Asset Depreciation Study for the Ontario Energy Board

Kinectrics Inc. Report No: K-418033-RA-001-R000

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DISCLAIMER

EXECUTIVE SUMMARY

Generally accepted accounting principles (GAAP) requires entities with property, plant and equipment (PP&E) to amortize the cost of assets over the period of time that they provide useful service. Prior to adoption of International Financial Reporting Standards (IFRS), GAAP in Canada permitted the use of asset service lives specified by the regulator. IFRS (without approval of a standard for Rate-regulated Activities) does not allow for the use of externally mandated depreciation rates. The Ontario Energy Board (OEB) stipulated that all Ontario's utilities are expected to adopt IFRS effective January 1, 2011[1]. At the same time, OEB is requiring all distributors to adopt useful life estimates that do not depend on the regulator and are determined by independent asset service life studies. In addition, IFRS is requiring componentization of assets placed in service by distributors at a sufficient level of detail to recognize that portions of an overall asset may be replaced or refurbished during the life of the asset of which they are a component, while the overall life of the asset may be somewhat longer.

The purpose of this Report is to assist utilities in making the transition from GAAP to IFRS and to assist them with determining appropriate initial service lives for assets most commonly used in the distribution of electricity in Ontario. This approach is considered an effective way to minimize the need and cost to Ontario consumers of a myriad of like studies by individual distributors. This report may also serve as a reference guide for the OEB in reviewing rate applications while keeping the responsibility for selecting and substantiating asset service lives with the utilities.

This Report identifies and describes common groups of assets and their most common "components". Total service lives are ascribed to each component, and assets are assigned to one of the following "parent" systems:

- Overhead Lines (OH)
- Transformer and Municipal Stations (TS&MS)
- Underground Systems (UG)
- Monitoring and Control Systems (S)

For each of the assets and their respective components, a useful life range and a typical useful life value within the range are given. This information is a composite of industry values known to Kinectrics Inc. (see Section E - 6) and information from six Ontario Local Distribution Companies (LDCs) of varying sizes and geographical locations selected as a sample, and with whom Kinectrics Inc. met on an individual basis.

It is also recognized that the useful lives of assets are dependent on a number of Utilization Factors (UFs) that are present within each jurisdiction. The degrees of impact of these influencing factors were qualitatively determined using information gathered from the LDCs. The UFs are identified as:

- Mechanical Stress
- Electrical Loading
- Operating Practices
- Environmental Conditions
- Maintenance Practices
- Non-Physical Factors

By considering the useful life ranges and the extent to which the utilization factors impact their assets, utilities will be able to select appropriate depreciation periods for their asset groups as

[1] *Report of the Board – Transition to International Financial Reporting Standards*, July 28, 2009

shown in the example for Power Transformers in Section E - 5 of this Report. The example demonstrates how UFs can be used in conjunction with local circumstances to estimate an appropriate depreciation period within the prescribed useful life range.

Table F-1 summarizes useful lives and the factors impacting those lives as developed by this report.

For completeness, Kinectrics has included a table that summarizes typical useful lives for Ontario's Local Distribution Companies' non-distribution assets, sometimes referred to as Minor Assets (Table F-2). The useful life values for Minor Assets were based on utility practices without further analysis.

In addition to the useful life information presented in this Report, Kinectrics has identified several areas for improvement that, once addressed, can enhance the Local Distributors' ability to improve the accuracy of their determination of asset service lives.

CREDENTIALS OF THE CONSULTANT

Kinectrics Inc is a recognized expert in determining useful lives of asset as a leader in developing "state of the art" Asset Condition Assessment methodology that estimates condition of assets based on their End-of-Life criteria and successfully completed a number of large scale Asset Management projects. These projects involved condition assessments of both station and lines distribution assets and included performing risk assessments based on the findings and recommending future life cycle sustaining investments, both capital and maintenance in nature.

Over the last year Kinectrics Inc completed a number of projects aimed at assisting Ontario's LDCs with the IFRS conversion. The projects involved developing LDC-specific assets groupings and componentization and for each asset grouping/component providing industry based useful life ranges. Kinectrics Inc has also provided information on typical industry time-based maintenance intervals and qualitative assessment of factors that may influence typical life within the range, such as operational practices, utilization, functional requirements, environmental impact etc. In addition, Kinectrics has acted as the Technical Due Diligence Consultant in many of the Ontario LDC mergers, in which depreciation assessments and valuation of assets were major tasks.

Kinectrics Inc observations on the useful life of assets as they relate to IFRS have recently been published in the November 2009 Special Edition of "The Distributor", an Electricity Distributors Association (EDA) publication.

Kinectrics staff understands power systems, having conducted comprehensive work on line design, standards, protection, losses and virtually every other aspect of planning and design for the last 30 years. Kinectrics has high voltage and high current lab testing expertise and has conducted many distribution asset failure investigations. Our theoretical knowledge is backed up by practical experience with power system components. This equipment expertise is of great practical value in working with utility staff whose mandate is to achieve the optimal physical and economic life cycle for these assets. Kinectrics asset management experience goes far deeper than logging equipment populations and demographics in computer databases.

Kinectrics has a unique and cost-effective capability covering a wide spectrum of areas including:

- Intimate knowledge of transmission and distribution systems equipment and their needs, and additional lifecycle-management or test result analysis services that we offer beyond testing and that are based on this extensive experience and understanding

- Kinectrics' testing facility that is world industry leader in capability and expertise in this domain and includes access to over 25 world-class Ontario-based laboratory and testing facilities, and to a range of proprietary technologies and processes

- In-depth experience in the management and execution of utility projects for numerous clients in Ontario and Canada, as well as North America and the rest of the world

- Access to staff from Kinectrics and other utility experts in key focus areas

- Operation under the ISO 9001 quality management system, with additional ISO 17025 qualification for key laboratories

- Project execution at the Project Management Professional (PMP) level

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A INTRODUCTION

Generally accepted accounting principles (GAAP) require entities with property, plant, and equipment (PP&E) to amortize the cost of such assets over the period of time that they provide useful service. Determination of such periods of time (total service lives) is generally based on engineering studies, asset retirement statistics and the experience of other utilities with like assets. Total service lives are reviewed from time to time to ensure they are current.

The majority of electricity distributors in Ontario continue to use asset service lives originally prescribed by Ontario Hydro at least 20 years ago.

Prior to adoption of International Financial Reporting Standards (IFRS), GAAP in Canada permitted the use of asset service lives specified by the regulator. IFRS (without approval of a standard for Rate-regulated Activities) does not allow for the use of externally mandated depreciation rates. Ontario Energy Board (OEB) has stipulated that all Ontario's distributors are expected to adopt IFRS beginning in 2011. In order to be IFRS compliant, distributors must adopt useful life estimates that do not depend on the regulator and are supported by independent asset service life studies.

In addition IFRS requires the componentization of assets placed in service by distributors at a sufficient level of detail to recognize that portions of an overall asset may be replaced or refurbished during the life of the asset of which they are a component, while the overall life of the asset may be somewhat longer. For many distributors, the level of detail maintained in their fixed asset and depreciation records is already sufficient to meet the IFRS componentization requirements. Such distributors have typically broken their PP&E into parts and have established formal "plant retirement units" (scaled in anticipation that they could be retired from service part way through the life of the asset of which they are a part). For other distributors, additional breakout may be necessary in adopting IFRS.

Because of the myriad of possible asset and system configurations, there are no industry standard components or plant retirement units. Nonetheless, industry practice in Ontario has been common enough that there are expected to be normative collections of asset components and system design configurations that can enable a study of service lives to be performed on the most commonly found components and configurations.

The purpose of this Report is to assist utilities in making the transition to IFRS and to assist them with determining appropriate initial service lives for assets most commonly used in the distribution of electricity in Ontario, particularly in situations where they have not conducted their own study. This approach is considered an effective way to minimize the need and cost to Ontario consumers of a myriad of like studies by individual distributors.

The method of depreciation of PP&E used by Ontario distributors is the straight-line remaining service life method, and Kinectrics understands this will continue to be the method used under IFRS.

This study will assist distributors with the determination of suitable asset total service lives. Distributors must still evaluate whether the total service lives set out in this Report are completely applicable to their own utility. This evaluation includes assessing the applicability of utilization factors (UF) that affect the most likely values provided in the Report, determining whether adjustments need to be made to reflect their individual componentization circumstances, determining how much service life remains for each component as well as the amount, if any, of residual or scrap value that is expected on disposition/removal from service of the component. Such utility-specific work is not part of the work for which Kinectrics Inc was engaged.

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B OBJECTIVE AND SCOPE

B - 1 OBJECTIVE

The objective of this Report is to assist electricity distributors in Ontario in determining total service lives for typical electricity distribution system assets that they own.

The information contained in the Report is expected to further facilitate transfer of responsibility for determining asset total service lives to distributors as they transition to IFRS.

B - 2 SCOPE OF WORK

This Report identifies and describes commonly configured groups of assets forming most commonly found “components” and ascribes total service lives to such components. In addition, assets are assigned to one of the following “parent” systems:

- Overhead Lines (OH)
- Transformer and Municipal Stations (TS&MS)
- Underground Systems (UG)
- Monitoring and Control Systems (S)

For each of the assets and their components, this Report provides a useful life range and a typical useful life value within the range. To further assist distributors with selecting the depreciation periods most appropriate for their utility, the Report also assesses the importance of various factors that affect the typical useful life value.

