VALIDATION OF THE DNO COMMON NETWORK ASSET INDICES METHODOLOGY

1 Purpose of this document

A collective validation exercise has been undertaken using a representative sample of DNO data sets on wood poles and oil-filled cables.

This paper has been prepared to explore the following three core components of the Common Methodology:

1. **Health Index:** The key inputs into the derivation of the Health Score and its subsequent conversion to Health Indices;

2. **Criticality Index:** The key inputs into the derivation of the Consequence of Failure and the sensitivity for each Asset Category to the four Consequence Categories; Financial, Safety, Environmental and Network Performance; and

3. **Monetised Risk:** The derivation of Monetised Risk and how the Average Consequence of Failure is used to determine the Criticality Bands.

The prime purpose has been to validate against known risks in DNO risk assessments and additionally to test the Methodology with multi-DNO datasets to ensure that the prime aim of commonality is validated.

The specific Asset Categories have been chosen to show:

- The interaction between age and condition information;
- How the methodology accommodates materially different asset categories with five Condition Inputs (for poles) versus two condition inputs (for oil-filled cables);
- The impact of caps and collars to reflect critical pieces of condition information (cables with excessive oil leaks, poles with substantial levels of decay or physical damage);
- The increased relevance of the safety factor for LV poles which inherently carry more Safety risk since they are normally located within populated areas and in many cases within customers' gardens;
- The sensitivity of Network Performance to the number of connected customers for HV Poles; and
- The importance of the Environmental Consequence (proximity to water courses) Factor for oil-filled cables.

For both asset types, the DNOs providing the data have associated existing risk assessments and HI profiles which serve as comparators. Due to the historic lack of commonality however, these have not been used for calibration as primacy has been given to the aim of ensuring commonality against the Methodology.

2 Oil-filled cables

2.1 Overview of the risk

The key failure mode relating to oil-filled cables is the failure of the pressurising system – this could be the cable sheath, cable plumbs, oil tanks and/or the associated pipework. The result of this failure mode is the escape of the oil into the surrounding environment.

Oil pressure in oil-filled cable systems is routinely monitored to assess when a cable pump-up is required such that appropriate arrangements can be made to do so.

The source of the leak can be determined when the leak rate is at a sufficient level, after which the cable can be taken out of service and repaired or replaced. Until that time, oil must continue to be pumped into the cable to maintain a positive pressure within the cable and prevent the ingress of moisture.

Once the loss of oil is remedied, the cable is adequate for continued use in service. However, the lost oil will have leaked from the cable system into the surrounding ground with potentially detrimental environmental consequences.

Historically the oil was a mineral oil derived from crude oil. Modern fluids are synthetic products developed to have improved electrical insulation characteristics. In either case, their escape can lead to contamination of the surrounding environment which can have a detrimental effect particularly on vegetation and wildlife.

2.2 Outputs from the Validation Exercise (132kV oil cable)

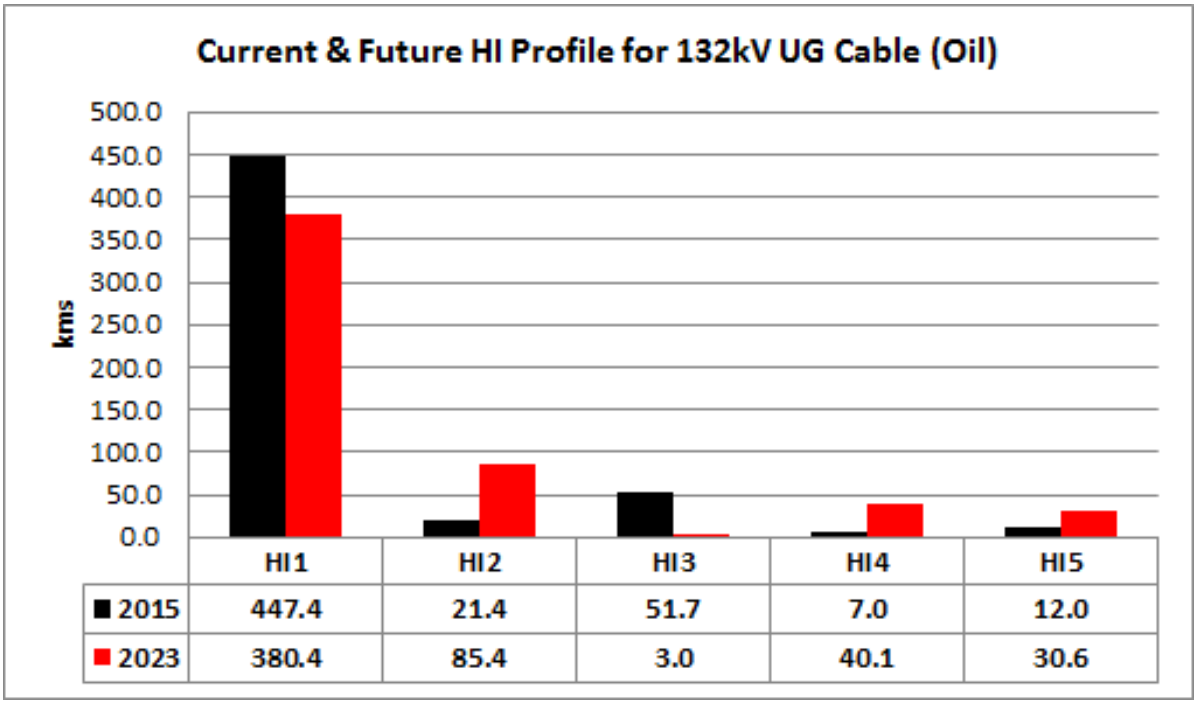
Data has been collected for a representative sample of 132kV fluid filled cables (132kV UG Cable (Oil)) across GB DNOs, amounting to 539.4km.

