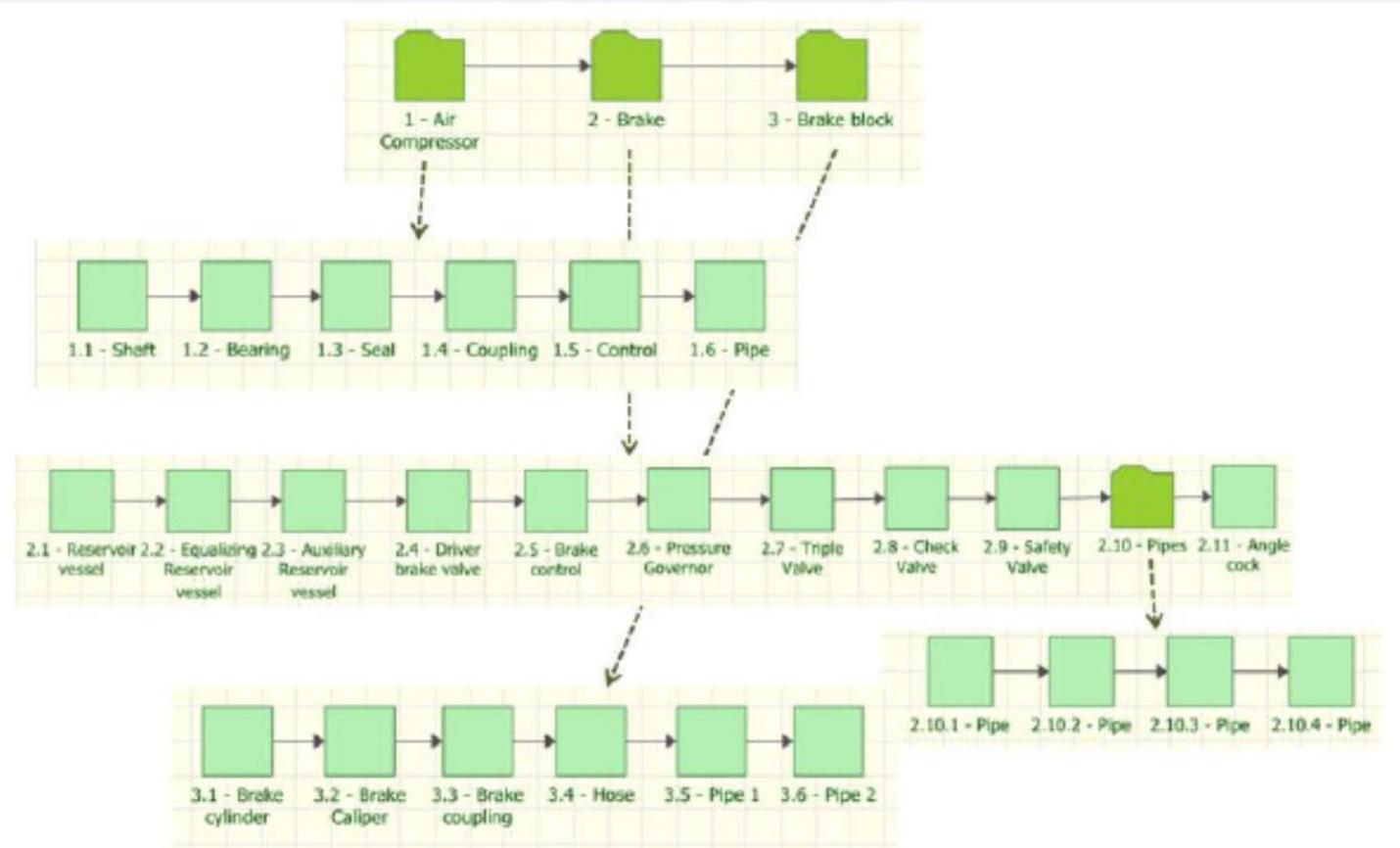


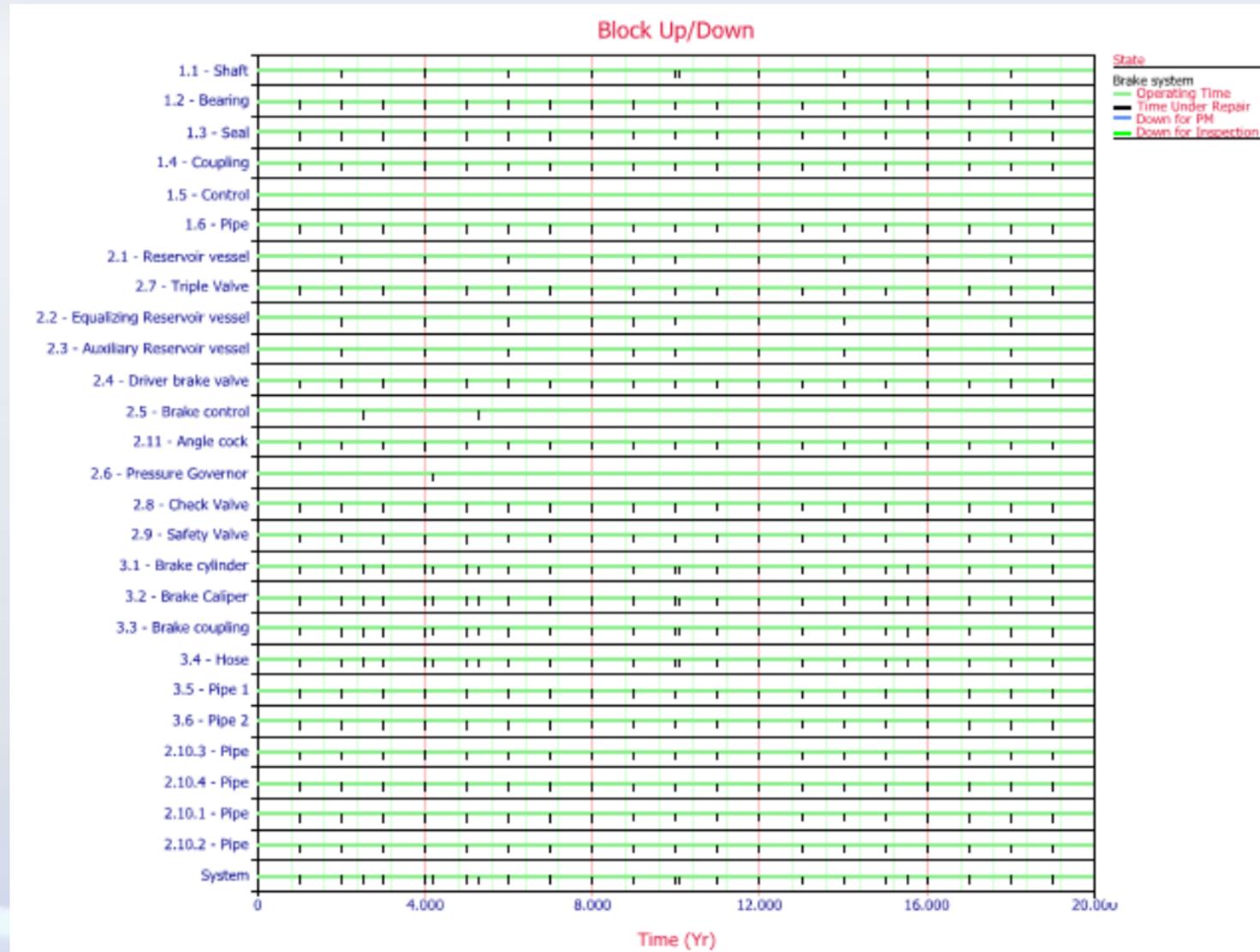
Figure 7-32 Brake RBD (Top Down configuration)