Useful life is expressed as a specific number of years rounded off to the nearest multiple of 5, being the Typical Useful Life (TUL). As well, a lower and upper limit of number of years is provided, within which most situations could be expected to occur. These upper and lower limits are referred to as the Minimum Useful Life (MIN UL) and Maximum Useful Life (MAX UL) and are also rounded off to the nearest multiple of 5. The definition of these terms is provided in Subsection E - 1 of this Report.

The Report also indicates the typical Utilization Factors (UF) affecting the degree to which shorter or longer total services lives could be judged by a distributor in a particular circumstance to be more appropriate. These factors include Maintenance Practices, Environmental Conditions, Mechanical Loading, Electrical Loading, Operating Practices, and Non-Physical Factors such as obsolescence. A description of these factors is provided in Subsection E - 1of this Report.

The Report includes a summary of the statistical analysis that establishes a percentage of assets that will reach their end-of-life (EOL) between MIN UL and MAX UL in Subsection E - 6.

In addition, the Report provides a guideline regarding the typical depreciation periods used in Ontario for other utility assets that do not fall under any of the above “parent” systems, such as office equipment, computers, buildings, vehicles, and communication equipment. These assets are often referred to as Minor Assets or General Plant.

Kinectrics selected six Ontario distributors in collaboration with the Ontario Energy Board staff and met with these distributors to ascertain what they consider to be appropriate values for TUL, MIN UL and MAX UL, as well as factors that they felt impacted the TUL for each class of depreciable property. A class of depreciable property is that grouping of components that is appropriate to consider together for purposes of this study. Some such distributors had recently completed depreciation studies of their own, and all were prepared to assist with this work.

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C EXECUTION PROCESS

The project execution process entailed seven steps to ensure that the industry-based information compiled by Kinectrics includes all the relevant assets and components used by Ontario's Local Distribution Companies (LDCs). The procedure was as follows:

Step 1

Kinectrics established a list of asset groupings representative of the typical breakdown of assets for Ontario's LDCs. This list was based on Kinectrics familiarity with LDCs business practices, particularly as a result of having performed a number of studies in support of the IFRS transition initiative for a number of large LDCs. The asset breakdown presented in this Report should be regarded as a guideline as it is likely that LDCs will have a somewhat different asset breakdown based on their specific asset mix and existing accounting practices.

Step 2

Kinectrics provided further breakdown or componentization for some of the asset categories. This was also based on Kinectrics familiarity with LDCs business practices and, at the same time was assessed against the following two criteria:

1. A value of component is significant or material enough relative to the value of the asset of which it is a component.
2. A need to replace the component does not necessarily warrant replacement of the entire asset.

Step 3

Kinectrics compiled industry based useful life values for the assets and their components using different sources, including industry statistics, research studies and reports (either by individuals or working groups, such as CIGRE), and Kinectrics Inc past experience (see Section E-2).

The listing for each asset/component includes a minimum and maximum useful life range (MIN UL and MAX UL) as well as TUL and utilization factors, such as maintenance practices, environmental conditions, mechanical and electrical loading, etc. that have an impact on whether the actual life for a particular utility is longer or shorter than the typical life.

Step 4

Six LDCs of different sizes were engaged to provide input to the study. The selection was made considering variables such as asset mix and geographical location. The utilities had varying experience regarding assets grouping, breakdown and componentization. Kinectrics Inc met with these utilities directly and obtained and discussed their assessments of each of the useful life values and the influencing utilization factors for each asset.

Step 5

The typical lives for some assets/components were combined with the corresponding lives obtained from utility interviews as described in Section E - 4 of this Report for each of the asset categories/components to come up with the recommended TUL, as well as recommended MIN UL and MAX UL. The study work also summarized and displayed the qualitative assessment of the degree to which each Utilization Factor underwrites the choice of TUL and affects TUL and the range between MIN UL, and MAX UL.

Step 6

A Draft Report was prepared by Kinectrics and circulated for comment from the LDC community.

Step 7

This Final Report was prepared and submitted to the OEB incorporating adjustments in response to comments on the Draft Report.

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D DELIVERABLES

This Report is the primary deliverable to the Ontario Energy Board from this engagement for use by electricity distributors in Ontario. In particular, this Report includes:

1. An Executive Summary and Table of Contents.

2. A summary of the credentials of the consultant.

3. A description of the methods used to determine estimated total life and estimated ranges of the respective categories of the depreciable assets, as well as a description of the data sources relied upon.

4. A description of each asset category and component for which Kinectrics has determined a service life.

5. A reference table listing the asset categories and components for which a service life has been determined:

    i. a most likely service life for the component expressed in years (referred to as the typical useful life or TUL), and

    ii. a reasonable upper and lower limit stated in years for the service life of the component under various operating or environmental conditions (referred to as the minimum and maximum useful live or MIN UL and MAX UL, respectively)

    iii. a description of the factors that impact the useful life of each asset.

6. Implementation suggestions that Kinectrics considers useful for distributors to consider when implementing the service lives (these suggestions include utilization and maintenance factors and practices).

7. Other matters Kinectrics considers relevant including the definition of Useful Life, Factors Impacting Typical Useful Life and statistical evaluation of percentage of the asset population that is expected to fall between MIN UL and MAX UL.

Kinectrics also provided in Section G some conclusions about areas of need where distributors could improve the overall process of managing depreciation cost.

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E METHODOLOGY

This Section defines some of the terms used throughout this report and describes the methodology used to estimate typical useful life, its range between minimum and maximum values for the defined distribution assets categories and the utilization factors influencing useful life.

E - 1 DEFINITIONS

The definitions of Asset Categories and Components, Useful Life Ranges, Typical Useful Life and the Factors that impact Useful Life (both physical and non-physical in nature) are listed below.

Asset Categories
Asset categories refer to typical distribution system assets such as as station transformers, distribution transformers (overhead and underground), breakers, switches, underground cables, poles, vaults, cable chambers, etc. Some of the assets, such as power transformers, are complex systems and include a number of components.

Components
For the purposes of this study, component refers to the sub-category of an asset that meets both of the following criteria:

1. Its replacement value is material enough to track.
2. A need to replace the component does not necessarily warrant replacing the entire asset.

An *asset* may be comprised of more than one component, each with independent failure modes and degradation mechanisms that may result in a substantially different useful life than that of the overall asset. A component may also be managed under an independent maintenance and replacement schedule.

Typical Useful Life (TUL)

TUL is defined differently, depending on the asset category and component type, and can be categorized under one of the following three scenarios:

i. Assets Are Replaced Only When Failed

TUL= Age when most of the assets fail and are replaced and is equal to the asset's physical EOL (physical EOL is defined as an asset's inability to perform its functions as designed).

ii. Assets Are Replaced Due to Reasons Not Related to Their Performance

TUL = Typical age when assets are replaced before they reach their physical EOL due to reasons such as lack of spare parts or replacement assets, incompatibility with system requirements, external drivers (e.g., road widening, or PCB Regulation), or internal initiatives (e.g., carbon print reduction or voltage conversion).

iii. Assets are Replaced for Economic Reason

TUL = Typical age when assets reach their "economic life", i.e., although physical EOL is not reached, high risk of failure cost makes it economical to replace them.

Depending on the utility's circumstances, replace vs. refurbish strategy and type and age distribution of a particular asset category/component, TUL may reflect a combination of all three scenarios described above. The degradation mechanism is discussed for each asset studied in this report.

Useful Life Ranges

TUL falls between Minimal Useful Life (MIN UL) and Maximum Useful Life (MAX UL) which for the purposes of this report are defined as:

MIN UL = Age when a small percentage of assets reach their physical EOL, usually at the beginning section of the statistical "bath-tub curve", where failure rate starts increasing exponentially

MAX UL = Age when most of the assets reach their physical EOL, usually at the end section of the statistical "bath-tub curve", where failure rate increases exponentially

The exact percentage of assets/components that fail before reaching MIN UL or MAX UL varies from utility to utility as well as among different asset categories/components. Although MIN UL and MAX UL are most often related to physical EOL, in some cases the range is defined by economic or other reasons. In such cases, the range is usually less than when MIN UL and MAX UL are dictated by the physical EOL alone.

It is worth noting that an asset category can have a typical life that is equal to either the maximum or minimum life. This fact is simply an indication that the majority of the units within a population will be operational for either the minimum or maximum number of years; i.e. the statistical data is skewed towards either the maximum or minimum values. This could also happen, for example, when assets are replaced for economic reasons to alleviate failure risk cost.

A statistical analysis that estimates the percentage of assets/components whose useful lives are within the range defined by MIN UL and MAX UL is presented in Subsection E - 6 of this report.

The range in useful lives that are found in practice reflects differences in various factors described in the "Utilization Factors" subsection below.

Utilization Factors

For the purposes of this Report, the term Utilization Factors (UFs) refers to factors that are expected to affect TUL of assets and their components and to a certain extent MIN UL and MAX UL. The degree of their effect is qualitatively described as High (H), Medium (M), Low (L), or No Impact (NI). The following UFs were identified:

1. **Mechanical stress** refers to forces and loads applied to an asset that may lead to degradation over time, e.g. wind load, ice load, gravitational and spring forces on components, etc.

2. **Electrical loading** refers to stresses such as continuous loading, temporary overloading and exposure to short circuit fault current.