2.2.1 Health Index

Key characteristics of the Common Methodology:

Normal Expected Life:	**Aluminium Sheath (Copper or Aluminium conductor):** - *75 years* **Lead sheath (Copper or Aluminium conductor):** - *85 years*
Measured Condition Factors:	**Partial Discharge:** - Factor *of 1.0 ("Low" levels of PD) to 1.5 ("High" levels of PD)* **Leakage:** - *Factor of 1.0 ("No (or very low) historic leakage recorded") to 2.0 (Very High)* - *Collars of 5.5 ("High" levels of leakage) and 8 ("Very High" levels of leakage)*
Observed Condition Factors:	**Not applicable**

The Health Index profile for the sample data is shown below:



As described earlier, the key failure mode relating to oil-filled cables is the failure of the pressurising system and this is the more sensitive of the two Measured Condition Inputs applicable to this Asset Category. The table below demonstrates the correlation between HI Band and the "leakage" Measured Condition Input for two scenarios; (a) for younger cables defined in this instance as <50 years old and (b) for older cables, defined in this instance as ≥50 years old:

Scenario (a) <50 years old: Length of Cable (km) by Health Index Band and Leakage Condition Factor

Leakage Factor	Length of cable (km) by HI Band					
	HI1	HI2	HI3	HI4	HI5	Total
No (or very low) historic leakage recorded	158.8					**158.8**
Low/ moderate	186.9					**186.9**
High			31.1			**31.1**
Very High					2.0	**2.0**
Total	**345.7**		**31.1**		**2.0**	**378.8**

For younger cables, the HI is limited to the HI1 band, unless there are "High" or "Very High" levels of leakage. At this point, the Health Score collars of 6 and 8 (which translate to HI bands of 3 and 5 respectively) become active.

Scenario (b) ≥50 years old: Length of Cable (km) by Health Index Band and Leakage Condition Factor

Leakage Factor	Length of cable (km) by HI Band					
	HI1	HI2	HI3	HI4	HI5	Total
No (or very low) historic leakage recorded	65.8	1.0	1.0			67.8
Low/ moderate	35.9	20.4	3.0	1.0		60.3
High			16.6	6.0	5.0	27.6
Very High					5.0	5.0
Total	**101.7**	**21.4**	**20.6**	**7.0**	**10.0**	**160.7**

The validation exercise has shown that:

1. The effect of the older ages on cables with “No” or “Low” levels of leakage is to drive the cable HI profile into the mid HI Bands; HI2 and HI3. Only where the age of the cable is at or in excess of its Normal Expected Life does the HI increase to HI4, for “Low” levels of Leakage (just 1km in this instance).

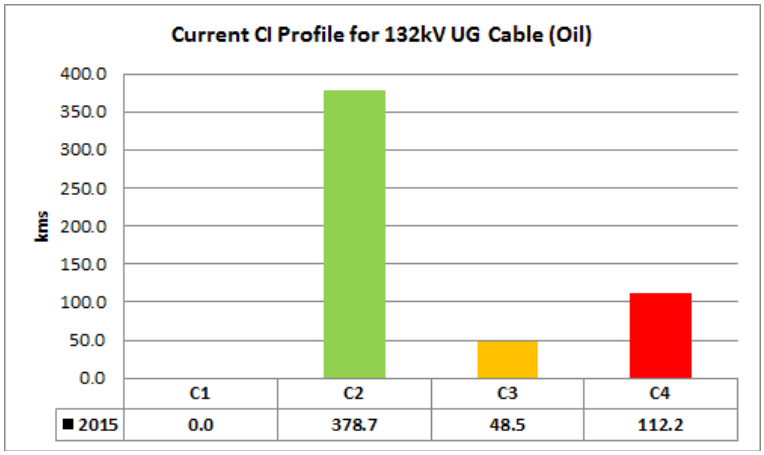
2. Cables with “High” or “Very High” levels of leakage fall into at least the HI3 Band. A much higher proportion of these older assets have “High” or “Very High” levels of leakage and would typically be considered for replacement in the short to medium term.

