SISTEMAS INTELIGENTES DE MANTENIMIENTO

Grupo de investigación: I+DT Organización Industrial

ESCUELA SUPERIOR DE INGENIEROS. UNIVERSIDAD DE SEVILLA

CONFERENCE OMAINTEC EXHIBITION 2019

17th Edition

International Operations & Maintenance Conference in the Arab Countries

Assets Heath Indexing Model. Implementation in a Process Pumps Fleet.

Adolfo Crespo Márquez

Full Prof. of Industrial management . University of Seville. Spain

President of INGEMAN

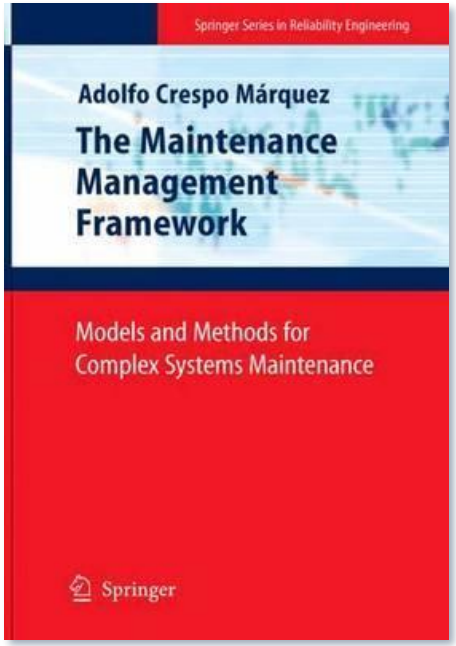
UNIVERSIDAD DE SEVILLA

ingeman ASOCIACIÓN PARA EL DESARROLLO DE LA INGENIERÍA DE MANTENIMIENTO

Content

1. Concept of Asset Health Index
2. Requirements for the AHI method and model
3. Conceptual basis
4. Review of relevant international models
5. Spanish Network AHI Model
6. Implementation

The Concept



Chapter VII.

A Review of key decision areas in maintenance management.

Crespo Márquez A.

2007. The Maintenance Management Framework.

Springer Verlag

The Concept

Asset Health is a measure of the condition of an asset and the proximity to the end of its useful life, as a consequence of its deterioration.

In order to take account of future deterioration it is necessary for the Methodology to:

i) include age based elements within the calculation of Asset Health; and

ii) use an Index scale for the evaluation of Asset Health.

As the health of an asset deteriorates (i.e. its condition worsens), the likelihood that it will fail due to condition increases.

The Concept

It is important to understand the differences between the study of **functional failures and corrective maintenance** versus **long-term asset degradation and asset replacement**.

Functional failures are associated with failure modes in the ancillary systems that affect operation and reliability of the asset well before its end-of-life.

These failures do not normally affect the life of the asset itself, if detected early and corrected. Defects are routinely identified during inspection and dealt with by corrective maintenance activities to ensure continued operation of the asset.

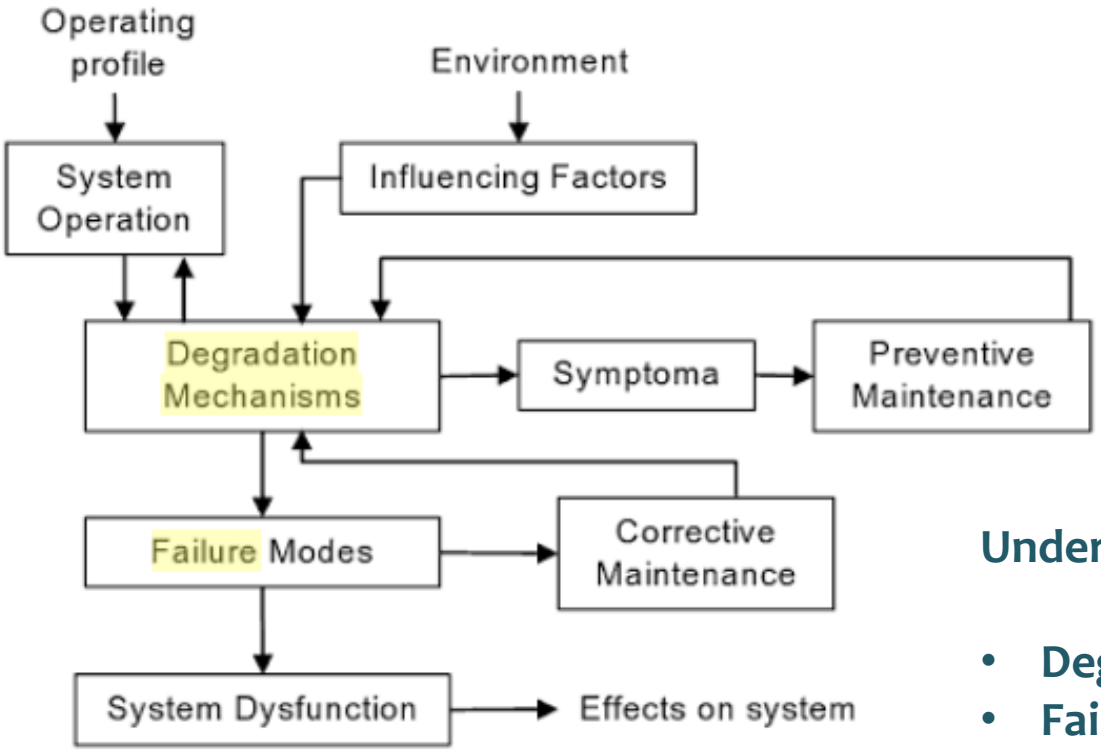
The Concept

Long-term degradation is generally less well defined and it is not easily determined by routine inspections.

The purpose of asset health assessment is to detect and quantify long-term degradation and to provide a means of quantifying remaining asset life.

This includes identifying assets that are at or near end-of-life and assets that are at high risk of generalized failure that will require major capital expenditures to either refurbish or replace the assets.

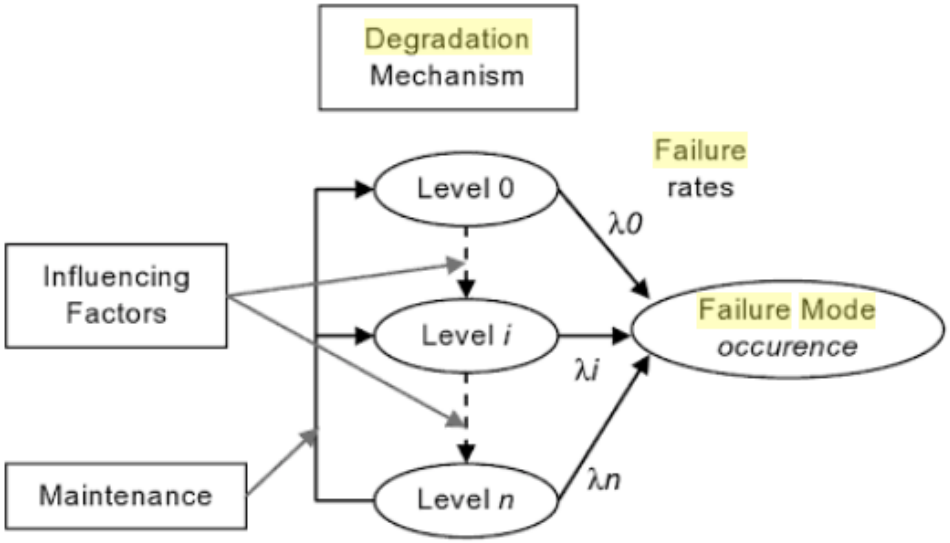
The Concept



Understanding relationships:

- **Degradation Mechanism**
- **Failure Modes**
- **Failure Symptoms**
- **Failure Rates**