3. **Operating practices** refers to how frequently an asset is subject to operations (automatic or manual) that impact its useful life, e.g. reclosers, switch or breaker operations.

4. **Environmental conditions** include pollution, salt, acid rain, humidity, extreme temperature, and animals that are prevalent and cause long-term degradation over a period of time.

5. **Maintenance Practices** refers to how frequently and regularly Routine Inspection or Routine Testing/ Maintenance is performed on assets/components.

6. **Non-Physical Factors** refers to things that are not directly related to physical condition of assets, e.g. obsolescence, economic considerations related to life cycle cost management, increased rating requirements due to system growth, regulatory changes, construction activities, etc. These factors could lead to asset replacement even when assets can still perform as designed.

Each asset may be impacted by one or more of the UFs, resulting in different degradation rates for the same assets and/or components in different jurisdictions. Therefore, it is expected that some of the utility-specific total lives chosen will be different than the TULs provided in this Report based on the qualitative assessment of the above factors.

As part of the interview, each of the six utilities was asked to rank the degree to which each UF impacts the life of each of their assets. For each UF, a singular degree of impact value (H, M, L, NI), based on a composite of the rankings provided by the utilities, is reported. The degree of impact (DI) is determined by the following formulation:

$$DI = \frac{\sum_{m=1}^{6} \alpha_m (RS)}{\sum_{m=1}^{6} \alpha_m (RS_{\max})}$$

m Utility number. Six (6) utilities were interviewed.

RS Ranking Score. This is a numerical score assigned to the qualitative rakings of H, M, L, and NI (no impact).

Qualitative Ranking	Ranking Score (RS)
H	4
M	3
L	1.5
NI (no impact)	0

α_m Data availability coefficient (1 when data is provided by utility, 0 otherwise).

RS_{max} Maximum possible Ranking Score. The maximum value is equal to the score of a qualitative ranking of “H”; in this case the numerical value is 4.

The numerical percentage of degree of impact (DI) is then translated into a singular, qualitative ranking as per the following:

Degree of Impact (%)	Qualitative Rating
< 10%	NI
10% – 44%	L
45% - 78%	M
79% - 100%	H

Consider, for example, the Mechanical Stress for Fully Dressed Concrete Poles. Three of six utilities provided qualitative rankings, as shown on the “Qualitative Ranking” column. The numerical scores for each of the rankings are shown on the “Ranking Score RS” column. The data availability coefficient and maximum ranking score are also shown.

Utility	Qualitative Ranking	Ranking Score RS	α	Maximum Ranking Score (RS_{max})
Utility 1	n/a	n/a	0	n/a
Utility 2	H	4	1	4
Utility 3	n/a	n/a	0	n/a
Utility 4	n/a	n/a	0	n/a
Utility 5	M	3	1	3
Utility 6	H	4	1	4

For the above data, the Degree of Impact (DI) = (0 + 1*4 + 0 + 0 + 1*3 + 1*4) / (0 + 1*4 + 0 + 0 + 1*4 + 1*4) = 92%. A score of 92% translates to a ranking of high (H). Thus, as per the utility interviews, Mechanical Stress has a high impact on the useful lives of concrete poles.

E - 2 INDUSTRY RESEARCH

Kinectrics compiled degradation and useful life data from several different sources to develop what Kinectrics refers to as the “industry” values for TUL, MIN UL and MAX UL in the tables provided in Section H – APPENDIX – DERIVATION OF USEFUL LIVES. These sources are:

- Industry statistics
- Information provided by manufacturers
- Research studies and reports by individuals and corporate entities, such as universities, utilities, research organizations, etc.
- Research studies conducted by working groups of international organizations such as CIGRE, EPRI, etc.
- Kinectrics applied its own extensive expertise in failure investigations conducted for many utilities across North America, knowledge gained from numerous completed Asset Condition Assessment project that involved determining appropriate EOL for different assets, testing of distribution assets and their components, and IFRS studies performed for many large Ontario LDCs.

All the sources are listed in Section J - REFERENCES of this Report.

E - 3 UTILITY INTERVIEWS

Kinectrics interviewed staff members from six utilities across Ontario. The utilities were selected in conjunction with OEB staff and the sample represents a good cross-section of Ontario's distributors based on their size, geographical location, and asset mix as follows:

- One utility from GTA
- One utility from the Niagara Escarpment Region
- One utility from South Western Ontario
- One utility from Eastern Ontario
- Two utilities from Northern Ontario

The interviews were focused on obtaining information from the utilities technical staff regarding:

- Appropriateness of the assets/components break down
- Utility-specific TUL, MIN UL and MAX UL
- Utilization factors affecting the above values

Actual asset failure information was not available so utility staff relied on existing age distribution information when available, hands-on field experience or budgetary forecasting experience to provide the required information. The utilities sampled had a good grasp of the challenge related to establishing realistic useful life and their responses were based on the mix of available data, actual experience and informed judgment.

E - 4 COMBINING INDUSTRY RESEARCH AND UTILITY INTERVIEW FINDINGS

Industry research was combined with interview results to ensure that the recommended values, although still based on the industry-wide experience, properly reflect Ontario's perspective.

The more utilities that provided input regarding a certain asset, the more weight utility input was given in arriving at the overall TUL, MIN UL and MAX UL as shown in the table below:

Number of Utility Inputs	Ontario Weight	Industry Weight
6	50%	50%
5	42%	58%
4	33%	67%
3	25%	75%
2	16%	84%
1	4%	96%

The overall values shown in the summary tables in Section F and H incorporate the logic described in the above table.

The summary of the results of combining both industry research and Ontario LDC survey findings is provided in Table F-1 of this Report for TUL, MIN UL and MAX UL along with summary assessments by the distributors of the impact of UFs on useful lives. A detailed description of degradation mechanism(s), TUL, MIN UL, MAX UL and UFs for each asset category and component is provided in Section H of this Report. Recommended ranges for the Minor Assets that do not fall under any of the "parent" systems are provided in the Table F-2.

E - 5 EXAMPLE OF USING THE REPORT

Following is an example demonstrating how an appropriate depreciation period could be selected by a utility for Power Transformers:

1. TUL from either Table F-1 in Section 0 or the detailed description in Section 12 of Section H- APPENDIX - DERIVATION OF USEFUL LIVES for the overall Fully Dressed Pole is 45 years, with MIN UL and MAX UL at 30 and 60 years, respectively.

2. The UFs are as follows:
   - Mechanical Stress – no impact
   - Electrical Stress – medium impact
   - Environmental Conditions – medium impact
   - Operating Practices – low impact
   - Maintenance Practices – low impact
   - Non-Physical Factors – no impact

3. A utility may select an appropriate depreciation period based on the specific UFs reflecting the actual utility conditions. For example, if electrical stress is not significant (lightly loaded transformer), environment in terms of pollution or weather extremes is not very harsh, the units are regularly maintained, and tap changers are operated not very frequently, the utility could select a depreciation period above the TUL but below MAX UL, say 50 years. Should the conditions and factors be more severe, the depreciation period chosen by the utility may be less than the TUL shown, (e.g., 40 years).

4. As more information is accumulated over time (e.g., several years of failure history), a utility may decide to adjust the depreciation period based on empirical information to better reflect its specific circumstances.

The decision on whether TUL should be the same as the one in the table or whether it should be shortened or prolonged and by how much is not an exact science and depends on the informed judgment of the utility's technical staff and the utility's approach to life cycle cost management.

Although the values provided in this study for the UFs are those that underwrite TUL in each case, statistical analysis described in Section E-6 suggests that there is between 67% and 91% probability that the selected depreciation period will fall within the prescribed range (i.e., between MIN UL and MAX UL). Therefore, it is possible that the selected depreciation period could be outside of the Min UL or Max UL provided in this report depending on the impact of the various UFs. In such cases, and particularly if the depreciation period is significantly longer or shorter than the recommended TUL, a utility's auditors and the OEB will likely require the utility to explain with more rigour the reasons for selecting the particular depreciation period.

E - 6 STATISTICAL ANALYSIS

Once Kinectrics determined the useful life values of TUL, MIN UL, and MAX UL using industry and Ontario LDC information, Kinectrics performed a statistical analysis to estimate what percentage of assets is expected to fall between MIN UL and MAX UL. A detailed description of the methodology is presented in APPENDIX I – PERCENT OF ASSETS IN THE USEFUL LIFE RANGE of this Report. The following assumptions were made in the analysis:

1. EOL distribution for all the assets is uni-modal with the peak potentially skewed towards MIN UL or MAX UL depending on the asset category/component.

2. The value corresponding to the peak of failure density function is the same as TUL.

3. In defining the useful life range, the MIN UL and MAX UL are within ($\sqrt{3}$ times standard deviation б) from the mean value μ of the useful life distribution, regardless of where TUL is relative to the mean value μ.

4. For any specific asset category/component TUL always lies within the useful life range.

Based on these assumptions, the percentage of assets with useful life within the range between MIN UL and MAX UL is found to be equal to 91% for a normally distributed useful life (i.e., TUL is the same as the mean value). If the useful life distribution is not normal (i.e., TUL is not the same as the mean value) the percentage of assets within the range between MIN UL and MAX UL will be less than 91% but more than the minimum value of 67%.

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F SUMMARY OF RESULTS

Table F - 1 summarizes useful lives, and factors impacting those lives as developed by this report.