RBD Brake System Simulation Result

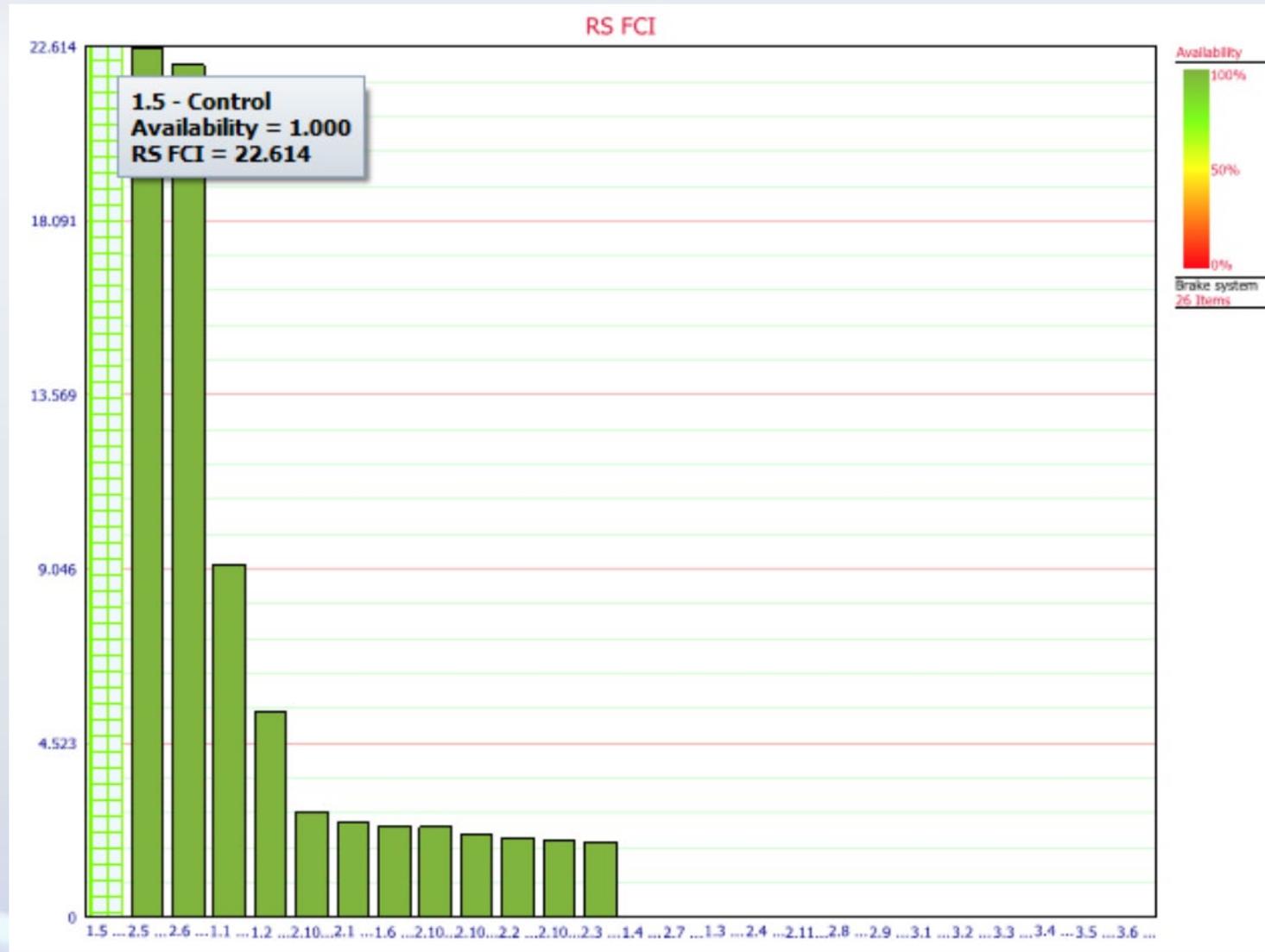


System Overview	
General	
Mean Availability (All Events):	0.999689
Std Deviation (Mean Availability):	0.000032
Mean Availability (w/o PM, OC & Inspection):	0.999958
Point Availability (All Events) at 20:	1
Reliability(20):	0
Expected Number of Failures:	8.928
Std Deviation (Number of Failures):	2.981897
MTTFF (Yr):	2.074811
MTBF (Total Time) (Yr):	2.240143
MTBF (Uptime) (Yr):	2.239447
MTBE (Total Time) (Yr):	0.523095
MTBE (Uptime) (Yr):	0.522932
System Uptime/Downtime	
Uptime (Yr):	19.993783
CM Downtime (Yr):	0.000843
Inspection Downtime (Yr):	0.004556
PM Downtime (Yr):	0.000818
OC Downtime (Yr):	0
Waiting Downtime (Yr):	0
Total Downtime (Yr):	0.006217
System Downing Events	
Number of Failures:	8.928
Number of CMs:	8.928
Number of Inspections:	24.26
Number of PMs:	5.046
Number of OCs:	0
Number of OFF Events by Trigger:	0
Total Events:	38.234
Costs	
Total Costs:	£17,697.60