The Concept



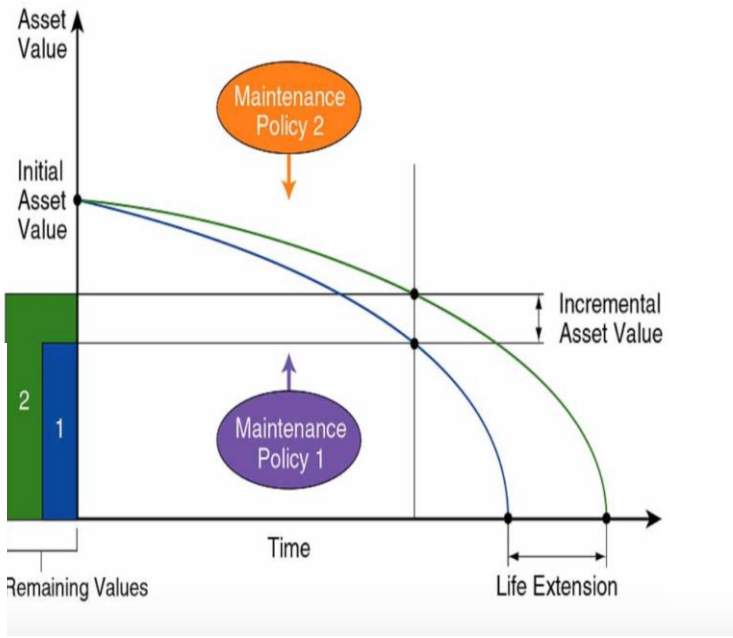


Figure 1. Two life curves for the same equipment under two different maintenance scenarios (Operating conditions are assumed to be the same)

The Concept

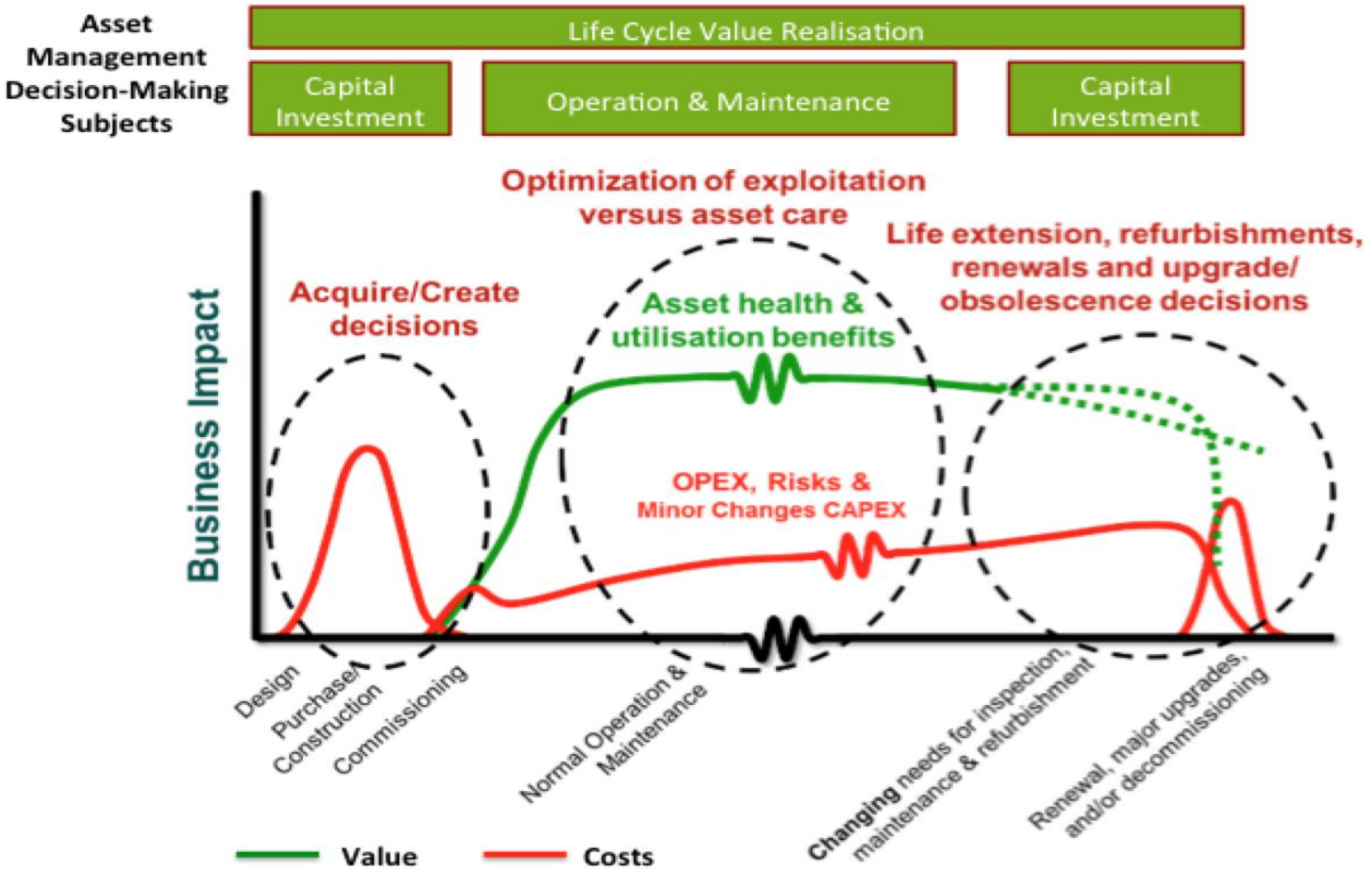


Figure Explaining Asset Value and Cost through Life cycle

The Concept

In the Spanish gas network the Network Asset Indices comprise two components:

i. Criticality Index - which relates to Consequences of Failure (risk); and
ii. Health Index - which relates to Asset Health and Probability of Failure;

		Water Bath Heaters	Boiler packages
HI1	New or as new	WBHs under 10 years old	Boiler packages under five years old
HI2	Good or serviceable condition	WBHs 10 to 20 years old.	Boiler package/heat exchangers, five to ten years old
HI3	Deterioration, requires assessment or monitoring	WBHs 20 to 30 years old	Boiler package/heat exchangers, 10 to 15 years old.
HI4	Material deterioration, intervention requires consideration	WBHs over 30 years old	Boiler package/heat exchangers, between 15 to 20 years old
HI5	End of serviceable life, intervention required	WBHs with over fifty faults in last 5 years.	Boilers packages over 20 years old

Criticality

Asset Health Indicator	1	2	3	4
1	1	2	3	4
2	2	4	6	8
3	3	6	9	12
4	4	8	12	16

Figure 11 Combining AHI and Criticality

The Concept

Common practice for maintenance and assets management excellence

The Concept

Proper control reinvestments in assets with high capitalization is now feasible.

Frecuencia Muy Alta	0 VER	0 VER	107 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	2	107
Frecuencia Alta	10 VER	8 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	0 VER	1,6	18
Frecuencia Media	47 VER	0 VER	7 VER	0 VER	89 VER	0 VER	21 VER	5 VER	0 VER	0 VER	5 VER	1,2	174
Frecuencia Baja	3965 VER	583 VER	588 VER	135 VER	172 VER	37 VER	63 VER	49 VER	3 VER	7 VER	61 VER	1	5663
Consecuencias	0	10	20	30	40	50	60	70	80	90	100		5962
#	4022	591	702	135	261	37	84	54	3	7	66	5962	