Table F - 1 Summary of Componentized Assets, Service Life and Factors

PARENT*	#	ASSET DETAILS			USEFUL LIFE			FACTORS **					
		Category| Component | Type			MIN UL	TUL	MAX UL	MC	EL	EN	OP	MP	NPF
OH	1	Fully Dressed Wood Poles	Overall		35	45	75	H	L	M	NI	L	L
			Cross Arm	Wood	20	40	55						
				Steel	30	70	95						
	2	Fully Dressed Concrete Poles	Overall		50	60	80	H	L	M	NI	L	NI
			Cross Arm	Wood	20	40	55						
				Steel	30	70	95						
	3	Fully Dressed Steel Poles	Overall		60	60	80	H	M	L	NI	L	NI
			Cross Arm	Wood	20	40	55						
				Steel	30	70	95						
	4	OH Line Switch			30	45	55	L	L	L	L	M	L
	5	OH Line Switch Motor			15	25	25	L	NI	L	L	M	L
	6	OH Line Switch RTU			15	20	20	NI	NI	L	L	L	M
	7	OH Integral Switches			35	45	60	L	M	M	M	L	H
	8	OH Conductors			50	60	75	M	L	M	NI	NI	L
	9	OH Transformers & Voltage Regulators			30	40	60	L	M	M	NI	NI	M
	10	OH Shunt Capacitor Banks			25	30	40	-	-	-	-	-	-
	11	Reclosers			25	40	55	L	L	L	M	L	M
TS & MS	12	Power Transformers	Overall		30	45	60	NI	M	M	L	L	NI
			Bushing		10	20	30						
			Tap Changer		20	30	60						
	13	Station Service Transformer			30	45	55	NI	L	M	L	NI	L
	14	Station Grounding Transformer			30	40	40	-	-	-	-	-	-
	15	Station DC System	Overall		10	20	30	NI	M	L	L	M	M
			Battery bank		10	15	15						
			Charger		20	20	30						
	16	Station Metal Clad Switchgear	Overall		30	40	60	L	L	M	M	M	M
			Removable Breaker		25	40	60						
	17	Station Independent Breakers			35	45	65	M	M	M	M	M	M
	18	Station Switch			30	50	60	M	L	M	M	M	L

* **OH = Overhead Lines System** **TS & MS = Transformer and Municipal Stations**

** MC = Mechanical Stress EL = Electrical Loading OP = Operating Practices EN = Environmental Conditions
MP = Maintenance Practices NPF=Non-Physical Factors
H=High M=Medium L=Low NI=No Impact

PARENT*	#	ASSET DETAILS		USEFUL LIFE			FACTORS **					
		Category| Component | Type		MIN UL	TUL	MAX UL	MC	EL	EN	OP	MP	NPF
TS & MS	19	Electromechanical Relays		25	35	50	NI	NI	NI	NI	NI	H
TS & MS	20	Solid State Relays		10	30	45	NI	NI	NI	NI	NI	H
TS & MS	21	Digital & Numeric Relays		15	20	20	NI	NI	NI	NI	NI	H
TS & MS	22	Rigid Busbars		30	55	60	L	L	L	NI	NI	L
TS & MS	23	Steel Structure		35	50	90	L	NI	M	NI	NI	L
UG	24	Primary Paper Insulated Lead Covered (PILC) Cables		60	65	75	L	L	M	L	NI	M
UG	25	Primary Ethylene-Propylene Rubber (EPR) Cables		20	25	25	NI	M	L	NI	NI	NI
UG	26	Primary Non-Tree Retardant (TR) Cross Linked Polyethylene (XLPE) Cables Direct Buried		20	25	30	M	M	M	L	L	L
UG	27	Primary Non-TR XLPE Cables In Duct		20	25	30	M	M	M	L	L	M
UG	28	Primary TR XLPE Cables Direct Buried		25	30	35	M	M	M	L	L	L
UG	29	Primary TR XLPE Cables In Duct		35	40	55	M	M	M	L	L	L
UG	30	Secondary PILC Cables		70	75	80	NI	L	L	NI	NI	H
UG	31	Secondary Cables Direct Buried		25	35	40	M	M	M	L	NI	NI
UG	32	Secondary Cables In Duct		35	40	60	M	M	M	L	NI	NI
UG	33	Network Transformers	Overall	20	35	50	NI	L	H	NI	NI	NI
			Protector	20	35	40						
UG	34	Pad-Mounted Transformers		25	40	45	L	M	M	NI	L	L
UG	35	Submersible/Vault Transformers		25	35	45	L	M	M	NI	L	L
UG	36	UG Foundations		35	55	70	M	NI	M	L	L	M
UG	37	UG Vaults	Overall	40	60	80	M	NI	M	L	L	L
			Roof	20	30	45						
UG	38	UG Vault Switches		20	35	50	L	L	L	L	L	NI
UG	39	Pad-Mounted Switchgear		20	30	45	L	L	H	L	L	L
UG	40	Ducts		30	50	85	H	NI	M	NI	NI	L
UG	41	Concrete Encased Duct Banks		35	55	80	M	NI	M	NI	NI	L
UG	42	Cable Chambers		50	60	80	M	NI	H	NI	L	NI
S	43	Remote SCADA		15	20	30	NI	NI	L	NI	L	H

* **TS & MS = Transformer and Municipal Stations** **UG = Underground Systems** **S = Monitoring and Control Systems**

** MC = Mechanical Stress EL = Electrical Loading OP = Operating Practices EN = Environmental Conditions
MP = Maintenance Practices NPF=Non-Physical Factors
H=High M=Medium L=Low NI=No Impact

Table F - 2 summarizes useful life ranges for Ontario's Local Distribution Companies' non-distribution assets. Table F - 2 contains assets that were not studied in detail in this analysis and represent recommended ranges based on the experience of Ontario LDCs interviewed. A further analysis of these assets is not considered necessary.

Table F - 2 Summary Useful Life of Minor Assets

#	ASSET DETAILS Category - Component - Type		USEFUL LIFE RANGE
1	Office Equipment		5-15
2	Vehicles	Trucks & Buckets	5-15
		Trailers	5-20
		Vans/Cars	5-10
3	Administrative Buildings		50-75
4	Leasehold Improvements		Lease dependent
5	Station Buildings	Station Building	50-75
		Parking	25-30
		Fence	25-60
		Roof	20-30
6	Computer Equipment	Hardware	3-5
		Software	2-5
7	Equipment	Power Operated	5-10
		Stores	5-10
		Tools, Shop, Garage Equipment	5-10
		Measurement & Testing Equipment	5-10
8	Communication	Towers	60-70
		Wireless	2-10
9	Residential Energy Meters		25-35
10	Industrial/Commercial Energy Meters		25-35
11	Wholesale Energy Meters		15-30
12	Current & Potential Transformer (CT & PT)		35-50
13	Smart Meters		5-15
14	Repeaters - Smart Metering		10-15
15	Data Collectors - Smart Metering		15-20

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G CONCLUSIONS

This Report provides reference information that will assist Ontario's electrical distribution utilities in selecting appropriate useful lives for typical distribution asset categories. The ultimate decision on what the appropriate useful lives are lies with utilities and they are expected to justify their selection based on the local circumstances vis-à-vis utilization factors that affect TUL and other relevant considerations such as empirical data and manufacturers recommendations.

This Report combines available industry information, Kinectrics expertise and survey results from 6 of Ontario's LDC. Thus, Kinectrics considers that the total service lives recommended are sufficiently reliable so that another independent expert would reasonably arrive at the same conclusion. Nevertheless, it is expected that for most asset categories/components TUL, and thus the selected depreciation period, will vary among utilities..,. The utility should be prepared and be able to provide a rationale for selecting a particular depreciation period based on the information in this Report and the utility's specific experience.

Asset categories and their componentization as presented in this report represent typical assets componentization in Ontario. In most cases utilities will only have a subset of the asset categories included in the Report. Furthermore, utilities may choose not to have some of the asset categories componentized as suggested in this Report and have depreciation tracked at the asset level.

In the course of our work Kinectrics identified several areas for improvement that, once addressed, should enhance distributors' ability to improve the accuracy of their determination of asset service lives. At the present time most distributors have limited data available on actual asset retirement history. One consequence of this is that the range of asset service lives from minimum to maximum tends to be broader that it would be if reliable asset retirement histories were available. To improve the overall process of managing depreciation cost, from this study Kinectrics concludes there is a need:

- For distributors to improve availability of asset retirement records that identify both the end of life and its causes (e.g., failures, non-physical factors (obsolescence), high risk of failure, etc).
- For ongoing comparison of the depreciation period selected with actual physical useful lives based on empirical evidence.
- To gather data to support probability of failure curves for assets that are run to failure.
- To consider whether there are other Utilization Factors that have significance and develop ways to quantify their impacts on Typical Useful Life.
- For distributors to acquire and maintain planned and corrective maintenance records in a manner that can be easily accessed and analyzed.
- To develop and maintain a record of assets replaced as a result of major projects (e.g., road widening or voltage conversion).

The depreciation periods selected are expected to be reviewed periodically and adjusted if and when required based on the knowledge and experience gained in the future.

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H APPENDIX - DERIVATION OF USEFUL LIVES

A results section has been created for each asset category. Each includes:

Description - The description of the asset category including componentization, design configurations, alternative design configurations and system hierarchy. For some assets their attributes such as type and material (e.g. wood poles) or interrupting mechanism (e.g. reclosers) were also mentioned. In such cases, although these attributes may result in useful lives being somewhat different, the useful lives information provided in this Report is for the overall asset category and Kinectrics recommends not breaking these asset categories down further based on their attributes.