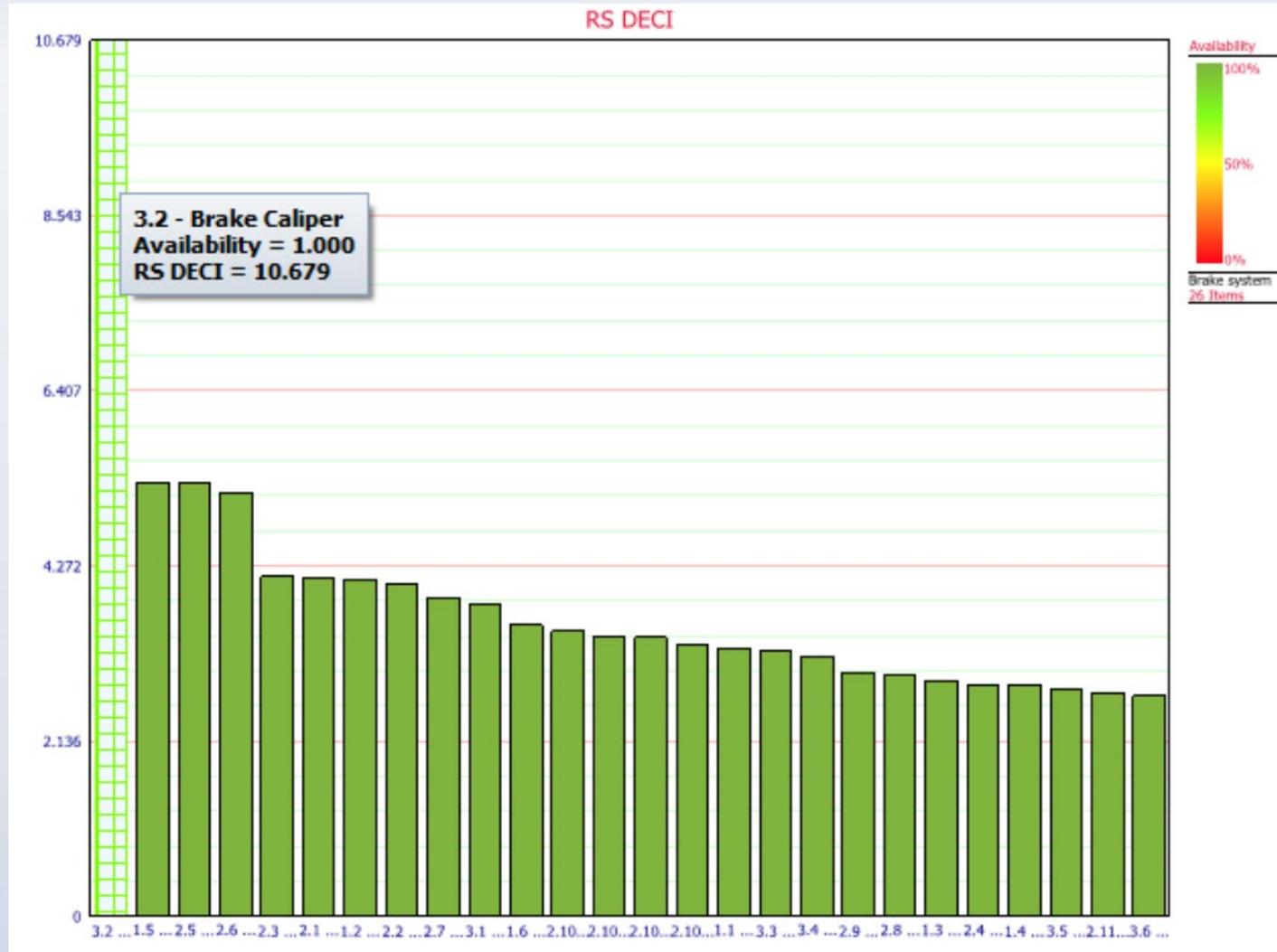
PM and Insp impact on downtime



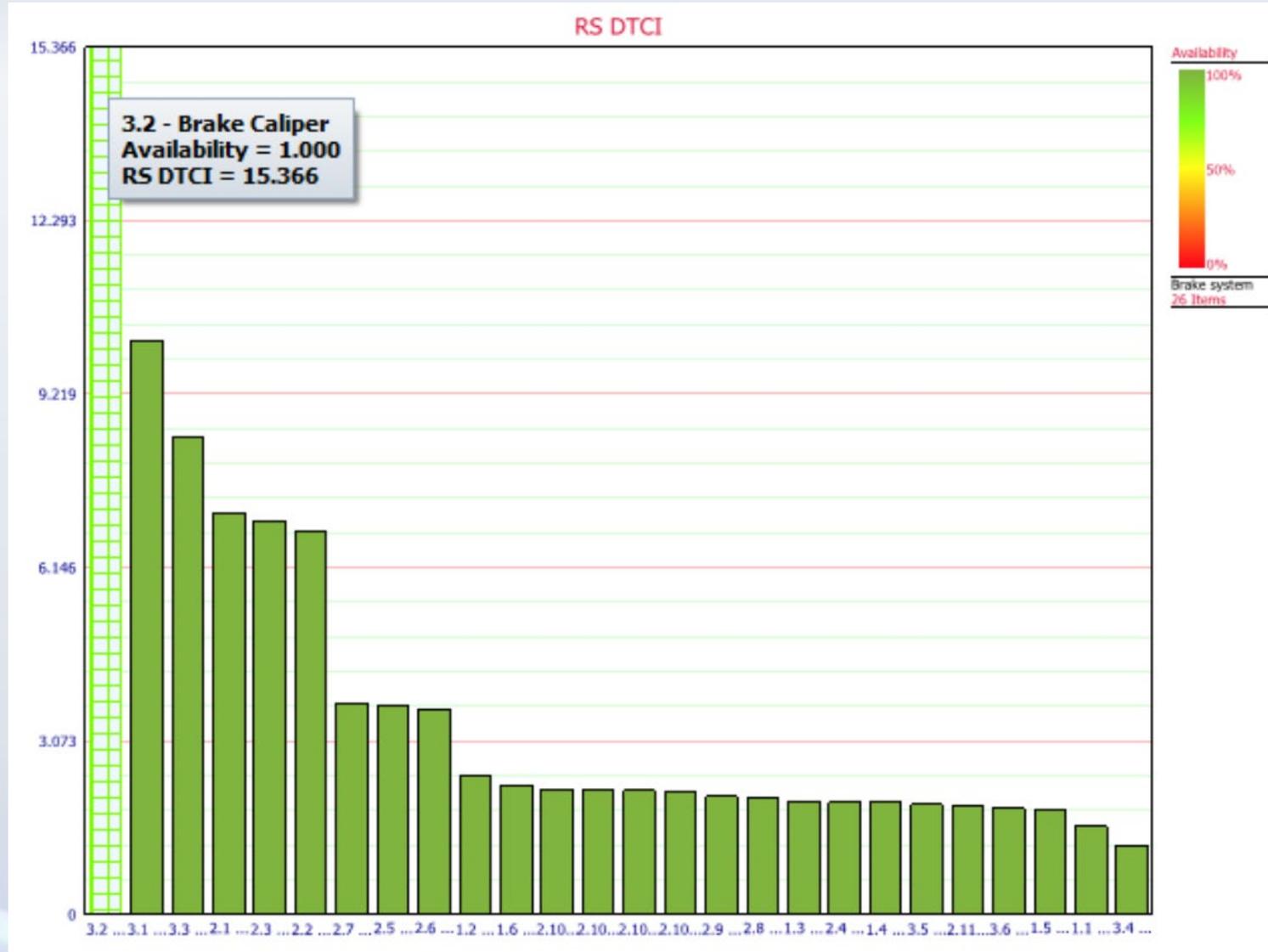
Criticality Analysis: Failure critical index



Criticality Analysis: Failure number of downtimes index



Criticality Analysis: Failure Downtime index



Criticality Analysis Summary



Block Name	RS FCI	RS DECI	RS DTCl	Mean Av. (All Events)	Mean Av. (w/o PM, OC & Insp.)	Expected # of Failures	System Downing Events	Block Downtime (Yr)	Block Uptime (Yr)	Number of CMs	CM Downtime (Yr)
1.1 - Shaft	9.17%	3.27%	1.57%	0.999946	0.999998	0.842	1.252	0.001075	19.99893	0.842	0.000048
1.2 - Bearing	5.34%	4.10%	2.44%	0.99989	0.999999	0.478	1.569	0.002196	19.9978	0.478	0.000027
1.3 - Seal	0.00%	2.87%	2.01%	0.999892	1	0	1.097	0.002169	19.99783	0	0
1.4 - Coupling	0.01%	2.83%	1.98%	0.999892	1	0.001	1.081	0.002169	19.99783	0.001	0
1.5 - Control	22.61%	5.28%	1.85%	0.999994	0.999994	2.019	2.019	0.000115	19.99989	2.019	0.000115
1.6 - Pipe	2.37%	3.55%	2.30%	0.999891	0.999999	0.213	1.357	0.002181	19.99782	0.213	0.000012
2.1 - Reservoir vessel	2.45%	4.14%	7.12%	0.999883	0.999997	0.227	1.581	0.002335	19.99767	0.227	0.000052
2.7 - Triple Valve	0.01%	3.89%	3.74%	0.999869	1	0.001	1.486	0.002626	19.99737	0.001	0
2.2 - Equalizing Reservoir vessel	2.06%	4.06%	6.78%	0.999884	0.999998	0.188	1.551	0.002326	19.99767	0.188	0.000043
2.3 - Auxiliary Reservoir vessel	1.97%	4.14%	6.98%	0.999884	0.999998	0.184	1.584	0.002325	19.99768	0.184	0.000042
2.4 - Driver brake valve	0.00%	2.83%	1.99%	0.999892	1	0	1.082	0.002169	19.99783	0	0
2.5 - Brake control	22.58%	5.27%	3.70%	0.999988	0.999988	2.016	2.016	0.00023	19.99977	2.016	0.00023
2.11 - Angle cock	0.00%	2.73%	1.91%	0.999892	1	0	1.042	0.002169	19.99783	0	0
2.6 - Pressure Governor	22.14%	5.17%	3.63%	0.999989	0.999989	1.977	1.977	0.000226	19.99977	1.977	0.000226
2.8 - Check Valve	0.00%	2.94%	2.06%	0.999892	1	0	1.123	0.002169	19.99783	0	0
2.9 - Safety Valve	0.00%	2.98%	2.09%	0.999892	1	0	1.138	0.002169	19.99783	0	0
3.1 - Brake cylinder	0.00%	3.82%	10.16%	0.999695	1	0	1.459	0.006104	19.9939	0	0
3.2 - Brake Caliper	0.00%	10.68%	15.37%	0.999695	1	0	4.083	0.006104	19.9939	0	0
3.3 - Brake coupling	0.00%	3.24%	8.44%	0.999695	1	0	1.239	0.006104	19.9939	0	0
3.4 - Hose	0.00%	3.18%	1.23%	0.999847	1	0	1.214	0.003052	19.99695	0	0
3.5 - Pipe 1	0.00%	2.77%	1.95%	0.999892	1	0	1.06	0.002169	19.99783	0	0
3.6 - Pipe 2	0.00%	2.68%	1.88%	0.999892	1	0	1.026	0.002169	19.99783	0	0
2.10.3 - Pipe	2.03%	3.31%	2.16%	0.999891	0.999999	0.188	1.265	0.00218	19.99782	0.188	0.000011
2.10.4 - Pipe	2.73%	3.48%	2.22%	0.999891	0.999999	0.246	1.33	0.002183	19.99782	0.246	0.000014
2.10.1 - Pipe	2.36%	3.41%	2.20%	0.999891	0.999999	0.213	1.302	0.002181	19.99782	0.213	0.000012
2.10.2 - Pipe	2.14%	3.40%	2.22%	0.999891	0.999999	0.194	1.301	0.00218	19.99782	0.194	0.000011