Criticality

Asset Health Indicator

	1	2	3	4
1	1	2	3	4
2	2	4	6	8
3	3	6	9	12
4	4	8	12	16

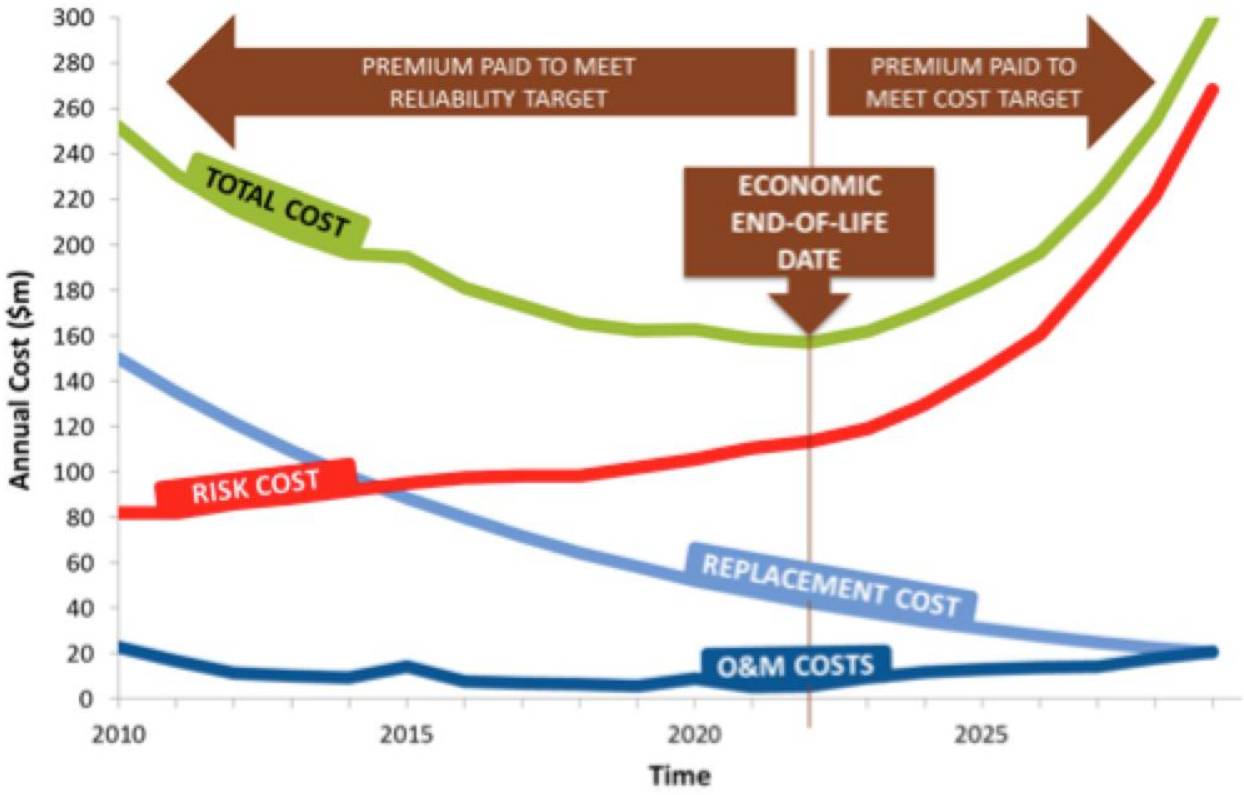
Combining AHI and Criticality

+

Asset's depreciation

Assets Reinvestments Decision Making

The Concept

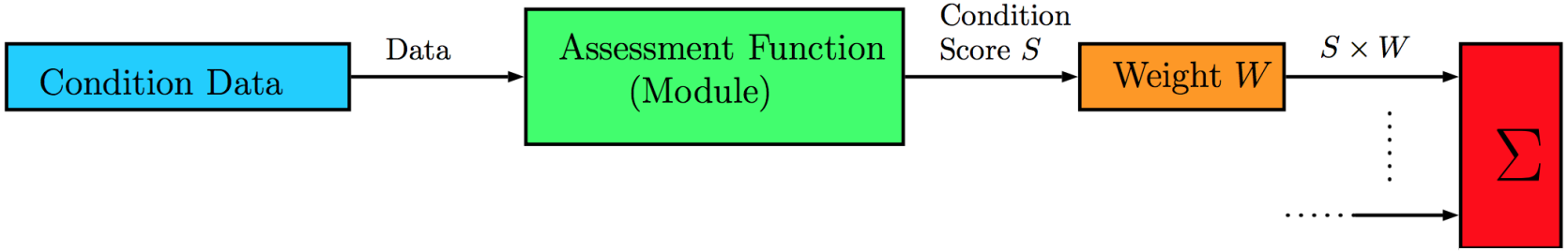


Determining the Economic End of Life as the Optimum date to retire an asset

AHI Model Requirements

1. It applies to assets of high capitalization of all the infrastructure.
2. Should offer support to strategic decisions on reinvestment, maintenance and extension of cycle of life, etc., of such assets.
3. Coherent and integrated methods like criticality analysis or LCCA.
4. Should put into value information today in business IT systems.
5. Should be innovative, and based on international best practices.
6. For easy implementation in business day-to-day operations.
7. Should summarize the health of the assets in standardized form
8. Should help to investigate those factors impacting on network assets degradation.

Relevant Models



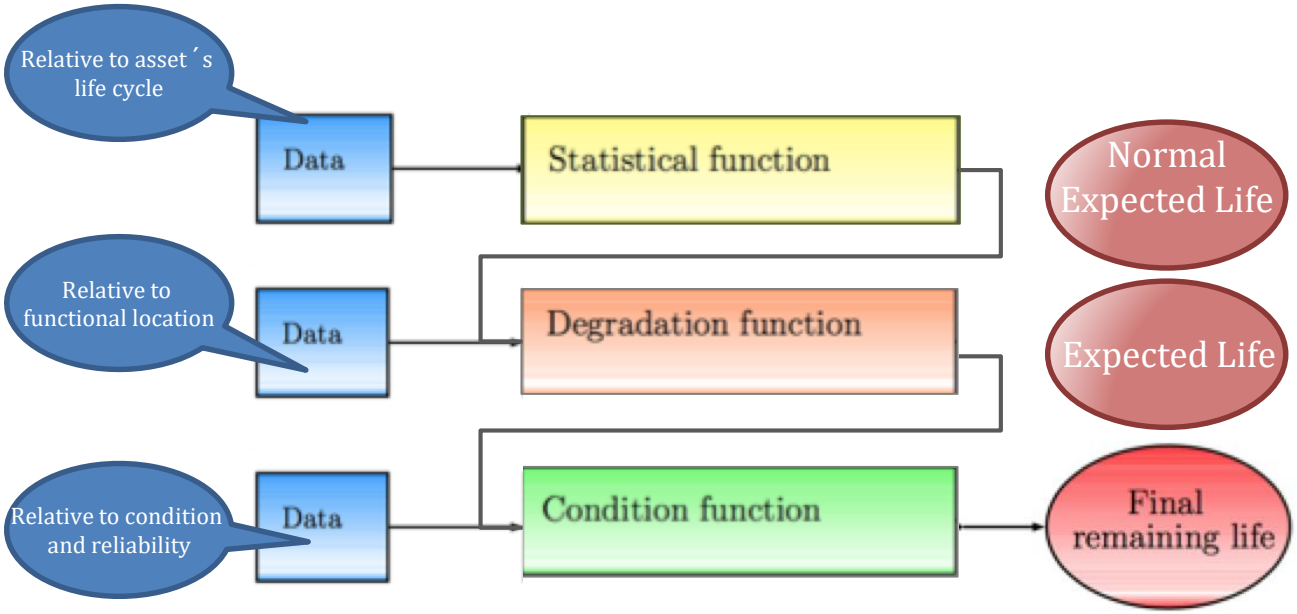
In the simplest case a generic AHI model contains:

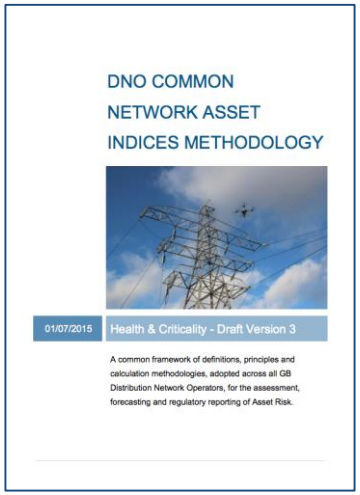
- **Details of the condition of the asset (Data).**
- **Data is processed with a function resulting scores.**
- **These scores are weighted relatively together, and**
- **They are summarized to calculate the AHI.**