1. Degradation Mechanism – A discussion of the degradation mechanism including end of life criteria. This describes physical EOL referred to in Section E-1 - DEFINITIONS.

2. Useful Life - The useful life values (MIN UL, TUL and MAX UL) for the asset and their respective components. This section presents both industry and survey values as well as the combined values.

3. Impact of Utilization Factors – This section discusses the factors (UFs) impacting useful life and includes qualitative degree of impact based on the utilities surveyed. If utilities considered the TUL to be impacted by a factor, they rated the magnitude of the impact on a scale of high, medium or low (displayed on the graph as red, orange and yellow, respectively). For the case where utilities felt that the factor has no impact on the TUL the space is left light gray. Finally, “No Response” is displayed as dark grey and signifies that one or more utility did not provide information for that asset.

Please refer to Table F - 1 for a summary of these results.

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1. Fully Dressed Wood Poles

1.1 Description

The asset referred to in this category is the fully dressed wood pole ranging in size from 30 to 75 feet. This includes the wood pole, cross arm, bracket, insulator, cutouts, arresters, and anchor and guys. Wood poles are typically the most common form of support for overhead distribution feeders and low voltage secondary lines.

1.1.1 Componentization Assumptions

For the purposes of this report, the Fully Dressed Wood Poles asset category has been componentized so that the cross arm can be regarded as a separate component. Therefore the Fully Dressed Wood Pole has overall useful life values based on the useful life of the pole itself, and useful life values for the cross arm component.

The most significant component of this asset is the wood pole itself. The wood species predominately used for distribution systems are Red Pine, Jack Pine, and Western Red Cedar (WRC), either butt treated or full length treated. Smaller numbers of Larch, Fir, White Pine and Southern Yellow Pine have also been used. Preservative treatments applied prior to 1980, range from none on some WRC poles, to butt treated and full length Creosote or Pentachlorophenol (PCP) in oil. The present day treatment, regardless of species, is CCA-Peg (Chromated Copper Arsenate, in a Polyethylene Glycol solution). Other treatments such as Copper Naphthenate and Ammoniacal Copper Arsenate have also been used, but these are relatively uncommon.

1.1.2 System Hierarchy

Fully Dressed Wood Poles are considered to be a part of the Overhead Lines asset grouping.

1.2 Degradation Mechanism

The end of life criteria for wood poles includes loss of strength, functionality, or safety (typically due to rot, decay, or physical damage). As wood is a natural material the degradation processes are somewhat different from those which affect other physical assets on the electricity distribution systems. The critical processes are biological, involving naturally occurring fungi that attack and degrade wood, resulting in decay. The nature and severity of the degradation depends both on the type of wood and the environment. Some fungi attack the external surfaces of the pole and some the internal heartwood. Therefore, the mode of degradation can be split into either external rot or internal rot. Wood poles can also be degraded by damage inflicted by woodpeckers, and insects such as carpenter ants. As a structural item the sole concern when assessing the condition for a wood pole is the reduction in mechanical strength due to degradation or damage.

1.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Fully Dressed Wood Poles are displayed in Table 1-1.

Table 1-1 Useful Life Values for Fully Dressed Wood Poles

ASSET COMPONENTIZATION		USEFUL LIFE (years)		
		MIN UL	TUL	MAX UL
Overall		35	45	75
Cross Arm	Wood	20	40	55
	Steel	30	70	95

1.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Fully Dressed Wood Poles. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Fully Dressed Wood Poles (Figure 1-1). For the cross arm component, five of the Utilities gave MIN UL, TUL and MAX UL Values for Wood Cross Arms (Figure 1-2) and two of the Utilities gave MIN UL, TUL and MAX UL Values for Steel Cross Arms (Figure 1-3).