Criticality Analysis Summary



Block Name	Number of Inspections	Inspection Downtime (Yr)	Number of PMs	PM Downtime (Yr)	Number of OCs	OC Downtime (Yr)	Total Cost
1.1 - Shaft	5	0.000571	4	0.000457	0	0	£968.40
1.2 - Bearing	10	0.001142	9	0.001027	0	0	£1,421.70
1.3 - Seal	10	0.001142	9	0.001027	0	0	£900.00
1.4 - Coupling	15	0.001712	4	0.000457	0	0	£200.05
1.5 - Control	0	0	0	0	0	0	£807.60
1.6 - Pipe	17	0.001941	2	0.000228	0	0	£221.30
2.1 - Reservoir vessel	8	0.001826	2	0.000457	0	0	£4,454.00
2.7 - Triple Valve	15	0.001712	4	0.000913	0	0	£840.30
2.2 - Equalizing Reservoir vessel	8	0.001826	2	0.000457	0	0	£2,188.00
2.3 - Auxiliary Reservoir vessel	8	0.001826	2	0.000457	0	0	£2,184.00
2.4 - Driver brake valve	15	0.001712	4	0.000457	0	0	£280.00
2.5 - Brake control	0	0	0	0	0	0	£100.80
2.11 - Angle cock	16	0.001826	3	0.000342	0	0	£300.00
2.6 - Pressure Governor	0	0	0	0	0	0	£395.40
2.8 - Check Valve	15	0.001712	4	0.000457	0	0	£280.00
2.9 - Safety Valve	15	0.001712	4	0.000457	0	0	£280.00
3.1 - Brake cylinder	26.563	0.006065	0.174	0.00004	0	0	£17.40
3.2 - Brake Caliper	26.565	0.006065	0.172	0.000039	0	0	£51.60
3.3 - Brake coupling	26.599	0.006073	0.138	0.000032	0	0	£3.45
3.4 - Hose	26.607	0.003037	0.13	0.000015	0	0	£19.50
3.5 - Pipe 1	16	0.001826	3	0.000342	0	0	£450.00
3.6 - Pipe 2	16	0.001826	3	0.000342	0	0	£450.00
2.10.3 - Pipe	17	0.001941	2	0.000228	0	0	£218.80
2.10.4 - Pipe	17	0.001941	2	0.000228	0	0	£224.60
2.10.1 - Pipe	17	0.001941	2	0.000228	0	0	£221.30
2.10.2 - Pipe	17	0.001941	2	0.000228	0	0	£219.40

RAM Quantitative Requirement

Equipment	Reliability Input target			Reliability requirement			OA Requirement
	PDF	μ	σ	R(T)	β 1%	β 10%	OA(T)
Compressors	Normal	2.5	0.1	100% in 2 years	2.1	2.3	100% in 2 years

Equipment	Maintanability Input target			Maintainability requirement	
	PDF	μ	σ	M(T)	
Compressors	Normal	1	0.5	100% in 0.5 hours	Repair \leq 0.5 hours

Equipment	Reliability Input target			Reliability requirement			OA Requirement
	PDF	μ	σ	R(T)	β 1%	β 10%	OA(T)
Compressors	Normal	2.5	0.1	100% in 2 years	2.1	2.3	100% in 2 years
Shaft	Gumbel	7	0.5	100% in 5 years	5.5	6.3	100% in 5 years
Bearing	Normal	3	0.1	100% in 2.5 years	2.7	2.85	100% in 2.5 years
Seal	Normal	3	0.1	100% in 2.5 years	2.7	2.85	100% in 2.5 years
Coupling	Normal	5	0.1	100% in 4.5 years	4.7	4.85	100% in 4.5 years
Control	Exponential	10	2	100% in 2 years	2.1	1	100% in 2 years
Pipes	Normal	10	0.5	100% in 8 years	8.5	9.3	100% in 8 years

Equipment	Maintanability Input target			Maintainability requirement	
	PDF	μ	σ	M(T)	
Shaft	Normal	0.5	0.1	100% in 0.5 hours	Repair \leq 0.5 hours
Bearing	Normal	0.5	0.1	100% in 0.5 hours	Repair \leq 0.5 hours
Seal	Normal	0.5	0.1	100% in 0.5 hours	Repair \leq 0.5 hours
Coupling	Normal	0.5	0.1	100% in 0.5 hours	Repair \leq 0.5 hours
Control	Normal	0.5	0.1	100% in 0.5 hours	Repair \leq 0.5 hours
Pipes	Normal	28	4	100% in 0.5 hours	Repair \leq 0.5 hours

Reliability Requirement Clarification

The screenshot displays the ReliaSoft Weibull++ software interface. The main window is titled "Folio2 - ReliaSoft Weibull++". The ribbon includes tabs for File, Home, My Portal, Project, Insert, View, Help, Life Data, and Sheet. The ribbon contains various toolbars such as Clipboard, Edit, Print, Tools, Launch, and Synthesis.

The Project Manager on the left shows a tree view with "Project 1" expanded, containing folders for "Weibull++Folios", "Specialized Folios", "Multiplots", "RBDs", "Tools", "Reports", and "Attachments". Under "Weibull++Folios", there are sub-folders for "Compressor", "Folio1", and "Folio2".

The main data table shows a list of failed units over time. The columns are "Time Failed (Yr)" and "Subset ID 1".

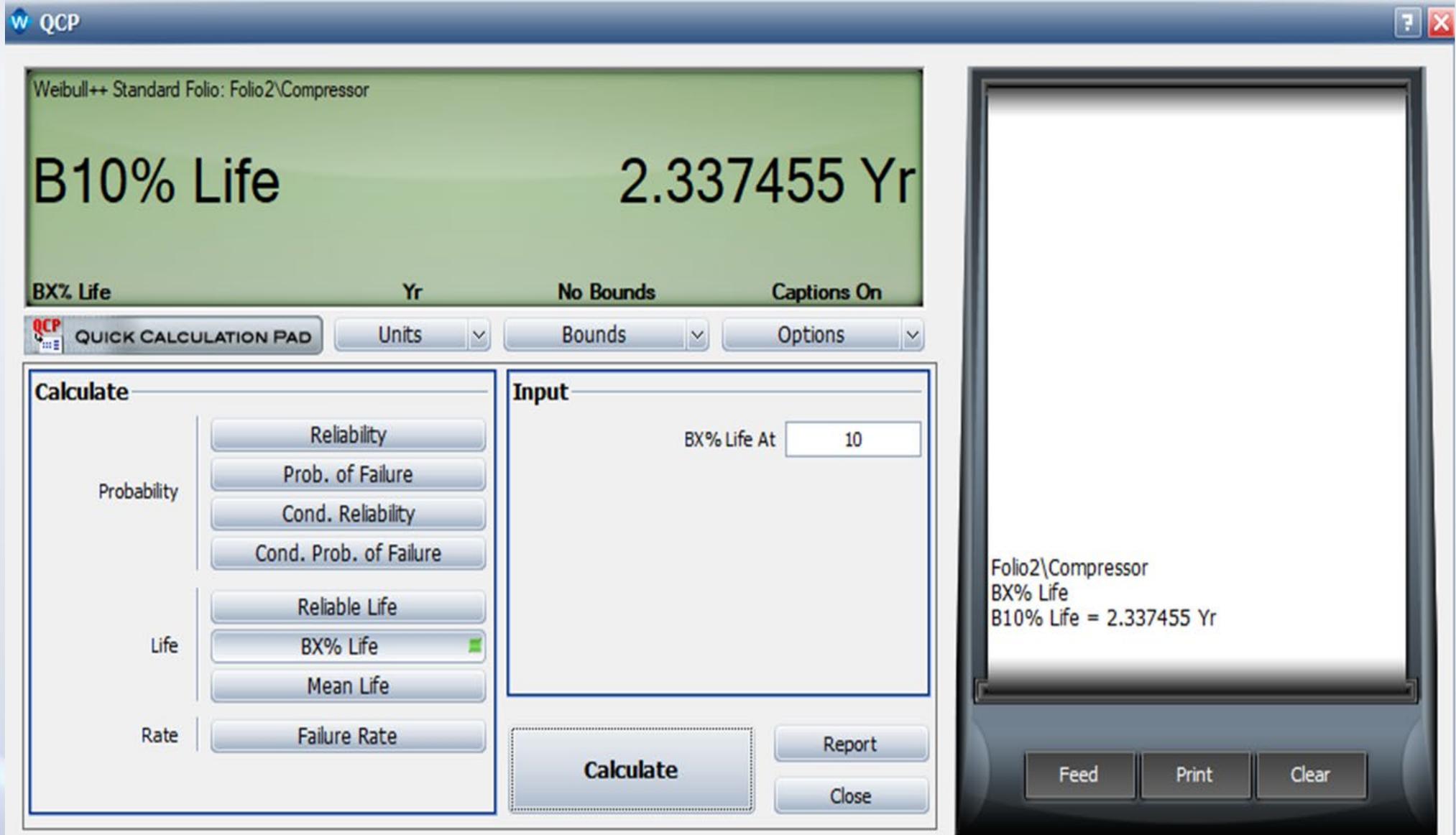
Time Failed (Yr)	Subset ID 1
1	2.3315
2	2.3537
3	2.3725
4	2.5086
5	2.5244
6	2.5508
7	2.5798
8	2.6302
9	2.6533
10	2.7422
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

The right-hand pane shows the "Main" window with the "STANDARD FOLIO" analysis settings. The "Distribution" is set to "Normal". The "Analysis Settings" section shows "RRX" and "SRM" selected, with "FM" and "MED" also visible. The "Analysis Summary" section displays the following parameters:

Parameters	Value
Mean (Yr)	2.524700
Std (Yr)	0.146108
Rho	0.979338
LK Value	6.093833

The "Failures/Suspensions" section shows "F/S" as "10/0". There is also a "Comments" section at the bottom.