Relevant Models

Model 5: UK DNO COMMON NETWORK ASSET INDICES METHODOLOGY

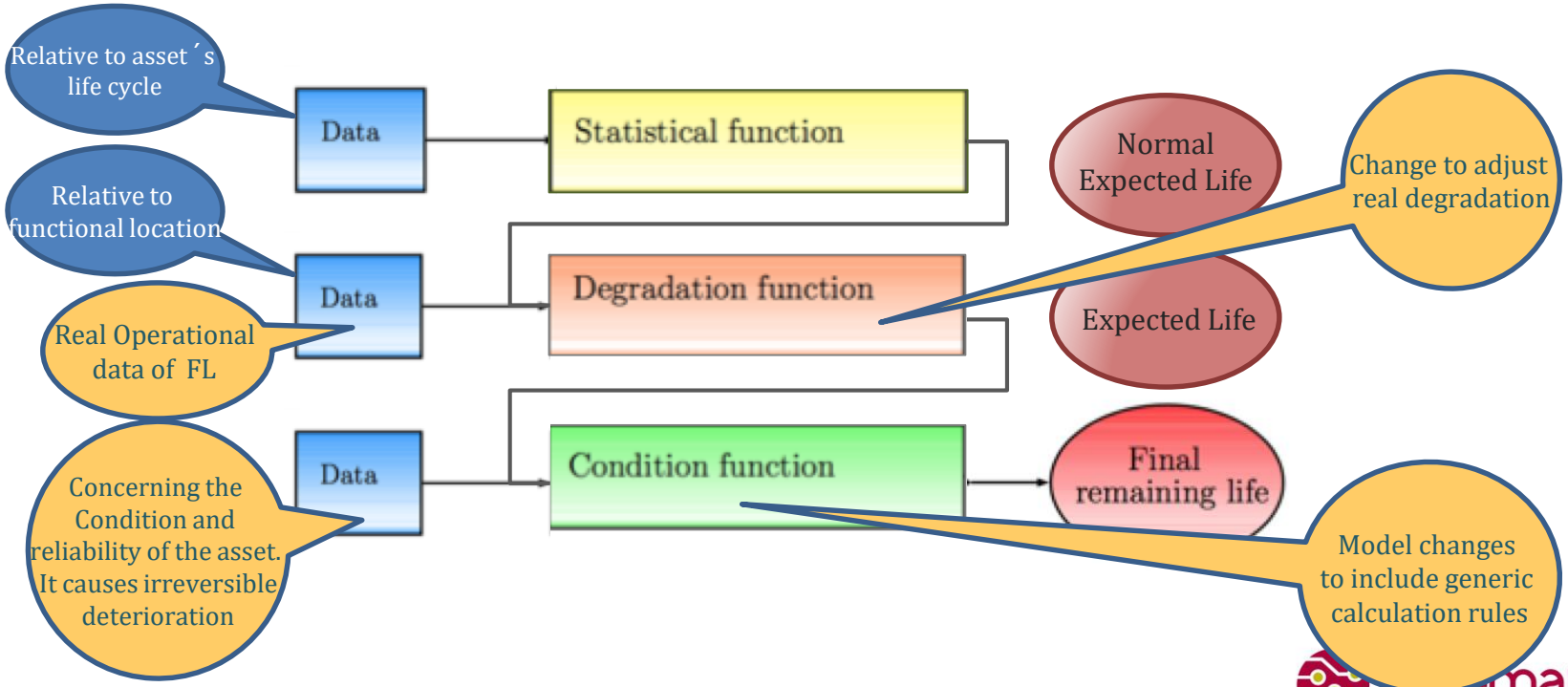
- A framework of common reference,
- Principles and calculation methodology adopted by all British network operators for the assessment, prediction and report regulatory risk of assets.
- In compliance with the requirements of the standard condition 51 (SLC 51) of the electricity distribution license for RIIO-ED1 (1 April 2015 to 31 March 2023).



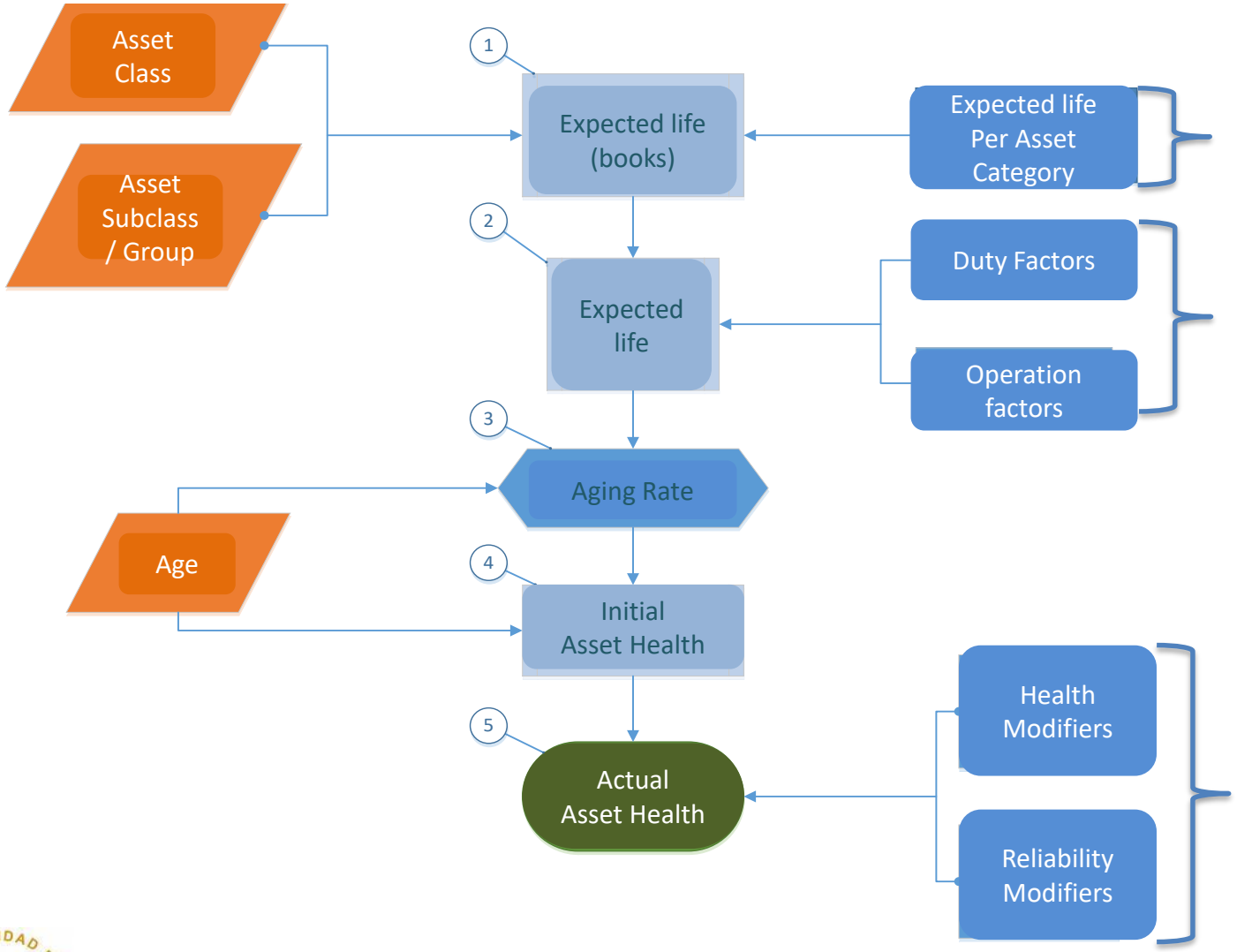


Spanish Network AHI Model

- Departs from model of the UK DNO
- Reorders the introduction of data in degradation and condition models
- Considers the impact of changes in Functional Locations duty
- Changes in the condition of the equipment only accelerate its deterioration
- Distinction is made between indications or evidence on the health of the assets is changing calculation algorithms