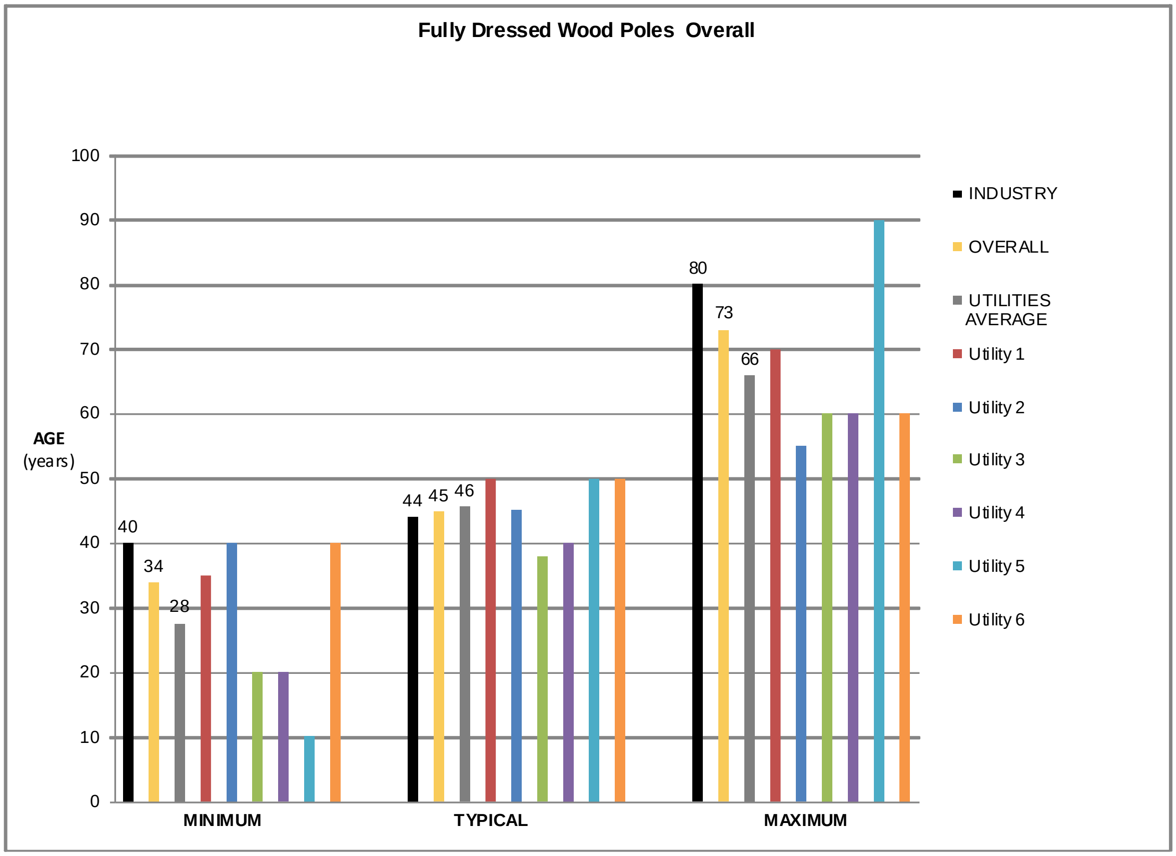


Figure 1-1 Useful Life Values for Fully Dressed Wood Poles

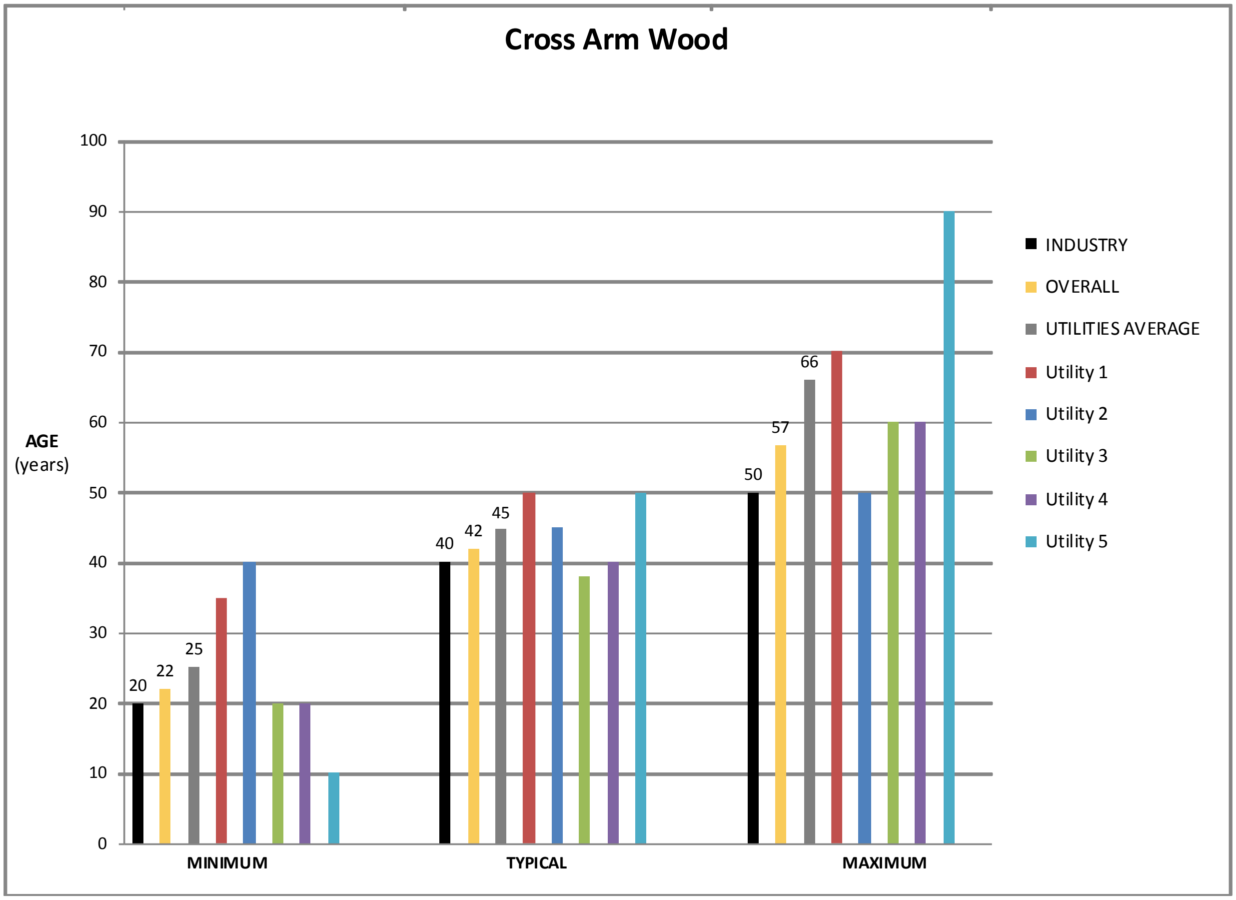


Figure 1-2 Useful Life Values for Fully Dressed Wood Poles – Cross Arm – Wood

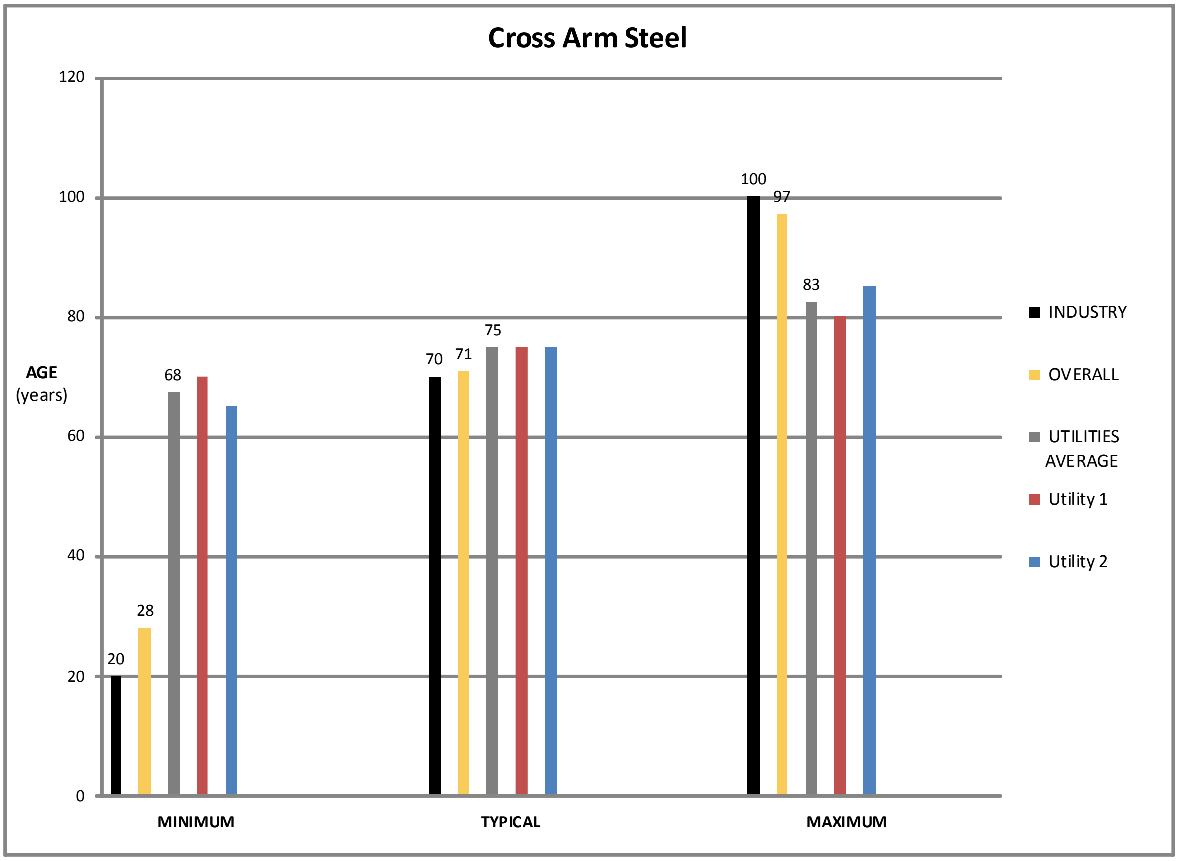


Figure 1-3 Useful Life Values for Fully Dressed Wood Poles – Cross Arm - Steel

1.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Fully Dressed Wood Poles are displayed in Table 1-2.

Table 1-2 - Composite Score for Fully Dressed Wood Poles

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	100%	13%	75%	0%	19%	31%
Overall Rating*	**H**	**L**	**M**	**NI**	**L**	**L**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

1.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Fully Dressed Wood Poles. All six of the interviewed utilities provided their input regarding the UFs for Fully Dressed Wood Poles (Figure 1-4). The UFs impacts were the same for poles and cross-arms.

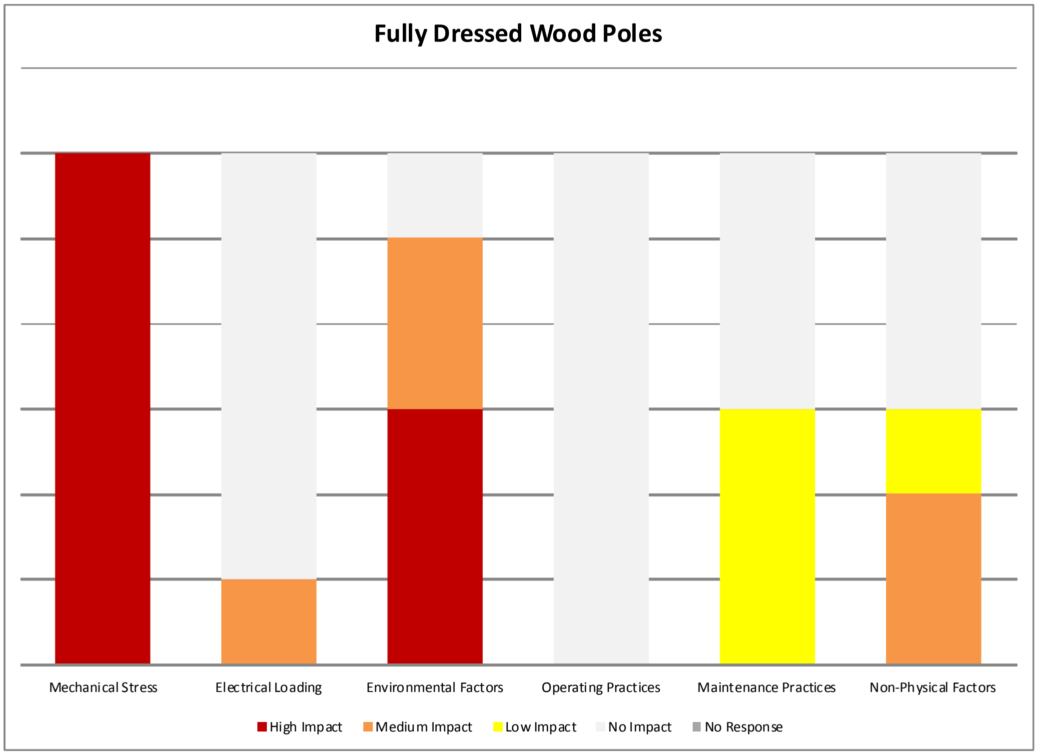


Figure 1-4 Impact of Utilization Factors of the Useful Life of Fully Dressed Wood Poles

2. Fully Dressed Concrete Poles

2.1 Description

The asset referred to in this category is the fully dressed concrete pole ranging in size from 30 to 75 feet. This includes the concrete pole, cross arm, bracket, insulator, cutouts, arresters, and anchor and guys. Concrete poles are a common form of support for overhead distribution feeders particularly in urban utilities.

2.1.1 Componentization Assumptions

For the purposes of this report, the Fully Dressed Concrete Poles asset category has been componentized so that the cross arm can be regarded as a separate component. Therefore the Fully Dressed Concrete Pole has an overall useful life value based on the useful life of the pole itself, and also a useful life value for the cross arm component.

2.1.2 System Hierarchy

Fully Dressed Concrete Poles are considered to be a part of the Overhead Lines asset grouping.

2.2 Degradation Mechanism

Concrete poles age, as do other concrete structures, by mechanisms such as moisture ingress, freeze/thaw cycles, and chemical erosion. Moisture ingress into cracks or concrete pores can result in freezing during the winter and damage to concrete surface. Road salt spray can further accelerate the degradation process and lead to concrete spalling. Typical concrete mixes employ a washed-gravel aggregate and have extremely high resistance to downward compressive stresses (about 3,000 lb/sq in); however, any appreciable stretching or bending (tension) will break the microscopic rigid lattice, resulting in cracking and separation of the concrete. The spun concrete process used in manufacturing poles prevents moisture entrapment inside the pores. Spun, pre-stressed concrete is particularly resistant to corrosion problems common in a water-and-soil environment.