Reliability Requirement Clarification



W QCP

Weibull++ Standard Folio: Folio2\Compressor

B10% Life **2.337455 Yr**

BX% Life Yr No Bounds Captions On

QCP QUICK CALCULATION PAD Units Bounds Options

Calculate

Probability

- Reliability
- Prob. of Failure
- Cond. Reliability
- Cond. Prob. of Failure

Life

- Reliable Life
- BX% Life**
- Mean Life

Rate

- Failure Rate

Input

BX% Life At

Calculate Report Close

Folio2\Compressor
BX% Life
B10% Life = 2.337455 Yr

Feed Print Clear

Reliability 4.0



EDUARDO CALISTO
Executive Dashboard | Operational Availability | Production Efficiency | Reliability | OCE Availability | OCE Availability | Production Losses | Daily Production Figures

BCE-01 Oil System

Daily Update

Show 10 entries

Date	Target Uptime	Operating	Planned
16/11/19	24	24	0
17/11/19	24	24	0
18/11/19	24	24	0
19/11/19	24	24	0
20/11/19	24	24	0
21/11/19	24	24	0
22/11/19	24	24	0
23/11/19	24	24	0
24/11/19	24	24	0
25/11/19	24	24	0

Showing 1 to 10 of 26 entries

League Table and Bad Actors

Show 10 entries

ID	Equipment	GM%
49775	HEATER MULTIFUNCTIONAL SEPARATOR OIL	100
49771	EXCHANGER A CRUDE CRUDE PLATE AND FRAME	100
49772	EXCHANGER B CRUDE CRUDE PLATE AND FRAME	100
49435	COOLER A SALES OIL PLATE AND FRAME	100
49436	COOLER B SALES OIL PLATE AND FRAME	100
49773	HEATER CRUDE CRUDE EXCHANGER A PLATE AND FRAME	100
49774	HEATER B CRUDE PLATE AND FRAME	100
49449	PUMP CRUDE OIL TRANSFER A CENTRIFUGAL	100
49430	PUMP CRUDE OIL TRANSFER B CENTRIFUGAL	100
86657	VALVE ON OFF SALES OIL COOLER TO CRUDE STORAGE CRUDE OIL	100

Showing 1 to 10 of 42 entries

Cumulative Business Critical Element
Uptime Operating

MTBF Graph

Please select a minimum of three values that are to be used for the graph. Note that the selected values will also be used in the reliability graph.

	Entered Service	Failure Event	Return to Service	Service Period (Days)	Time Between Failures (Days)
✓	01/02/13	01/04/14		424	10176
✓	01/04/12	01/01/13		275	6600
✓	01/02/11	01/03/12	04/10/18	394	9456
✓	01/01/10	01/01/11	04/10/18	365	8760

Load graph

The MTBF Graph displays three metrics over time (x-axis: 0 to 34992):

- Failure Intensity x Time (RT):** Shows a linear increase from approximately 10 to 45.
- MTBF x Time (Poly(MTBF)):** Shows a decreasing trend from approximately 12,000 to 8,000.
- Cumulative Number of Failures x Time (ND):** Shows a linear increase from 0 to 4.

Prognostic Health Management

integrityPRO

ARULE Application

EDUARDO CALIXTO

- HOME
- PROACTIVE WORKFLOW
- ACTION CENTRE >
- REPORTING >
- REGISTERS >
- FORUM

Input

Select Model File
BHR01BMOD.txt

Select Data File
BHR01.txt

Generate Graph

Save to IntegrityPro

Download Result File

Output

RUL = 0 EOL = 15082.15 % SOH = 0 %

Input and Model Data

RUL and EOL

SOH

FMEA Methodology

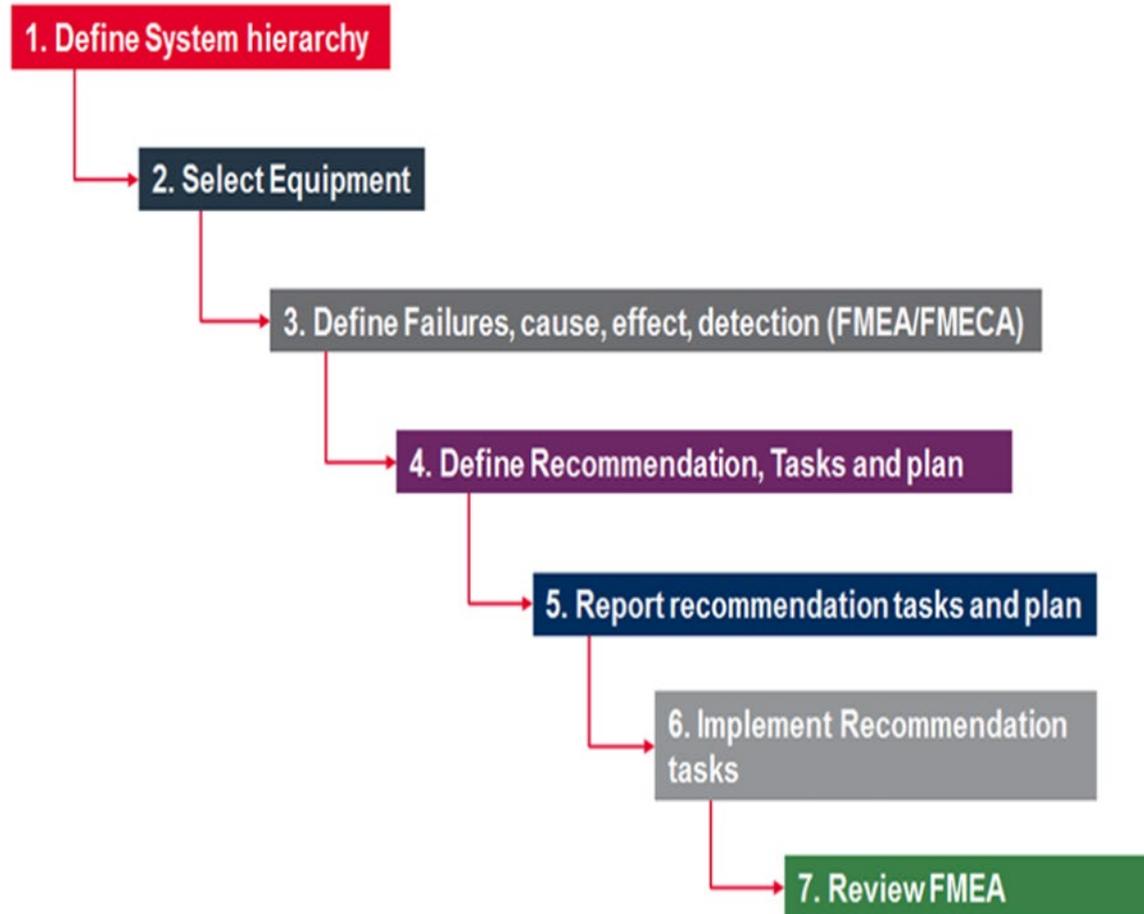


Figure 2-2 FMEA methodology

FMEA Methodology

		Hazard Severity Level				
		Insignificant	Marginal	Critical	Catastrophic	
		IV	III	II	I	
Frequency of occurrence	Frequent	A	Undesirable	Intolerable	Intolerable	Intolerable
	Probable	B	Tolerable	Undesirable	Intolerable	Intolerable
	Occasional	C	Tolerable	Undesirable	Undesirable	Intolerable
	Remote	D	Negligible	Tolerable	Undesirable	Undesirable
	Improbable	E	Negligible	Negligible	Tolerable	Tolerable
	Incredible	F	Negligible	Negligible	Negligible	Negligible

Description	Abbreviation
Catastrophic : Fatalities and/or multiple severe injuries and/or major damage to the environment.	I
Critical : Single fatality and/or severe injury and/or significant damage to the environment.	II
Marginal : Minor injury and/or significant threat to the environment.	III
Insignificant : Possible minor injury or minor system damage.	IV