2.2.2 Criticality Index

Key characteristics of the Common Methodology:

	Consequence Factor				
	Financial	**Safety**	**Environmental**	**Network Performance**	**Total**
Reference Costs:	£129	£2	£6,167	£10	£6,308
Factors:	Not applicable	Location: Buried: 1.0 Exposed: 2.0	Proximity: <50m: 2.5 50-100m: 1.6 >100m: 1.0	Network Type: Secure: 1.0 Unsecure: 2.5 Scaling factor based on Demand	

The Criticality Index profile for the sample data is shown below:

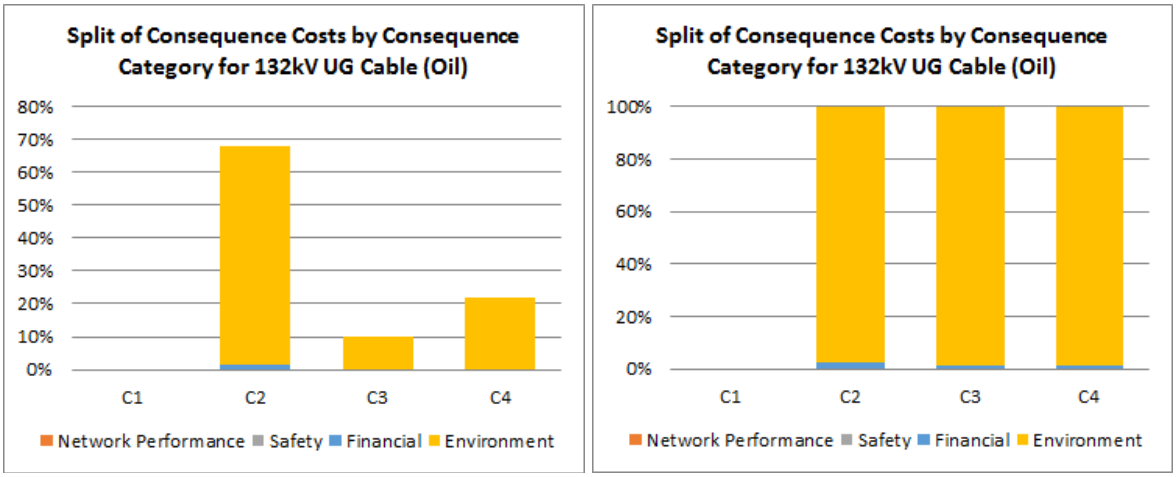


The validation exercise shows that:

1. The Overall Consequences of Failure for 132kV UG Cable (Oil) is driven almost entirely by the Environmental Consequence of Failure for the asset; and
2. Cables in close proximity to watercourses would fall into the higher Criticality Bands, C3 and C4.

By way of further comparison, the graph below describes the proportion of the total Monetised Risk for the Asset Category by Consequence Category:

1. By Criticality Band (on the left); and
2. As a proportion of all Monetised Risk within the Criticality Band.



As shown earlier, 98% of the Reference Cost of Failure for this Asset Category is associated with the Environmental Cost of Failure. It therefore follows that once the Consequence Factors are applied, the overall Consequence of Failure will be driven by the Environmental Factors and specifically the proximity of the cable to a watercourse. The table below demonstrates this relationship:

Factor Description	Factor Weighting	Length of cable (km) by Criticality Band			
		C1	C2	C3	C4
Not close to water course (>100m) or no oil	1.0		378.7		
Close to water course (between 50m and 100m)	1.5			48.5	
Very close to water course (<50m)	2.0				112.2
Total			**378.7**	**48.5**	**112.2**

2.2.3 Monetised Risk

Based upon the sample data within the data set, the Average Consequence of Failure is **£7,578** (compared with a Reference Cost of Failure of **£6,308**). This now defines the Criticality Index Bands:

Criticality Index Bands			
>= Minimum		< Maximum	
%	£	%	£
		75	5,683
75	5,683	125	9,472
125	9,472	200	15,155
200	15,155		

With reference to the PoF Curve Parameters detailed in Table 19 of the Methodology, risk can now be evaluated. For the sample data shown, the Risk Matrix is shown below:

CI / HI	Length of cable (km) by Health and Criticality Band					
	HI1	HI2	HI3	HI4	HI5	Total
C1						
C2	324.6	19.4	29.7	3.0	2.0	**378.7**
C3	27.1	1.0	12.4	1.0	7.0	**48.5**
C4	95.6	1.0	9.6	3.0	3.0	**112.2**
Total	**447.4**	**21.4**	**51.7**	**7.0**	**12.0**	**539.4**