Spanish Network AHI Model



Established by the business

Associated to the technical location where the asset is placed

Associates to specific circumstances of the physical asset, its operation and maintenance

Implementation

- Generating awareness

Higher deterioration than expected

Lower deterioration than expected

Adolfo Crespo: Normalmente entre 0,9 y 1,4

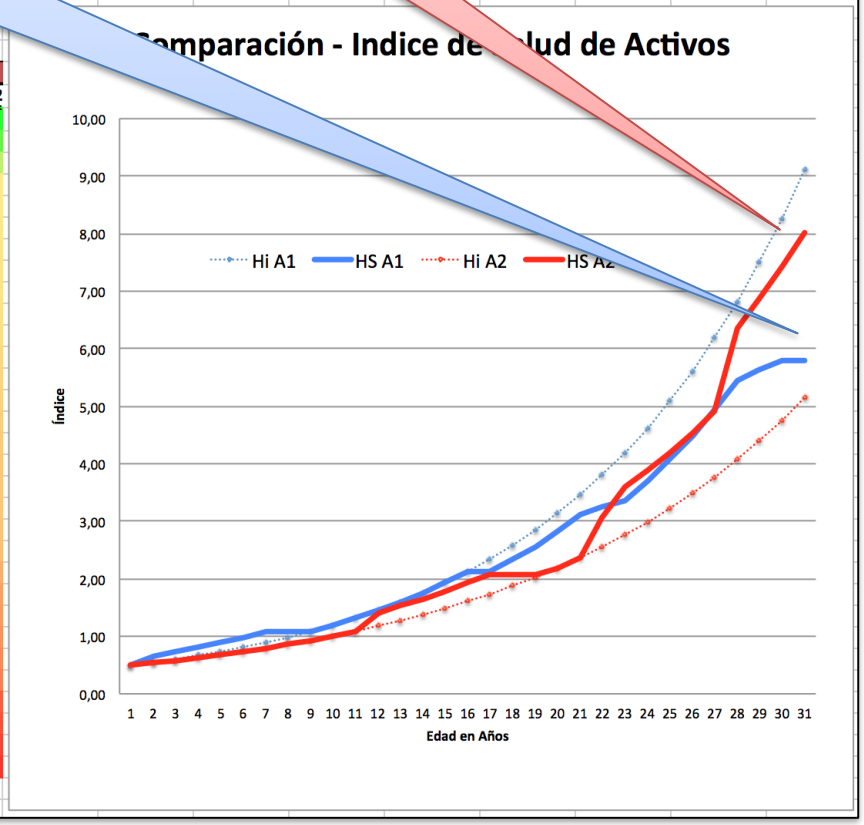
Adolfo Crespo: Normalmente entre 0,6 y 1,5

Hipótesis del Modelo	
0,5	= Índice de salud inicial (Ho)
5,5	= Índice de salud al final de la vida prevista (He)=
Datos del Negocio	
30	= Vida normal prevista
Datos de la Ubicación Técnica	
1,1	= Factor carga
1,1	= Factor Localización
Cálculos del Modelo	
24,79	= Vida estimada por el modelo
0,10	= Tasa de Envejecimiento(β)

Adolfo Crespo: Normalmente entre 0,7 y 1,4

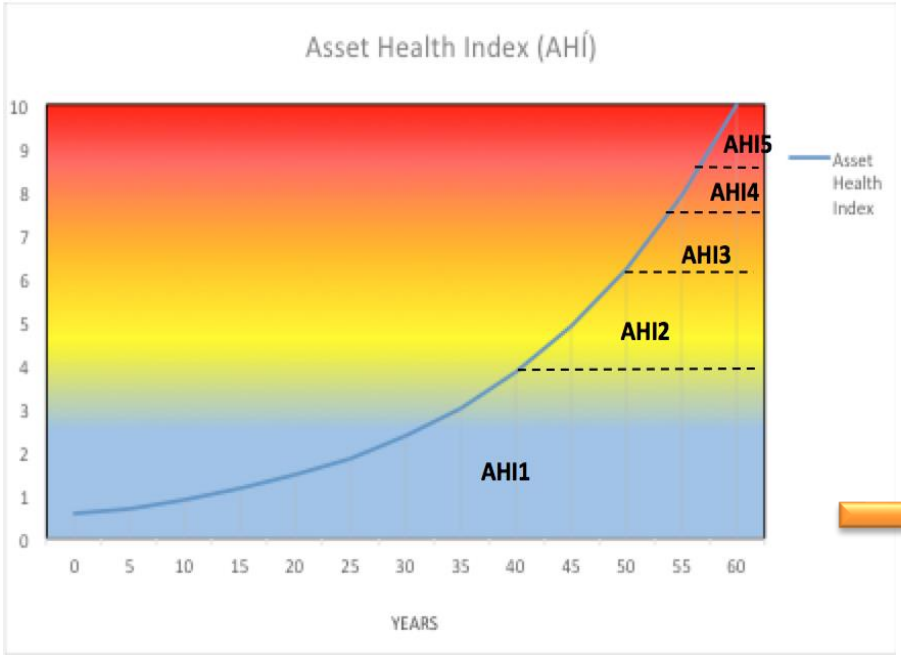
Adolfo Crespo: Normalmente entre 0,7 y 2

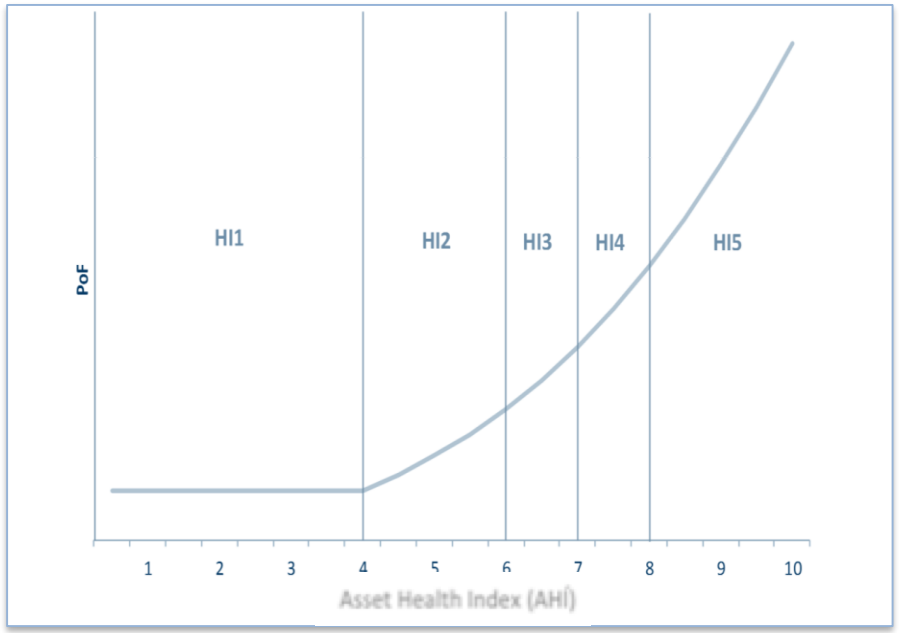
	Modelado Activo 1					Modelado Activo 2					
t	Hi A1	FUT	MS	MF	HS A1	t	Hi A2	FUT	MS	MF	HS A2
0	0,50		1	1	0,50	0	0,50		1	1	0,50
1	0,55		1,2	1	0,66	1	0,54		1	1	0,54
2	0,61		1,2	1	0,73	2	0,58		1	1	0,58
3	0,67		1,2	1	0,80	3	0,63		1	1	0,63
4	0,74		1,2	1	0,88	4	0,68		1	1	0,68
5	0,81		1,2	1	0,97	5	0,74		1	1	0,74
6	0,89		1,2	1	1,07	6	0,80		1	1	0,80
7	0,98		1	1	1,07	7	0,86		1	1	0,86
8	1,08		1	1	1,08	8	0,93		1	1	0,93
9	1,19		1	1	1,19	9	1,01		1	1	1,01
10	1,32		1	1	1,32	10	1,09		1	1	1,09
11	1,45		1	1	1,45	11	1,18		1,2	1	1,41
12	1,60		1	1	1,60	12	1,27		1,2	1	1,52
13	1,76		1	1	1,76	13	1,37		1,2	1	1,65
14	1,94		1	1	1,94	14	1,48		1,2	1	1,78
15	2,13		1	1	2,13	15	1,60		1,2	1	1,92
16	2,35		1	0,9	2,13	16	1,73		1,2	1	2,08
17	2,59		1	0,9	2,33	17	1,87		1	1	2,08
18	2,85		1	0,9	2,57	18	2,02		1	1	2,08
19	3,14		1	0,9	2,83	19	2,19		1	1	2,19
20	3,46		1	0,9	3,11	20	2,36		1	1	2,36
21	3,81		1	0,9	3,24	21	2,56		1	1,2	3,07
22	4,20		1	0,8	3,36	22	2,76		1	1,3	3,59
23	4,62		1	0,8	3,70	23	2,99		1	1,3	3,88
24	5,09		1	0,8	4,08	24	3,23		1	1,3	4,19
25	5,61		1	0,8	4,49	25	3,49		1	1,3	4,53
26	6,18		1	0,8	4,94	26	3,77		1	1,3	4,90
27	6,81		1	0,8	5,45	27	4,07		1,2	1,3	6,35
28	7,50		1	0,8	5,62	28	4,40		1,2	1,3	6,87
29	8,26		1	0,7	5,78	29	4,76		1,2	1,3	7,42
30	9,10		0,9	0,7	5,78	30	5,14		1,2	1,3	8,02