FMEA Case Study – Reliability Requirement

Failure Mode and Effect analysis (FMEA)												
FMEA Leader: Dr. Eduardo Calixto			Document: DE-101223-001 Rev01			Date:18-03-2016						
System: Train			Subsystem: Brake			Equipment: Brake compressor			Component: Shaft, control, Engine, Bearing			
N0	Component	Failure mode	Phase	Root Cause	O	Consequence	S	R	Mitigate Action	O	S	Risk Post
1	Shaft	Worn out	Ins	Incorrect installation	B	Loss of Brake	I	BI	To implement installation procedure and Training	E	I	EI
			Op	Normal wear.	C		I	CI	To implement RCM to define PM/Insp	E	I	EI
		Fracture	Op	High Vibration	C		I	CI	To implement RCM to define preventive Maintenance	E	I	EI
	Control	Lack of signal	Op	Open/Short Circuit	C	Loss of Brake	I	CI	To implement RCM to define PM/Insp	E	I	EI
		Continuous Signal	De	Software fault	C		I	CI	To implement RCM to define software test	E	I	EI
		Disconnection	Ma	High Vibration	C		I	CI	To implement RCM to define PM/Insp	E	I	EI
				Incorrect installation	B		I	BI	To implement montage test and procedure definition	E	I	EI
	Bearing	Seizing	OP	Lack of Procedure for lubrication	B	Loss of Brake	I	BI	To implement lubrication procedure and Training.	E	I	EI
		Cracking	OP	High vibration caused by overload	B		II	BII	To implement RCM to define PM/Insp	E	II	EII

FMEA Case Study – Reliability Requirement



Failure Mode and Effect analysis (FMEA)													
FMEA Leader: Dr. Eduardo Calixto			Document: DE-101223-001 Rev01				Date: 18-03-2016						
System: Train			Subsystem: Brake				Equipment: Brake Compressor			Component: Shaft, control, Engine, Bearing			
NO	Component	Failure mode	Phase	Cause	Root Cause	O	Consequence	S	R	Mitigate Action	O	S	Risk Post
1	Shaft	Worn out	Ins	Lack of procedures and supervision for installation	Incorrect installation	B	Loss of Brake	I	BI	To implement installation procedure and Training	E	I	EI
2			Op	Aged	Normal wear.	C		I	CI	To implement RCM to define PM/Insp	E	I	EI
3		Fracture	Op	Lack of robustness against high vibration	High Vibration	C		I	CI	To implement RCM to define preventive Maintenance	E	I	EI
								I	CI	To implement Vibration test (HALT/ALT/RGA)	E	I	EI
4	Control	Lack of signal	Op	Lack of robustness against high voltage	Open/Short Circuit	C	Loss of Brake	I	CI	To implement Temperature and voltage test (HALT/ALT/RGA) To implement RCM to define PM/Insp	E	I	EI
5		Continuous Signal	De	Software wrong configuration	Software fault	C		I	CI	V&V software test and Reliability software Target	E	I	EI
6		Disconnection	Ma	Lack of robustness against high vibration	High Vibration	C		I	CI	To implement Vibration test (HALT/ALT/RGA) To implement RCM to define PM/Insp	E	I	EI
7				Lack of procedures and supervision for installation	Incorrect installation	B		I	BI	To implement montage test and procedure definition	E	I	EI
8	Bearing	Seizing	De	Lack of robustness against high temperature	Wrong bearing material selection	B	Loss of Brake	II	BII	To implement Temperature and voltage test (HALT/ALT/RGA) To implement RCM to define PM/Insp	E	II	EII
9			OP	Lack / Improper Lubrication	Lack of Procedure for lubrication	B		I	BI	To implement lubrication procedure and Training.	E	I	EI
10		Cracking	OP	Lack of robustness against high vibration	High vibration caused by overload	B		II	BII	To implement Vibration test (HALT/ALT/RGA) To implement RCM to define PM/Insp	E	II	EII

ECC FMEA Database



"FMEA Database for Railway Industry"

(Rail Infrastructure, Electric Power Supply, Signalling and Rolling Stock)



2025

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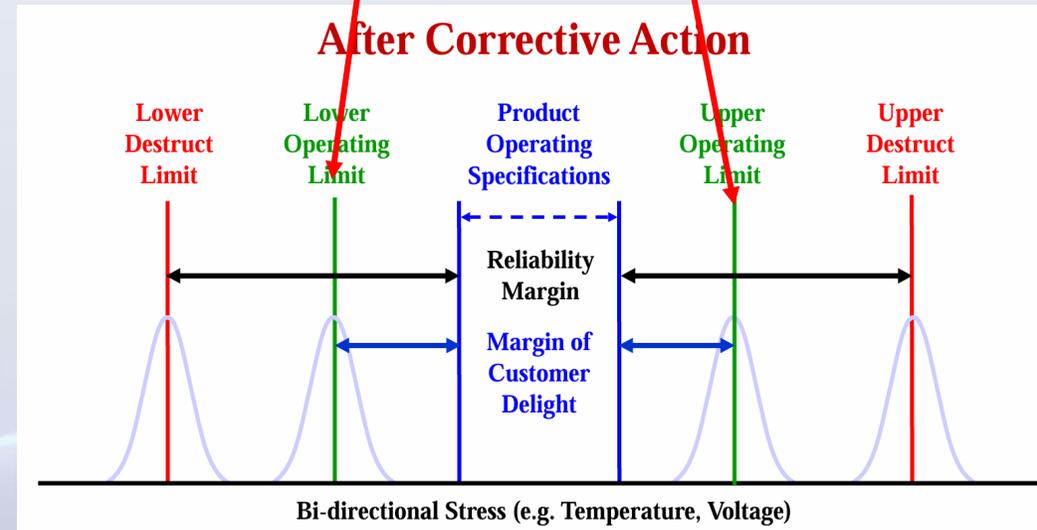
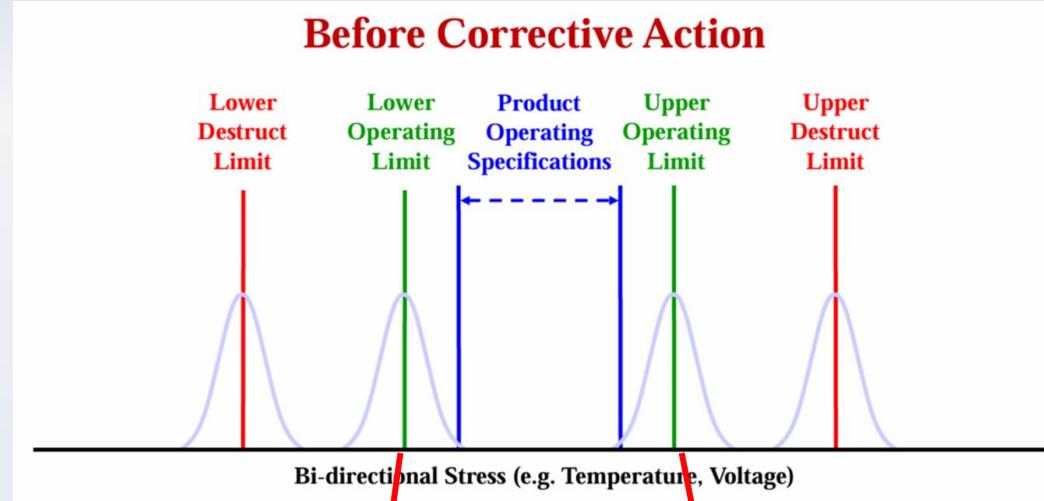
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Reliability requirement form FMEA