CI / HI	Monetised Risk (£) by Health and Criticality Band					
	HI1	HI2	HI3	HI4	HI5	Total
C1						
C2	£2,646,772	£235,125	£638,432	£104,286	£163,075	**£3,787,690**
C3	£331,818	£18,210	£398,208	£52,143	£856,146	**£1,656,524**
C4	£1,949,443	£30,350	£514,126	£260,714	£611,533	**£3,366,166**
Total	**£4,928,033**	**£283,685**	**£1,550,766**	**£417,143**	**£1,630,753**	**£8,810,380**

For example, the HI5 / C3 band contains 1% of the assets in terms of volume (7.0 out of a total of 539.4km), but 10% of the risk (£856,146 out of a total of £8,810,380 Monetised Risk £).

By way of further comparison, taking a HI2 / C2 asset as the reference point, the relative risk for assets with a different HI and/or CI can now be determined as shown in the table below:

CI / HI	Monetised Risk Weighting Relative to a HI2 / C2 Asset				
	HI1	HI2	HI3	HI4	HI5
C1	0.50	0.75	1.33	2.15	5.04
C2	0.67	1.00	1.77	2.86	6.72
C3	1.01	1.50	2.65	4.30	10.07
C4	1.68	2.50	4.42	7.16	16.79

Proximity to watercourses

Age

Leakage history

This validation exercise has shown that the key outputs produced by the Common Methodology for this Asset Category are:

(a) Age alone will discriminate between:
    a. assets in HI1 (very young assets);
    b. assets in HI2 (assets close to their Normal Expected Life)
    c. Assets at the very bottom of the HI3 band (at or beyond their Normal Expected Life);
(b) Leakage History will drive the HI of the Asset further into the HI3 band for moderately leaking cables or into the higher HI4/HI5 Bands for excessively leaking cables; and
(c) Further discrimination with respect to Criticality is provided based on the proximity of a cable to a watercourse.

3 Wood Poles

3.1 Overview of the risk

Wood poles are manufactured and then treated with a preservative. With time, this treatment gradually loses its protective properties and the pole begins to decay, although not necessarily at a uniform rate. The onset of decay and the rate of deterioration vary depending on external factors, such as the quality of the original treatment and the type of ground in which the poles are situated.

3.2 Outputs from the Validation Exercise (HV Poles)

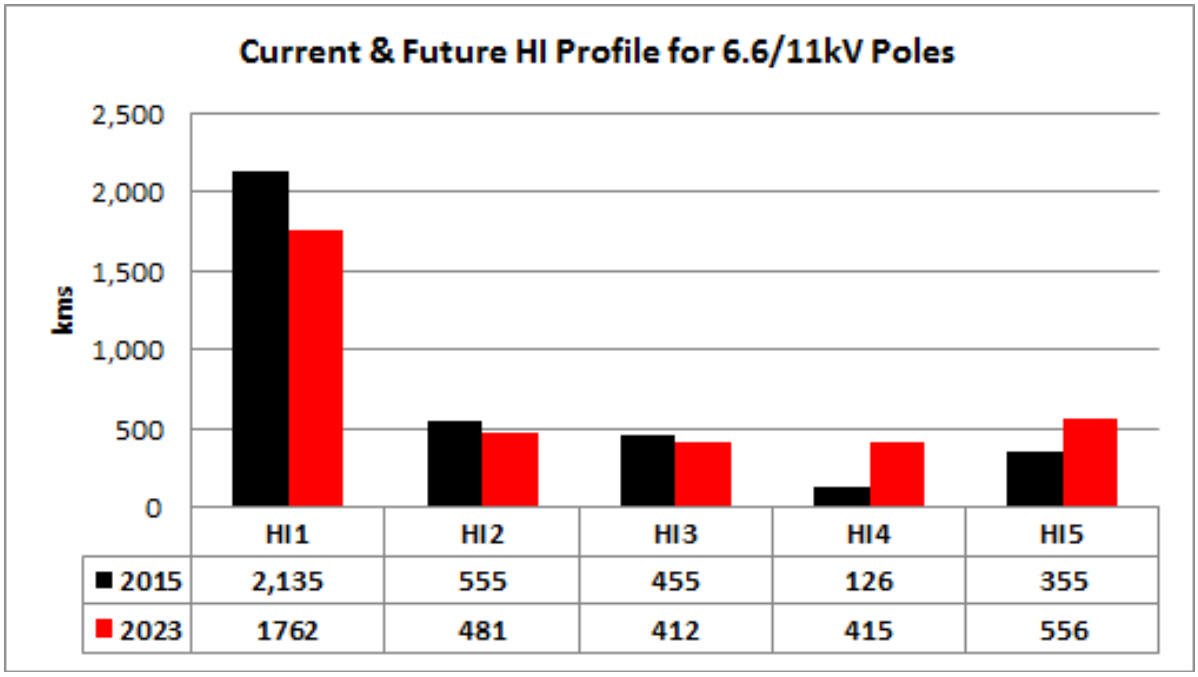
Data has been collected for a representative sample of HV Poles across GB DNOs, amounting to 3,626 poles.