Spanish Network AHI Model

- Relationship between the asset's health (AHI or HI) and the Probability of Failure (PoF).





Implementation

LNG Plant Primary Pumps Case Study

Selected Assets in LNG Plant in Huelva:

- Pumps GA 101 A y GA 101 B in Tank FB-101
- Pumps GA 231 A y GA 231 B in Tank FB-121

MTB Major Maintenance = **15.930 hrs.**

Different duty factors since they have functional locations in different tanks and they are different pump models.

Description of the Asset Functional Location			Asset individual features				Load Factor	Location factor
Location	Instalation	TAG	Manufacturer	Model	Expected Load	Nominal Load	Expected/Nominal	Inmersion in LNG Tank
Huelva Plant	FB-101	GA-101 A	EBARA CRYODINAMICS	4ECR-123	64	97	0,66	1
Huelva Plant	FB-101	GA-101 B	EBARA CRYODINAMICS	4ECR-123	64	97	0,66	1
Huelva Plant	FB-121	GA-231 A	EBARA CRYODINAMICS	8ECR-152	253	300	0,84	1
Huelva Plant	FB-121	GA-231 B	EBARA CRYODINAMICS	8ECR-152	253	300	0,84	1

Implementation

Pumps data compilation & input to the model

1. Manufacturer specifications:
   - Recommended pump flow ranges for expected operation y selected location
   - Recommended operation temperature.

2. Warning and Alarm levels in the plant control system :
   - For operation temperature ranges.
   - Warning and shutdown levels in LNG Tanks.

3. Data coming from the business “health matrix” information:
   - Equipment operating time.
   - Operating time since last major maintenance.
   - Nº of pump Start-Ups.

4. Equipment Hr-meter:
   - Nº of major maintenance.

5. PI extracted data:
   - Evolution of Variables: flow, impulsion temperature, tank level, power & hrs.

Implementation

Sample data: Primary LNG Tank Pumps

1	FECHA DE INICIO	01/01/2015 0:00																	
2	FECHA DE FIN	01/12/2016 0:00																	
3	INTERVALO (m)	1 d																	
4	Nº TAG UTILIZADOS	8																	
5	TAG 1	HUE-FIC-1110_PV	Caudal																
6	TAG 2	HUE-PI-1023	Presión																
7	TAG 3	HUE-II-1001A	Intensidad																
8	TAG 4	HUE-JI-1001A	Potencia																
9	TAG 5	HUE-TI-1017-C	Tª Tanque																
10	TAG 6	HUE-TI-1021	Tª salida de GNL																
11	TAG 7	HUE-REN-GA101A	Rendimiento																
12	TAG 8	HUE-LI-1008	Nivel tanque																
13	Hrs,	Flow,	Pressure	Amps	Power	Temp in	Temp out	Perf,	Tank level	Avail	ΔTemp								
15	FECHA-HORA	CAUDAL	PRESION	INTENSIDAD	POTENCIA	Tª ASPIRACION	Tª IMPULSION	Rendimiento	Nivel tanque	En operacionamiento de tempe	Carga real								
16		Load																	
17	01/01/2015	5,35	0,24	0,56	0,41	-158,71	-157,30	0,00	17.369,30	No	1,41	0							
18	02/01/2015	4,80	0,25	0,58	0,42	-158,46	-156,70	0,00	19.543,26	No	1,76	0							
19	03/01/2015	2,68	0,26	0,58	0,44	-158,40	-123,50	0,00	21.673,64	No	34,90	0							
20	04/01/2015	2,97	0,26	0,58	0,41	-158,40	-122,50	0,00	21.818,52	No	35,90	0							
21	05/01/2015	2,97	0,25	0,61	0,43	-158,54	-120,70	0,00	21.899,93	No	37,84	0							
22	06/01/2015	2,66	0,26	0,61	0,42	-158,60	-121,60	0,00	21.423,63	No	37,00	0							
23	07/01/2015	2,75	0,26	0,60	0,43	-158,70	-105,00	0,00	21.485,50	No	53,70	0							
24	08/01/2015	2,66	0,25	0,58	0,42	-158,75	-136,70	0,00	20.615,44	No	22,05	0							
25	09/01/2015	3,25	0,23	0,58	0,47	-158,70	-136,40	0,00	19.630,38	No	22,30	0							
26	10/01/2015	2,75	0,23	0,61	0,45	-158,83	-128,50	0,00	22.102,59	No	30,33	0							
27	11/01/2015	2,74	0,24	0,63	0,47	-158,97	-129,00	0,00	25.166,94	No	29,97	0							
28	12/01/2015	2,72	0,24	0,63	0,45	-158,98	-105,90	0,00	24.881,12	No	53,08	0							

GA-101 - A

Trimestre 1			Trimestre 2	
01/01/2015 0:00	31/03/2015 0:00	126,28	01/04/2015 0:00	30/06/2015 0:00

Trimestre 1			Trimestre 2	
01/01/2016 0:00	31/03/2016 0:00	256,90	01/04/2016 0:00	30/06/2016 0:00

0,659793814

Implementation

Sample data: Primary LNG Tank **Pumps operating flow** over lifetime

Data pre-processing for model imput:

Estimating % Time within pump flow optimal range (over & under)

		Pumps	Porcentaje de tiempo de operación en el rango { "Tiempo en funcionamiento en rango/tiempo total de operación"}											
		Bomba	GA-101-A			GA-101-B			GA-101-C			GA-101-D		
		Flow Caudal (M3/h)	Dentro del rango óptimo	Por encima del rango óptimo	Por debajo del rango óptimo	Dentro del rango óptimo	Por encima del rango óptimo	Por debajo del rango óptimo	Dentro del rango óptimo	Por encima del rango óptimo	Por debajo del rango óptimo	Dentro del rango óptimo	Por encima del rango óptimo	Por de ó
			116 a 135	mayor que 135	inferior que 116	116 a 135	mayor que 135	inferior que 116	116 a 135	mayor que 135	inferior que 116			
Periodos	2015	T1	0,4	0	0,6	0	0	1						
		T2	0,57142857	0	0,42857143	0	0	1						
		T3	0,5	0	0,5	0,05882353	0	0,94117647						
		T4	0,11111111	0	0,88888889	0,02564103	0	0,97435897	0	0	1			
	2016	T1	0,2	0	0,8	0,04347826	0	0,95652174	0,66666667	0	0,33333333			
		T2	0,06666667	0	0,93333333	0,08333333	0	0,91666667	1	0	0			
		T3	0,11764706	0	0,88235294	0,11363636	0	0,88636364	0,25	0,125	0,625			
		T4	0	0	1	0,14285714	0	0,85714286	0,33333333	0	0,66666667			