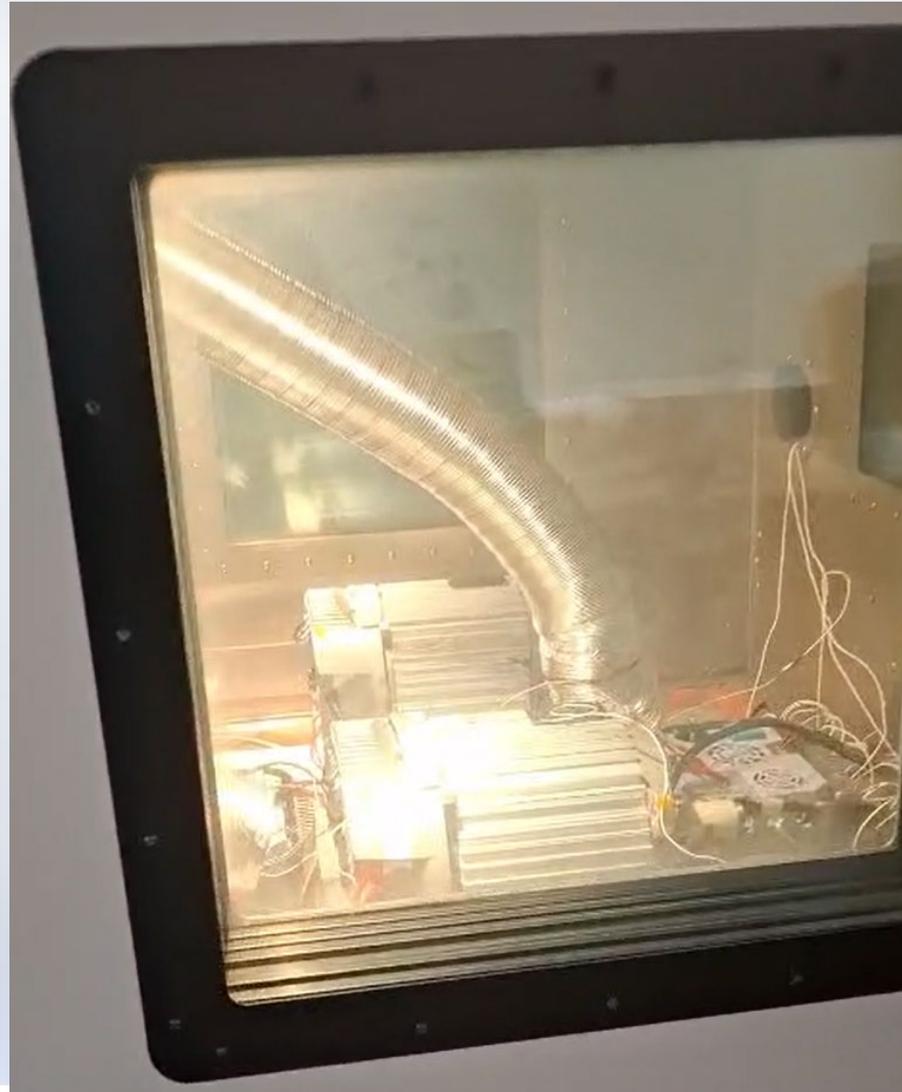


Equipment	Qualitative Reliability and Maintainability Requirement	References
Compressors		
Shaft	To implement installation procedure and Training	Organization Procedure
	To implement RCMto define PM/Insp	Organization Procedure
	To implement Vibration test (HALT/ALT/RGA)	Organization Procedure
Control	To implement Temperature and voltage test (HALT/ALT/RGA/HASS)	Organization Procedure
	V&V software test and Reliability software Target	Organization Procedure
	To implement Vibration test (HALT/ALT/RGA/HASS)	Organization Procedure
	To implement RCMto define PM/Insp	Organization Procedure
Bearing	To implement Temperature test (HALT/ALT/RGA/HASS)	Organization Procedure
	To implement RCMto define PM/Insp	Organization Procedure
	To implement lubrication procedure and Training.	Organization Procedure
	To implement Vibration test (HALT/ALT/RGA/HASS)	Organization Procedure

HALT (Reliability Qualitative requirement clarification)



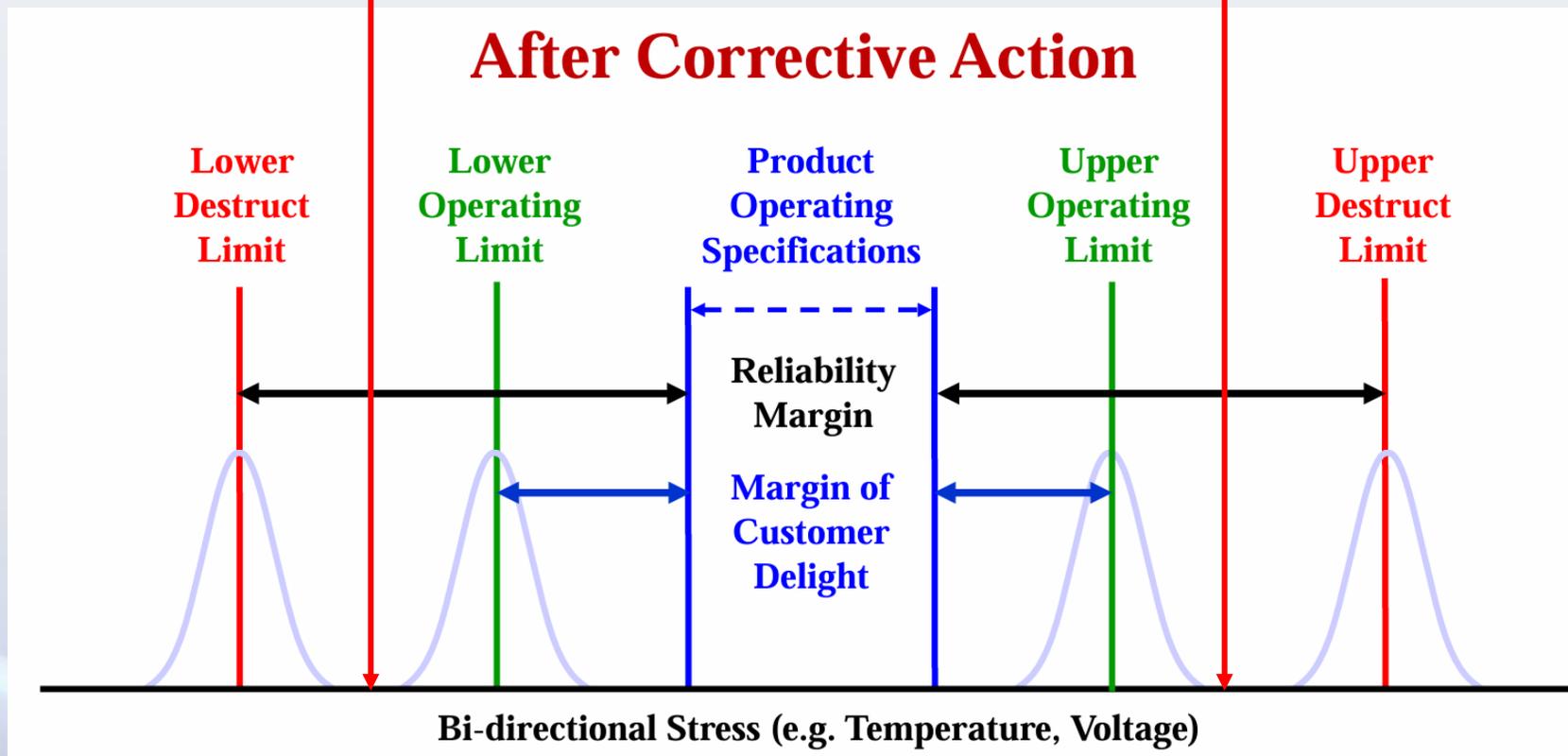
HALT (Reliability Qualitative requirement clarification)