2.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Fully Dressed Concrete Poles are displayed in Table 2-1.

Table 2-1 Useful Life Values for Fully Dressed Concrete Poles

ASSET COMPONENTIZATION		USEFUL LIFE (years)		
		MIN UL	TUL	MAX UL
Overall		50	60	80
Cross Arm	Wood	20	40	55
	Steel	30	70	95

2.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Fully Dressed Concrete Poles. Two of the interviewed utilities gave MIN UL Values and three of the interviewed utilities gave TUL and MAX UL Values for Fully Dressed Concrete Poles (Figure 2-1 Useful Life Values for Fully Dressed Concrete Poles). For the cross arm component, refer to Section 1.3.1 for Fully Dressed Wood Poles.

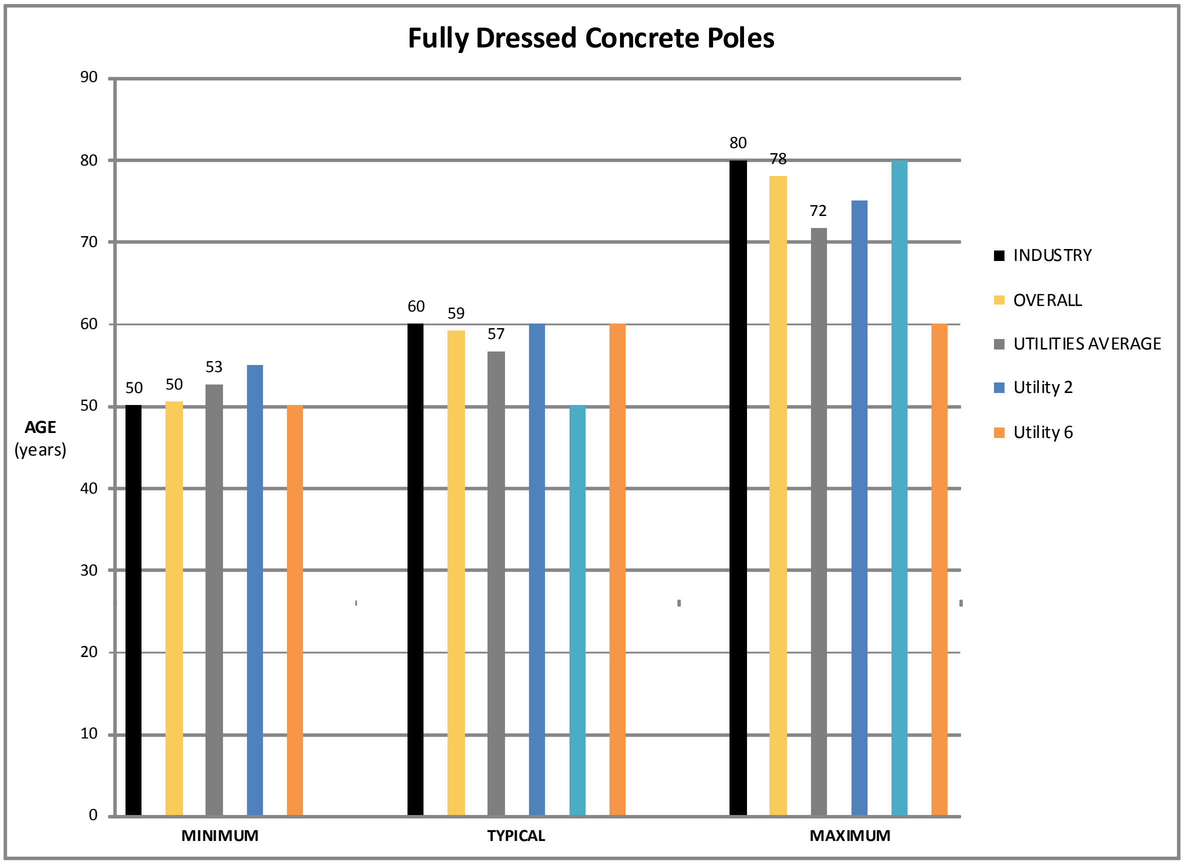


Figure 2-1 Useful Life Values for Fully Dressed Concrete Poles

2.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Fully Dressed Concrete Poles are displayed in Table 2-2.

Table 2-2 - Composite Score for Fully Dressed Concrete Poles

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	92%	25%	58%	0%	13%	0%
Overall Rating*	H	L	M	NI	L	NI
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

2.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Fully Dressed Concrete Poles. Three of the interviewed utilities provided their input regarding the UFs for Fully Dressed Concrete Poles (Figure 1-42).

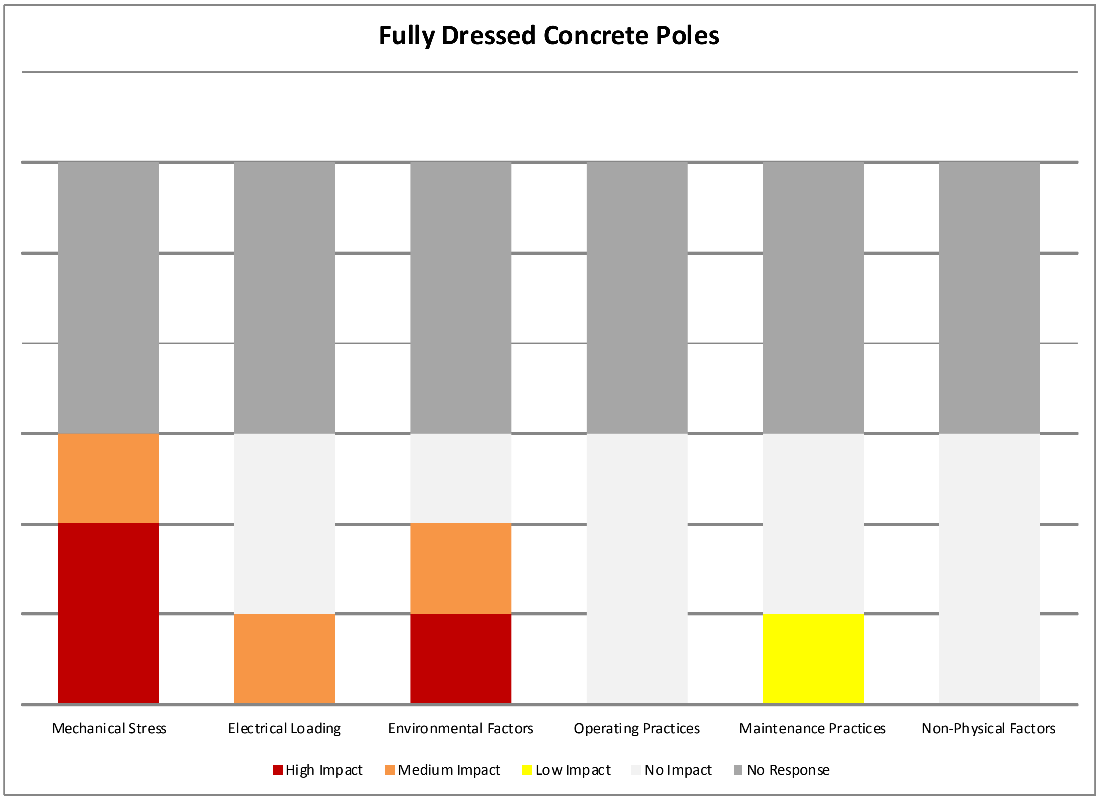


Figure 2-2 Impact of Utilization Factors on the Useful Life of Fully Dressed Concrete Poles

3. Fully Dressed Steel Poles

3.1 Description

The asset referred to in this category is the fully dressed steel pole ranging in size from 30 to 75 feet. This includes the steel pole, cross arm, bracket, insulator, cutouts, arresters, and anchor and guys. Steel poles are an alternative form of support for some overhead distribution feeders, used primarily by urban distribution utilities.

3.1.1 Componentization Assumptions

For the purposes of this report, the Fully Dressed Steel Poles asset category has been componentized so that the cross arm can be regarded as a separate component. Therefore the Fully Dressed Steel Pole has overall useful life values based on the useful life of the pole itself, and separate useful life values for the cross arm component.

3.1.2 System Hierarchy

Fully Dressed Steel Poles are considered to be a part of the Overhead Lines asset grouping.

3.2 Degradation Mechanism

The degradation of directly buried steel poles is mainly due to steel corrosion in-ground and at the ground line. In-ground situations are vastly different from one installation to anther because of the wide local variations in soil chemistry, moisture content and conductivity that will affect the way coated or uncoated steel will perform in the ground. There are two issues that determine the life of buried steel. The first is the life of the protective coating and the second is the corrosion rate of the steel. The item can be deemed to have failed when the steel loss is sufficient to prevent the steel performing its structural function. Where polymer coatings are applied to buried steel items, the failures are rarely caused by general deterioration of the coating. Localized failures due to defects in the coating, pin holing or large-scale corrosion related to electrolysis are common causes of failure in these installations. Metallic coatings, specifically galvanizing, and to a lesser extent aluminum, fail through progressive consumption of the coating by oxidation or chemical degradation. The rate of degradation is approximately linear, and with galvanized coatings of known thickness, the life of the galvanized coating then becomes a function of the coating thickness and the corrosion rate.