40% of the time within the optimal range during this period (1st Q 2015)

60% of the time below the optimal range during this period (1st Q 2015)

Implementation

Sample data: Primary LNG Tank Pumps

Full data prepared for model input:

Estimating impact/weight intervals of each health modifier over time

I		Health Modifiers					Reliability Modifiers		
Periods:(Year/Quarter)		FLOW [1-1,4]	INTAKE TEMPERATURE [1-1,4]	INCREMENT in TEMPERATURE [1-1,5]	TANK LEVEL [1-1,2]	Nº START-UPS [1-1,5]	NO ACTIVITY [1-1,1]	MANUFACTURER [0,95-1,05]	MAJOR MAINTENANCES [1-1,1]
2015	T1	1,24	1,00	1,00	1,00	1,10	1,10	0,95	1,10
	T2	1,17	1,00	1,00	1,00	1,10	1,10	0,95	1,10
	T3	1,20	1,00	1,00	1,00	1,10	1,10	0,95	1,10
	T4	1,36	1,00	1,00	1,00	1,10	1,10	0,95	1,10
2016	T1	1,32	1,00	1,00	1,00	1,10	1,10	0,95	1,10
	T2	1,37	1,00	1,00	1,00	1,10	1,10	0,95	1,10
	T3	1,35	1,00	1,00	1,00	1,10	1,10	0,95	1,10
	T4	1,40	1,00	1,00	1,00	1,10	1,10	0,95	1,10

Flow without optimal limits may have a weight of [1-1.4] as impact on asset degradation over time

Low tank level may have a weight of [1-1.2] as impact on asset degradation over time. Half the impact of wrong flow.

Number of major maintenances has a weight of [1-1.1] as impact on asset degradation over time. 25% the impact of wrong flow.

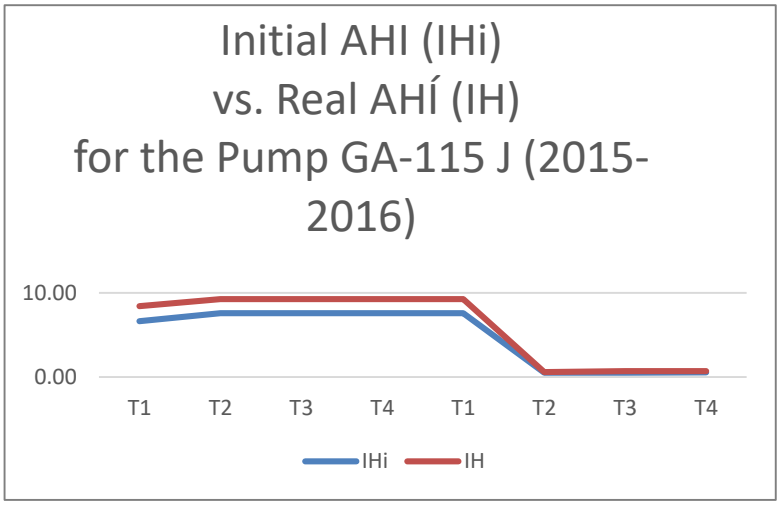
Implementation

Identificación

Activo (Tag):	GA 115 J
Ubicación:	Planta Huelva Línea 72 bar
Modelo y fabricante:	60788R, ARGO-TECH/J.C.CARTER
Factor de carga:	0,81
Factor de emplazamiento:	1
Vida normal esperada:	19,400

Histórico

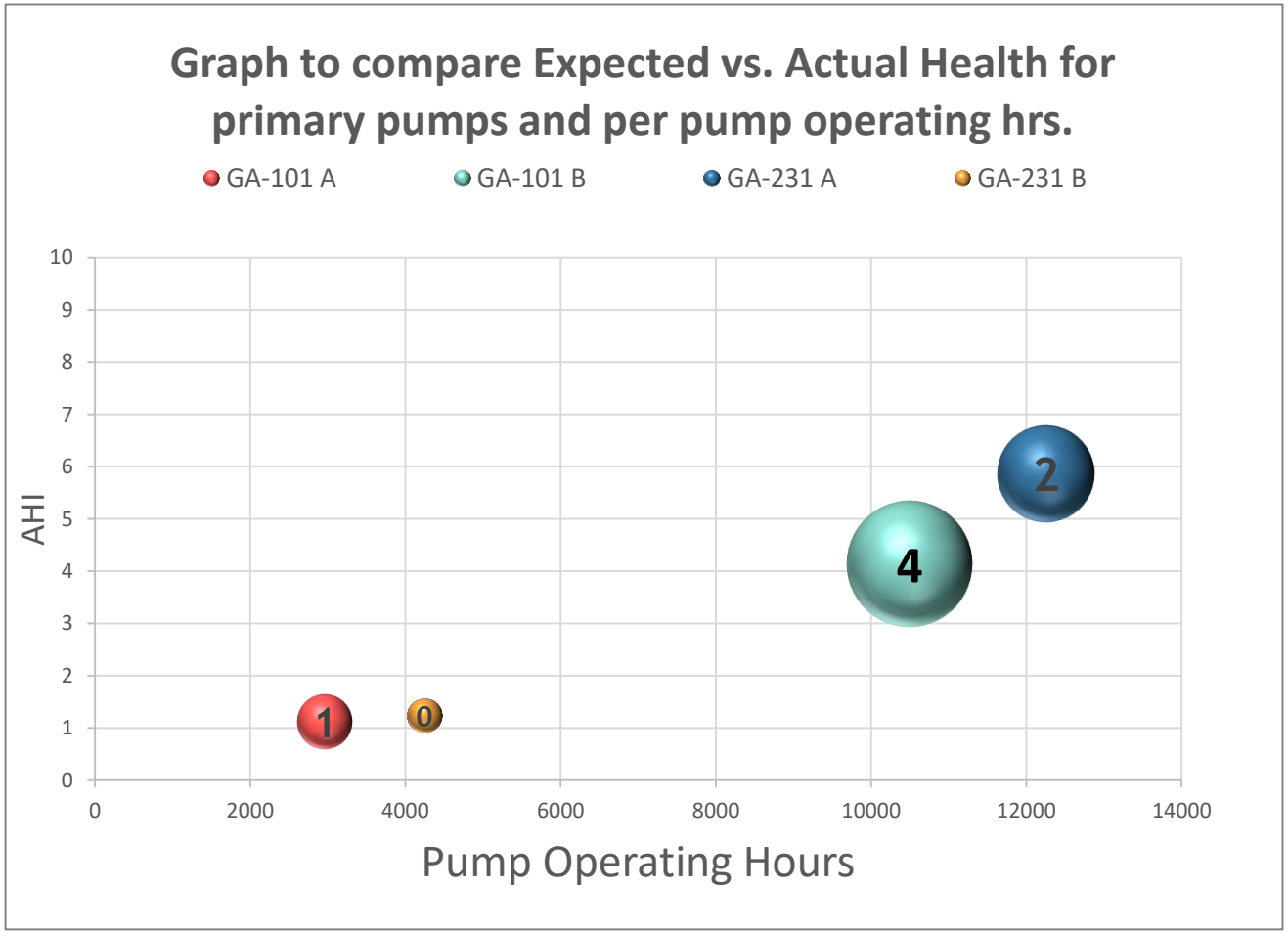
Horas totales de operación:	29.518
Horas de operación desde último gran mtto.:	740
Nº grandes mttos.:	1