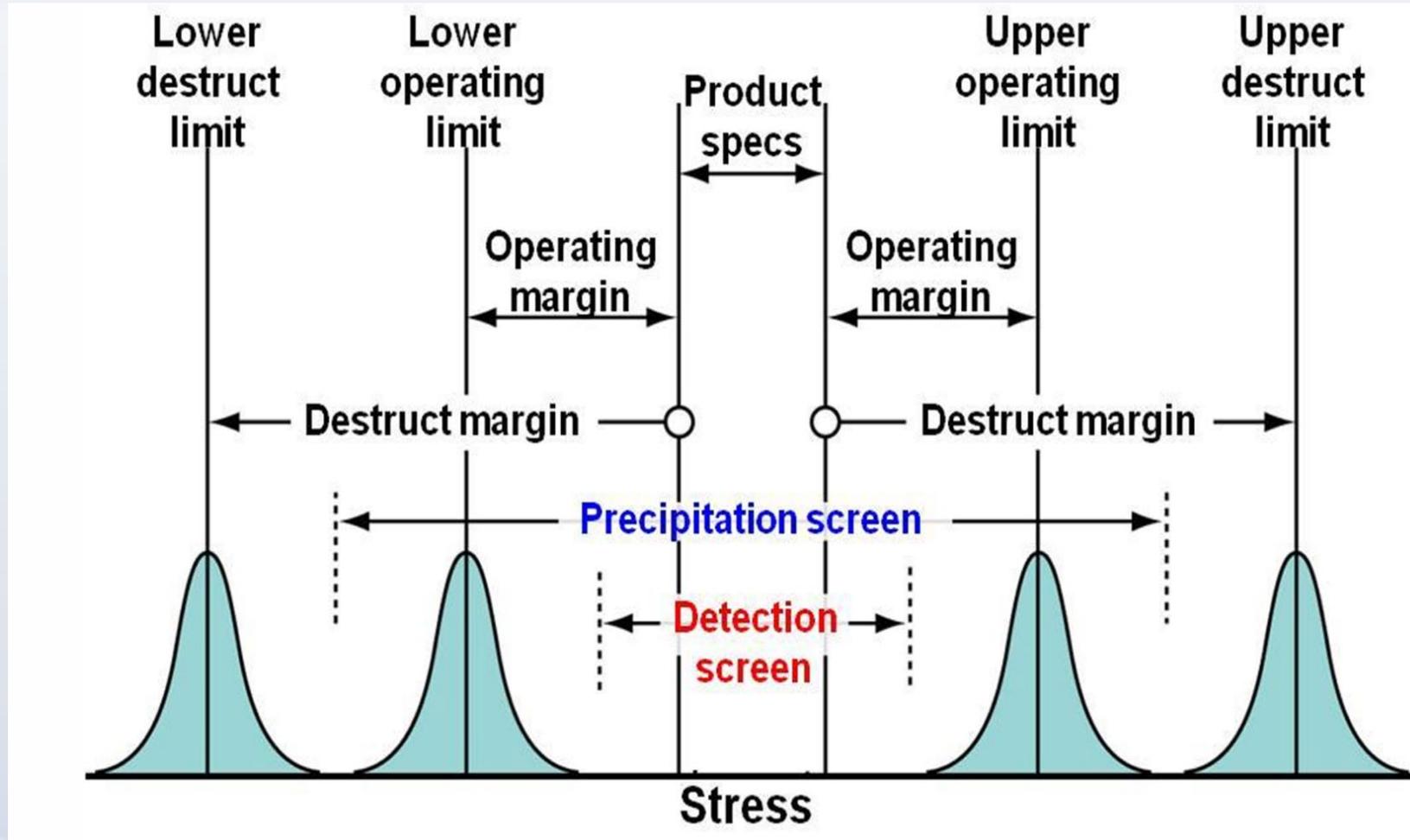
QALT (Reliability Qualitative requirement clarification)

QALT LL

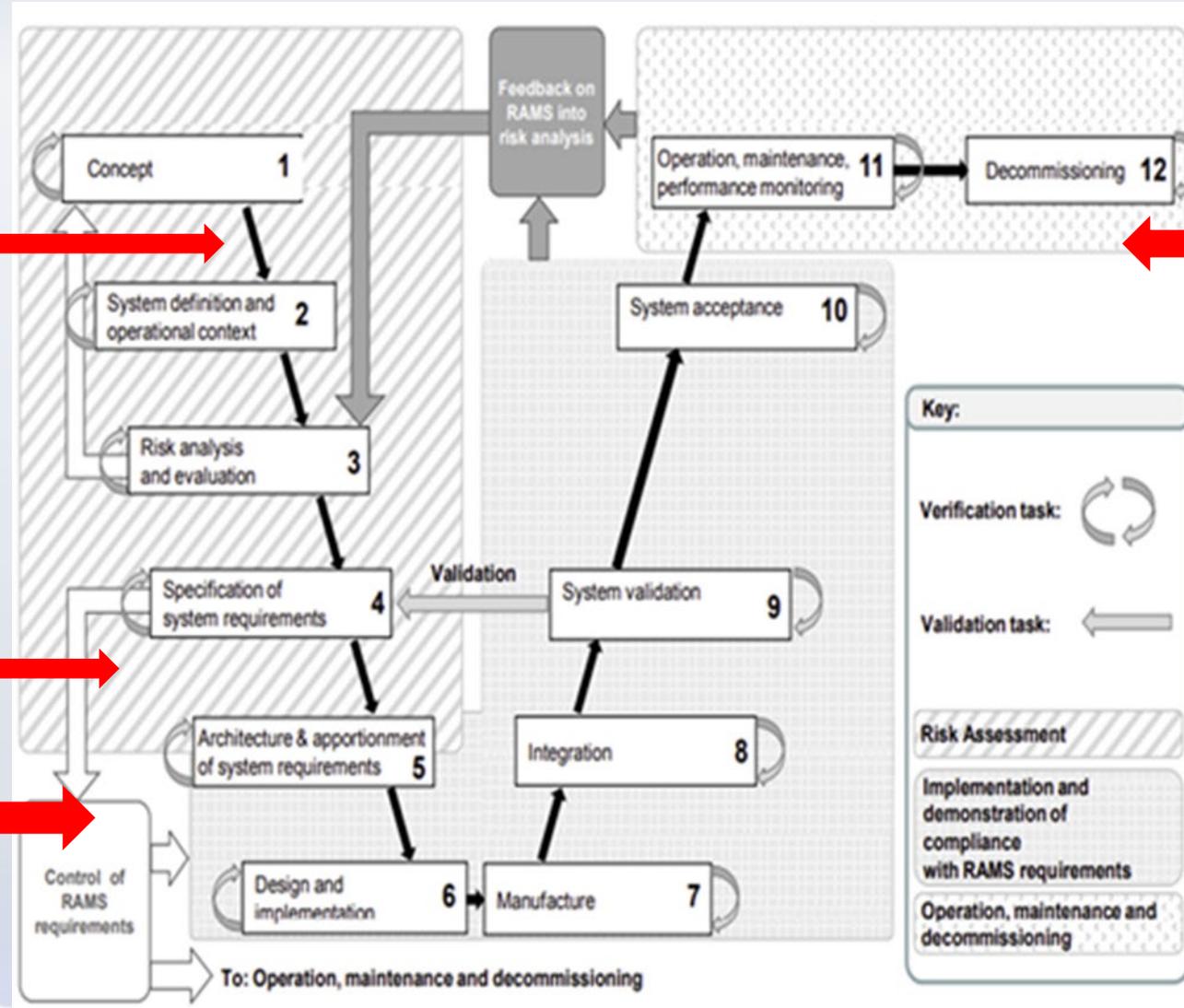
QALT UL



HASS (Reliability Qualitative requirement clarification)



Conclusion



“RAM Requirement for System and equipment BID”

RAM Validation for System and Equipment

“RAM Assurance for System “

“RAM Assurance and for System and Equipment Verification”

“The Best Maintenance and A.I strategy is to have a reliable, Robust and durable equipment”.

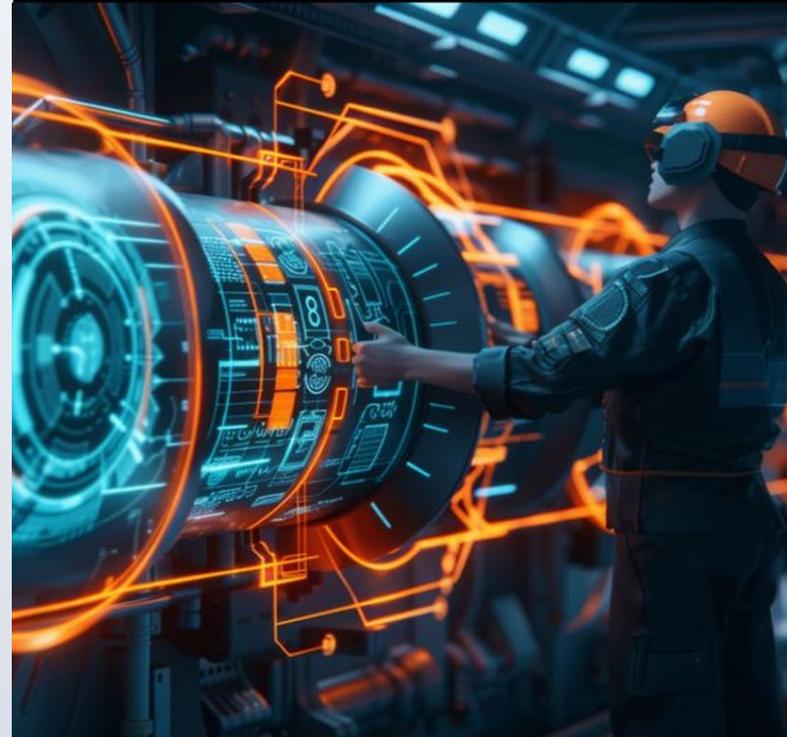
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