3.2.1 Health Index

Key characteristics of the Common Methodology:

Normal Expected Life:	**Wood:** - *55 years* **Concrete:** - *60 years* **Steel:** - *50 years* **Other (e.g. fibreglass):** - *80 years*
Observed Condition Factors:	**Visual Pole Condition** - *Factor of 0.8 ("As New") to 1.8 ("Substantial Deterioration")* - *Collar of 8 ("Substantial Deterioration")* **Pole Top Rot** - *Factor of 1.0 ("No") to 1.3 ("Yes")* **Pole Leaning** - *Factor of 1.0 ("No") to 1.2 ("Yes")* **Bird / Animal damage** - *Factor of 1.0 ("No") to 1.3 ("Yes")*
Measured Condition Factors:	**Pole Decay / Deterioration** - *Factor of 0.8 ("None") to 1.8 ("Very High")* - *Collars of 5.5 ("High") and 8 ("Very High")* - *Caps of 5.4 ("None") and 6.4 ("No significant decay/ deterioration")*

The Health Index profile for the sample data is shown below:



The key failure modes relating to poles are the failure of the pole due to decay and/or physical damage. This may be assessed visually (i.e. observed) or via a quantitative method to determine residual strength (i.e. measured). These Factors, given their strong correlation to residual strength and therefore probability of failure, have a relatively strong impact on HI when compared with other Asset Categories:

Observed Condition Modifier	Measured Condition Modifier	Number of poles by HI Band					
		HI1	HI2	HI3	HI4	HI5	Total
≤1	≤1	1,819	489	294			2,602
	>1			41	36	50	127
>1	≤1	316	66	80	86	126	674
	>1			40	4	179	223
	Total	**2,135**	**555**	**455**	**126**	**355**	**3,626**

The extensive use of Caps and Collars is a particularly important feature for this Asset Category in order to reflect the intelligence that can be gathered on pole Health from the routine or ad-hoc inspection processes. This is particularly true for the Measured Condition Input “Pole Decay / Deterioration”:

Measured Condition	Factor	Cap	Collar
None	0.8	5.4	0.5
No significant decay/ deterioration	1	6.4	0.5
High	1.4	10	5.5
Very High	1.8	10	8
Default	1	10	0.5

Where data is available to positively confirm levels of “Pole Decay / Deterioration” then this becomes the overriding driver in the HI assessment, i.e.;

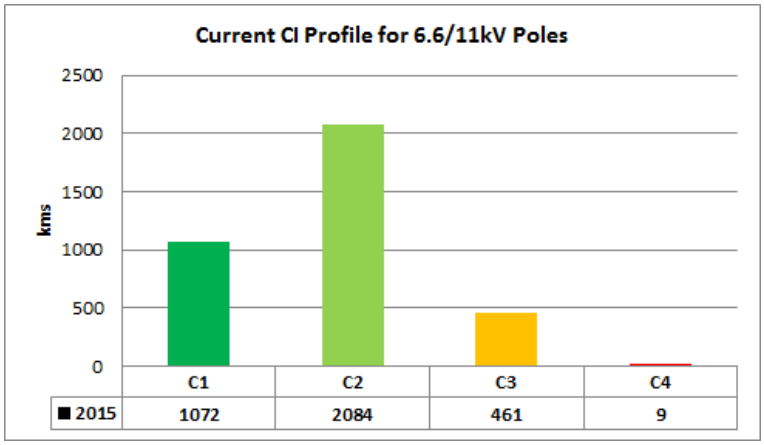
- a pole which has no measured decay would have a Health Score no greater than 5.4, which would lead to it being no greater than HI Band 2 (age and the other Condition Factors providing discrimination between HI Bands 1 and 2);
- a pole which has "No significant decay" would have a Health Score of no greater than 6.4 (no greater than HI Band 3, again age and the other Condition Factors providing discrimination between HI Bands 1 and 3);
- a pole which has "High" levels of decay would have a Health Score of at least 5.5 (HI Band 3); and
- a pole which has "Very High" levels of decay would have a Health Score of at least 8 (HI Band 5).