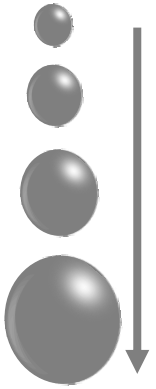


Periods: (Year/Quarter)		Health Modifiers					Reliability Modifiers			Data Retrieved for the AHÍ Assessment										
		FLOW [1-1,4]	INTAKE TEMPERATURE [1-1,4]	INCREMENT in TEMPERATURE [1-1,5]	TANK LEVEL [1-1,2]	Nº START-UPS [1-1,5]	NO ACTIVITY [1-1,1]	MANUFACTURER [0,95-1,05]	MAJOR MAINTENANCES [1-1,1]	Estimated Life	Real Load	Real vs Expected Load	Estimated Life	Toperating time	Tiime since last maintenance	AIHIi	Ihi_Real	Health Modifier	Reliability Modifier	AHI
2015	T1	1,12	1,00	1,00	1,00	1,3	1,00	0,95	1,00	24.062	0,83	1,03	23.355	2129,0	25.931	**6,63**	**7,16**	1,24	1,00	**8,86**
	T2	1,06	1,00	1,00	1,00	1,3	1,00	0,95	1,00	24.062	0,84	1,04	23.193	1365,5	27.296	**7,59**	**8,41**	1,16	1,00	**9,77**
	T3	1,00	1,00	1,00	1,00	1,3	1,10	0,95	1,00	24.062	0,81	1,00	24.062	0,02	27.296	**7,59**	**7,59**	1,10	1,10	**9,77**
	T4	1,00	1,00	1,00	1,00	1,3	1,10	0,95	1,00	24.062	0,81	1,00	24.062	0,00	27.296	**7,59**	**7,59**	1,10	1,10	**9,77**
2016	T1	1,00	1,00	1,00	1,00	1,3	1,10	0,95	1,00	24.062	0,81	1,00	24.062	0,11	27.296	**7,59**	**7,59**	1,10	1,10	**9,77**
	T2	1,00	1,00	1,00	1,00	1,10	1,10	0,95	1,00	24.062	0,81	1,00	24.062	0,37	0	**0,50**	**0,50**	1,10	1,10	**0,61**
	T3	1,24	1,00	1,00	1,00	1,10	1,10	0,95	1,00	24.062	0,81	1,01	23.921	119,32	119	**0,51**	**0,51**	1,36	1,10	**0,76**
	T4	1,03	1,00	1,00	1,00	1,10	1,05	0,95	1,00	24.062	0,83	1,02	23.508	621,07	740	**0,54**	**0,54**	1,13	1,05	**0,76**

Implementation

- Comparisson per same equipment category



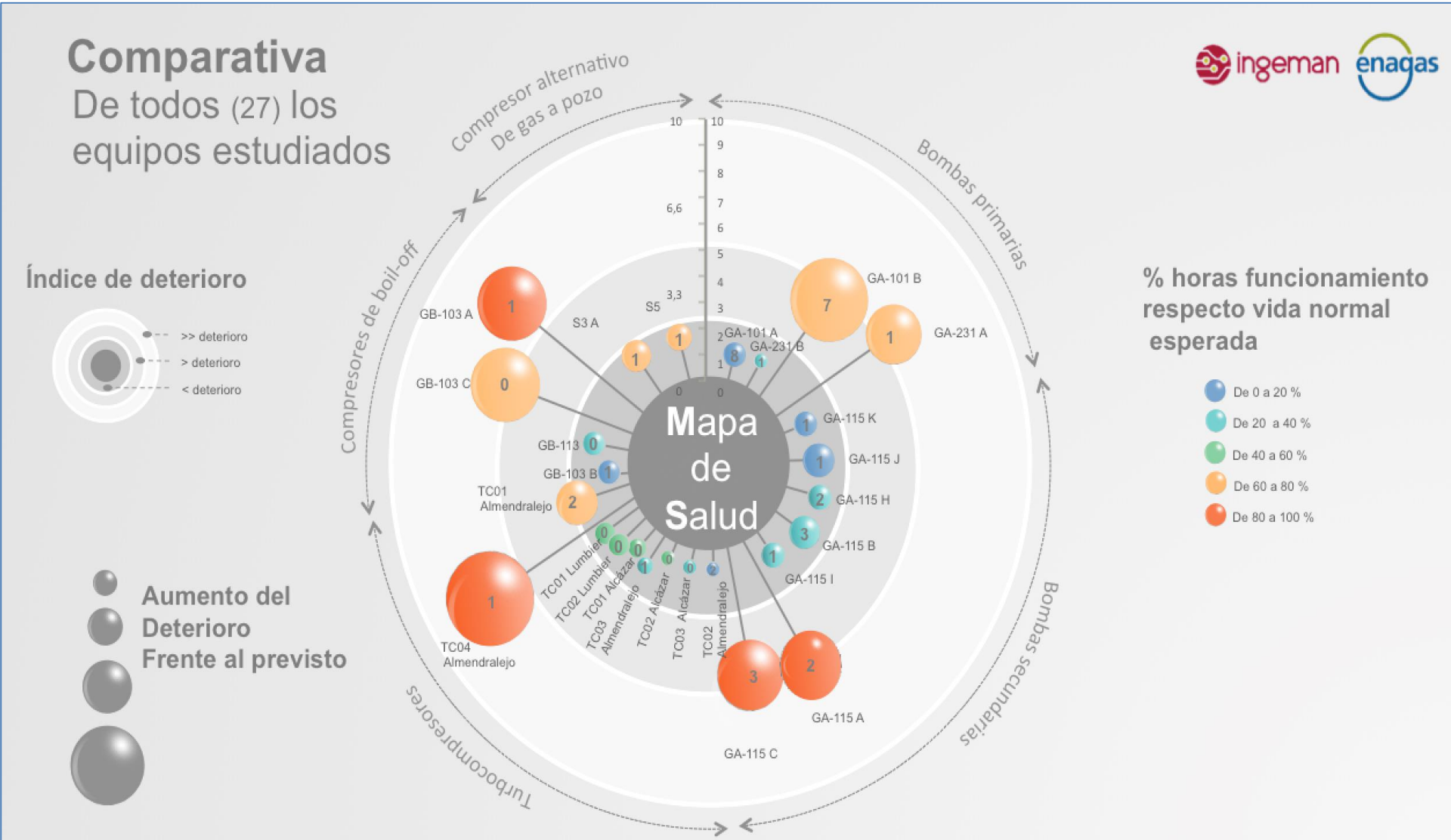


Extra degradation

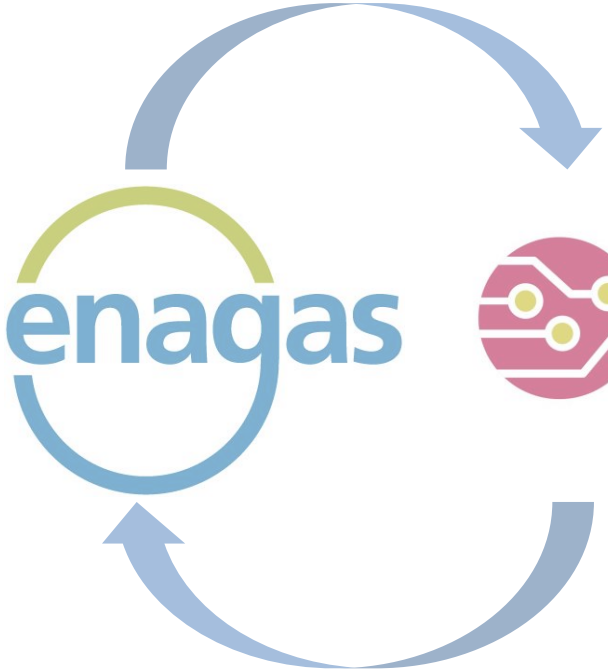
Number of Major maintenances

Implementation

- Global Comparison for all equipment



New book release in Arabic:



Thanks

Celebrating
a 6 years of Partnership
2012-2017 ✔