3.2.2 Criticality Index

Key characteristics of the Common Methodology:

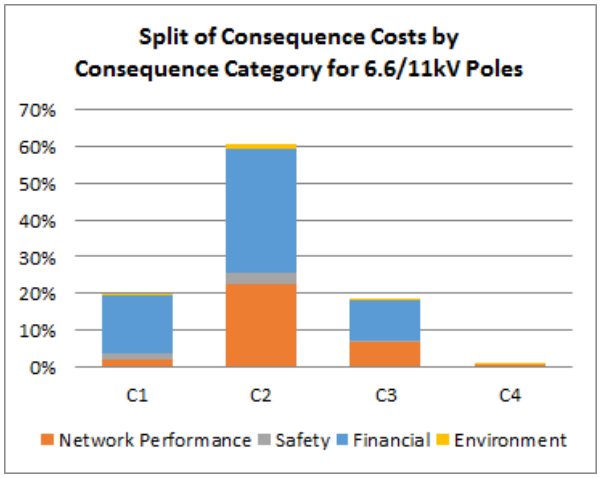
	Consequence Factor				
	Financial	**Safety**	**Environmental**	**Network Performance**	**Total**
Reference Costs:	£1,592	£179	£75	£1,297	£3,143
Factors:	1.0 to 2.0 based on type of support	0.7 to 1.6 based on type of support and location	N/A	Scaling factor based on number of connected customers	

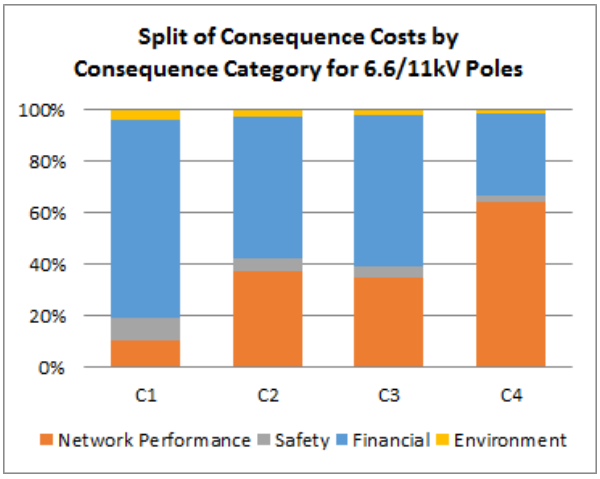
The Criticality Index profile for the sample data is shown below:



By way of further comparison, the graph below describes the proportion of the total Monetised Risk for the Asset Category by Consequence Category:

1. By Criticality Band (on the left); and
2. As a proportion of all Monetised Risk within the Criticality Band.





Since Network Performance and Financial Consequences of failure make up the majority of the overall Monetised Risk for this Asset Category, the key Consequence Factors providing Criticality Discrimination are therefore:

(a) the Scaling Factor based on number of connected customers; and
(b) the type of support Consequence Factor (eg whether the support hosts equipment such as transformers, which materially affect the cost of replacing a pole).

The validation exercise shows an increasing proportion of Monetised Risk within the C4 Band is associated with Network Performance, i.e. the Network Performance scaling factor is a more dominant factor since its range is a scaling factor based on customer numbers, rather than a restricted discrete weighting based on support type like is the case for the Financial Consequence Factor.

3.2.3 Monetised Risk

Based upon the sample data within the data set, the Average Consequence of Failure is **£3,177** (compared with a Reference Cost of Failure of **£3,143**). This now defines the Criticality Index Bands:

Criticality Index Bands			
>= Minimum		< Maximum	
%	£	%	£
		75	2,383
75	2,383	125	3,972
125	3,972	200	6,355
200	6,355		

With reference to the PoF Curve Parameters detailed in Table 19, risk can now be evaluated. For the sample data shown, the Risk Matrix is shown below:

CI / HI	Number of poles by Health and Criticality Band					
	HI1	HI2	HI3	HI4	HI5	Total
C1	720	158	151	31	12	**1,072**
C2	1,154	336	244	73	277	**2,084**
C3	255	59	60	21	66	**461**
C4	6	2	0	1	0	**9**
Total	**2,135**	**555**	**455**	**126**	**355**	**3,626**

CI / HI	Monetised Risk (£) by Health and Criticality Band					
	HI1	HI2	HI3	HI4	HI5	Total
C1	£13,937	£4,554	£7,694	£2,558	£2,323	**£31,066**
C2	£29,783	£12,911	£16,578	£8,032	£71,491	**£138,796**
C3	£9,872	£3,401	£6,115	£3,466	£25,551	**£48,404**
C4	£387	£192	£0	£275	£0	**£854**
Total	**£53,979**	**£21,058**	**£30,387**	**£14,332**	**£99,365**	**£219,120**

This validation exercise has shown that the key outputs produced by the Common Methodology for this Asset Category are:

(a) Age alone will discriminate between:
   a. assets in HI1 (very young assets);
   b. assets in HI2 (assets close to their Normal Expected Life)
   c. Assets at the very bottom of the HI3 band (at or beyond their Normal Expected Life);

(b) Condition will drive the HI of the asset into the middle HI Bands for poles with moderate levels of decay or levels of physical damage and into the higher HI4/HI5 Bands with more substantial levels of decay or physical damage;

(c) The more significant effect of Measured Condition Inputs compared with Observed Condition Inputs; and

(d) Further discrimination with respect to Criticality is provided based on the Type of Pole (Financial Consequence) and more significantly based on the number of connected customers (Network Performance Consequence).

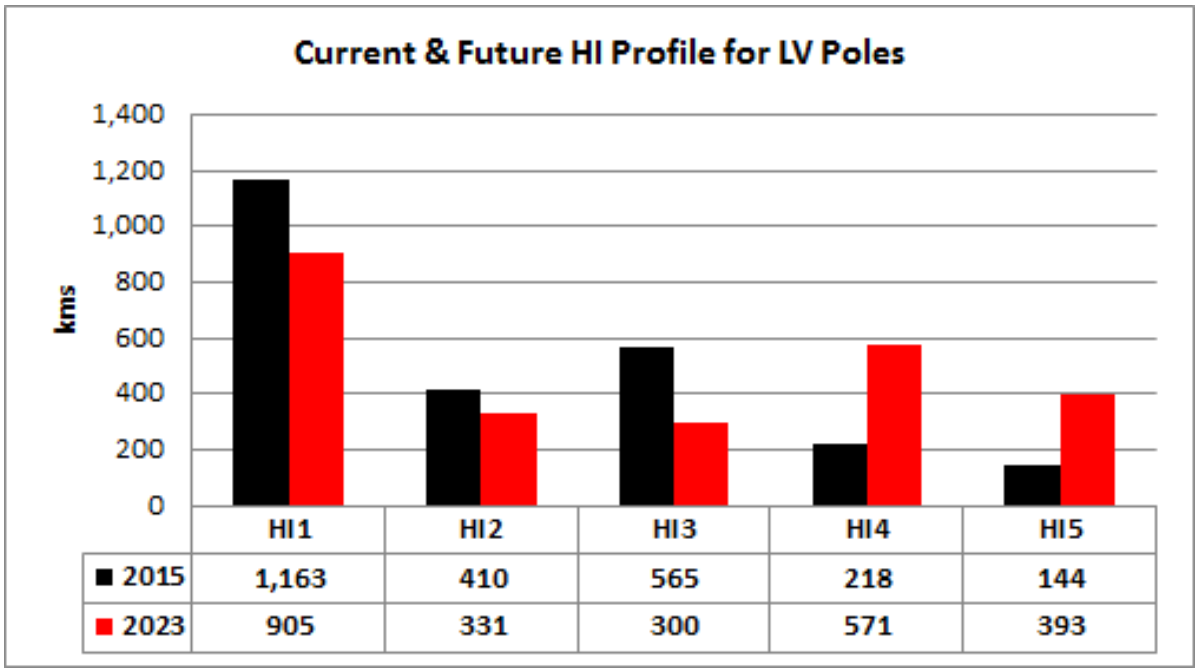
3.3 Outputs from the Validation Exercise (LV Poles)

Data has been collected for a representative sample of LV Poles across GB DNOs, amounting to 2,500 poles.

3.3.1 Health Index

Key characteristics of the Common Methodology: As per HV OHL Support – Poles described earlier.

The Health Index profile for the sample data is shown below:

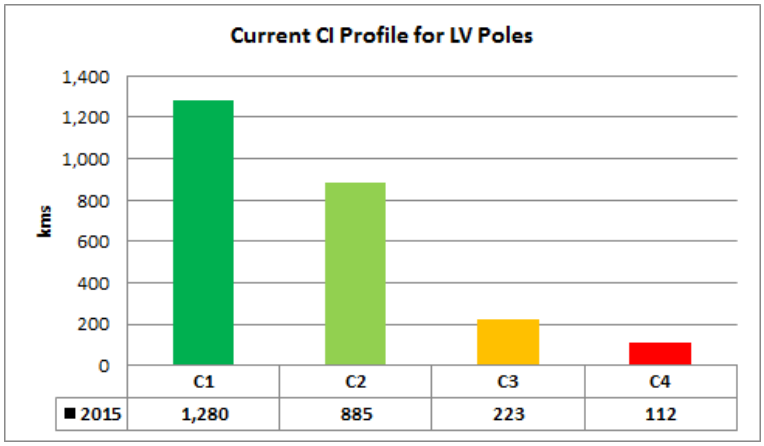


3.3.2 Criticality Index

Key characteristics of the Common Methodology:

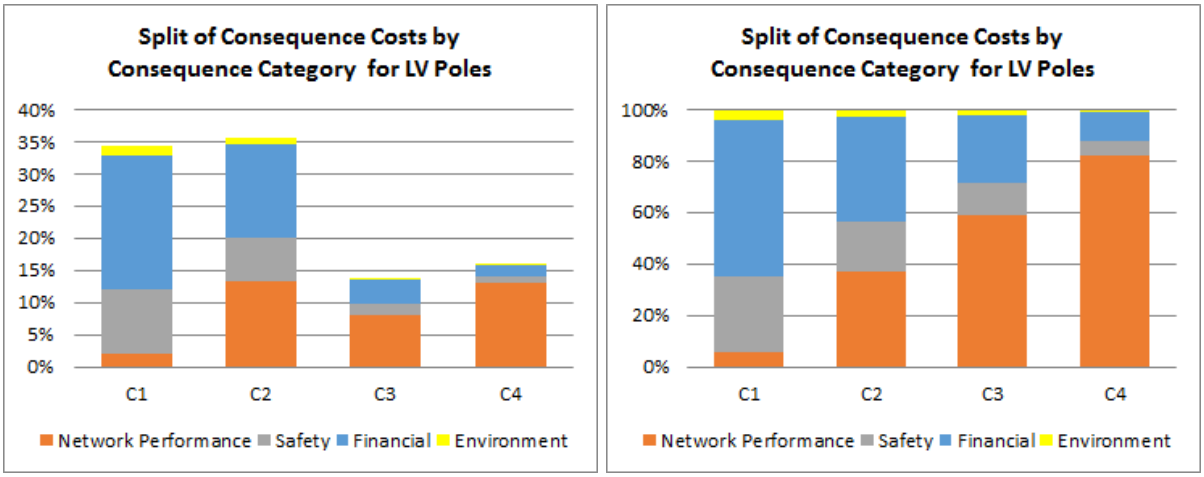
	Consequence Factor				
	Financial	**Safety**	**Environmental**	**Network Performance**	**Total**
Reference Costs:	£1,113	£536	£75	£1,208	£2,932
Factors:	1.0 to 2.0 based on type of support	0.7 to 1.6 based on type of support and location	N/A	Scaling factor based on number of connected customers	

The Criticality Index profile for the sample data is shown below:



By way of further comparison, the graph below describes the proportion of the total Monetised Risk for the Asset Category by Consequence Category:

1. By Criticality Band (on the left); and
2. As a proportion of all Monetised Risk within the Criticality Band.



Low Voltage overhead lines in particular are normally located within populated areas and in many cases within customers' gardens, given that they are embedded within the communities they serve, giving rise to greater contact and accessibility by the general public as shown by the increased contribution to the overall Consequence of Failure from the Safety Consequence Factor.

3.3.3 Monetised Risk

Based upon the sample data within the data set, the Average Consequence of Failure is **£2,731** (compared with a Reference Cost of Failure of **£3,136**). This now defines the Criticality Index Bands:

Criticality Index Bands			
>= Minimum		< Maximum	
%	£	%	£
		75%	2,048
75%	2,048	125%	3,414
125%	3,414	200%	5,462
200%	5,462		

With reference to the PoF Curve Parameters detailed in Table 19, risk can now be evaluated. For the sample data shown, the Risk Matrix is shown below:

CI / HI	Number of poles by Health and Criticality Band					
	HI1	HI2	HI3	HI4	HI5	Total
C1	581	222	309	100	68	**1,280**
C2	425	140	194	78	48	**885**
C3	108	35	44	26	10	**223**
C4	49	13	18	14	18	**112**
Total	**1,163**	**410**	**565**	**218**	**144**	**2,500**

CI / HI	Monetised Risk (£) by Health and Criticality Band					
	HI1	HI2	HI3	HI4	HI5	Total
C1	£9,667	£5,499	£13,534	£7,093	£11,314	**£47,107**
C2	£9,428	£4,624	£11,329	£7,377	£10,648	**£43,407**
C3	£3,594	£1,734	£3,854	£3,688	£3,328	**£16,198**
C4	£2,717	£1,073	£2,628	£3,310	£9,983	**£19,712**
Total	**£25,406**	**£12,931**	**£31,345**	**£21,469**	**£35,273**	**£126,424**

This validation exercise study has shown that the key outputs produced by the Common Methodology for this Asset Category are:

(a) Age alone will discriminate between:
   a. assets in HI1 (very young assets);
   b. assets in HI2 (assets close to their Normal Expected Life); and
   c. Assets at the very bottom of the HI3 band (at or beyond their Normal Expected Life);

(b) Condition will drive the HI of the Asset into the middle HI Bands for poles with moderate levels of decay or levels of physical damage and into the higher HI4/HI5 Bands with more substantial levels of decay or physical damage;

(c) The bigger effect of Measured Condition Inputs compared with Observed Condition Inputs; and

(d) Further discrimination with respect to Criticality is provided based on the Type of Pole (Financial Consequence), the number of connected customers (Network Performance Consequence) and the location of the pole (Safety Consequence).