3.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Fully Dressed Steel Poles are displayed in Table 3-1.

Table 3-1 Useful Life Values for Fully Dressed Steel Poles

ASSET COMPONENTIZATION		USEFUL LIFE (years)		
		MIN UL	TUL	MAX UL
Overall		60	60	80
Cross Arm	Wood	20	40	55
	Steel	30	70	95

3.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Fully Dressed Steel Poles. Two of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX

UL) Values for Fully Dressed Steel Poles (Figure 3-1). For the cross arm component, refer to Section 1.3.1 for Fully Dressed Wood Poles.

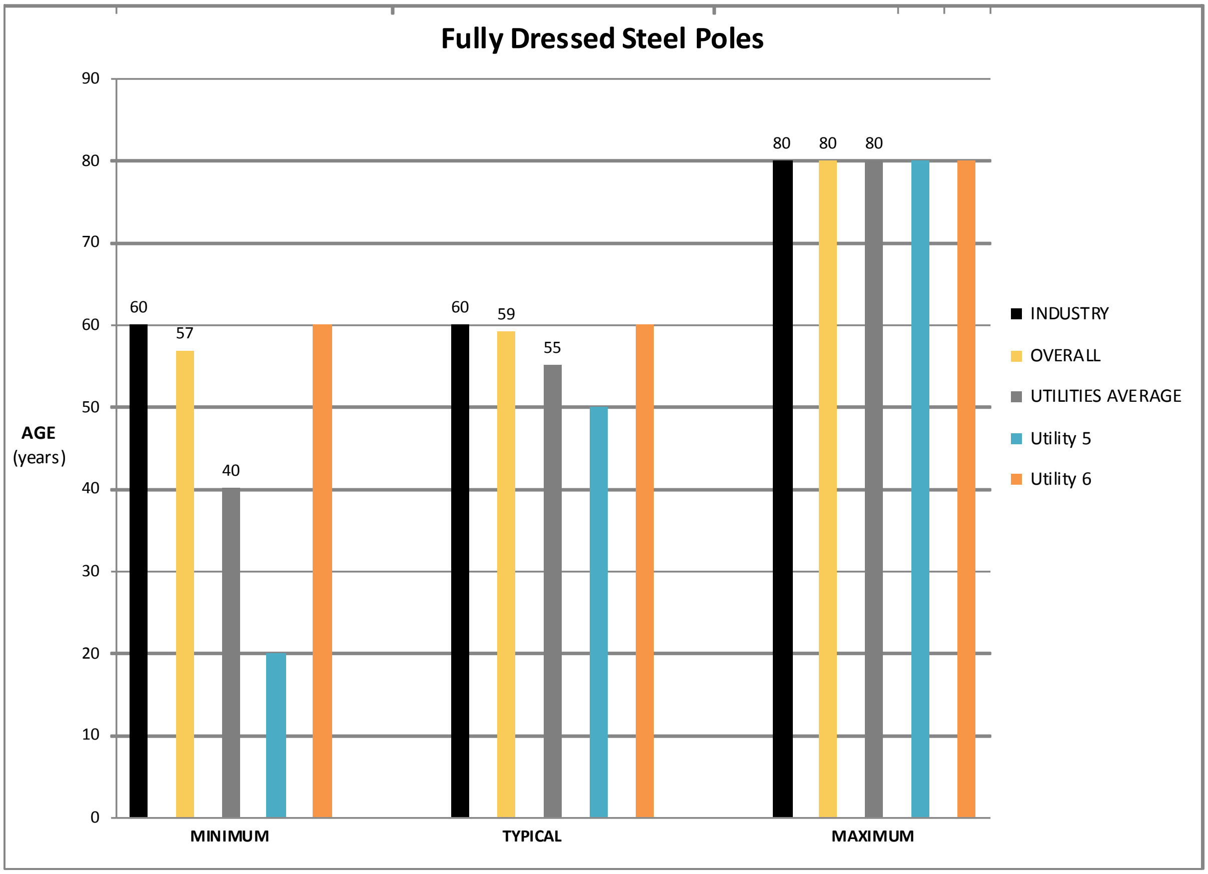


Figure 3-1 Useful Life Values for Fully Dressed Steel Poles

3.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Fully Dressed Steel Poles are displayed in Table 3-2.

Table 3-2 - Composite Score for Fully Dressed Steel Poles

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	88%	56%	38%	0%	19%	0%
Overall Rating*	H	M	L	NI	L	NI
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

3.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Fully Dressed Steel Poles. Two of the interviewed utilities provided their input regarding the UFs for Fully Dressed Steel Poles (Figure 1-42).

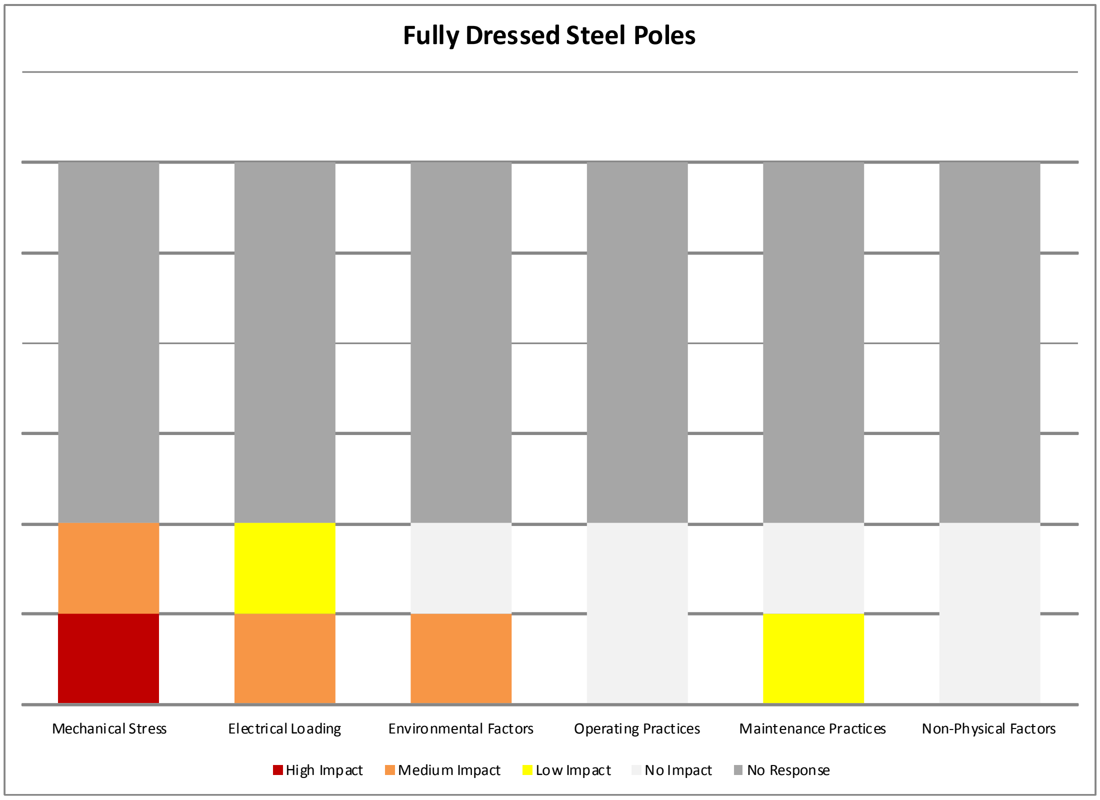


Figure 3-2 Impact of Utilization Factors on the Useful Life of Fully Dressed Steel Poles

4. Overhead Line Switch

4.1 Asset Description

This asset class consists of overhead line switches, focusing primarily on 3-phase outdoor pole-mounted switches but also including in-line switches. The primary function of switches is to allow for isolation of line sections or equipment for maintenance, safety or other operating requirements. The operating mechanism can be either a manual gang operating linkage or a simple hook stick.

4.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Line Switch asset category has not been componentized.

4.1.2 Design Configuration

There are several types of Overhead Line Switches. For the purposes of this report, the types are air, oil, vacuum and gas (SF6). Also for the purpose of this study it is considered that the switch type does not make a significant difference to the degradation or useful life of this asset.

4.1.3 System Hierarchy

Overhead Line Switch is considered to be a part of the Overhead Lines asset grouping.

4.2 Degradation Mechanism

The main degradation processes associated with overhead line switches include the following, with rate and severity depending on operating duties and environment:

- Corrosion of steel hardware or operating rod
- Mechanical deterioration of linkages
- Switch blades falling out of alignment
- Loose connections
- Insulators damage

The rate and severity of these degradation processes depends on a number of inter-related factors including the operating duties and environment in which the equipment is installed. In most cases, corrosion or rust represents a critical degradation process. The rate of deterioration depends heavily on environmental conditions in which the equipment operates. Corrosion typically occurs around the mechanical linkages of these switches. Corrosion can cause seizing. When lubrication dries out, the switch operating mechanism may seize making the disconnect switch inoperable. In addition, when blades fall out of alignment, excessive arcing may result. While a lesser mode of degradation, air pollution also can affect support insulators. Typically, this occurs in heavy industrial areas or where road salt is used.

4.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Line Switch are displayed in Table 4-1.

Table 4-1 Useful Life Values for Overhead Line Switch

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Line Switch	30	45	55

4.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Line Switch. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Line Switch (Figure 4-1).

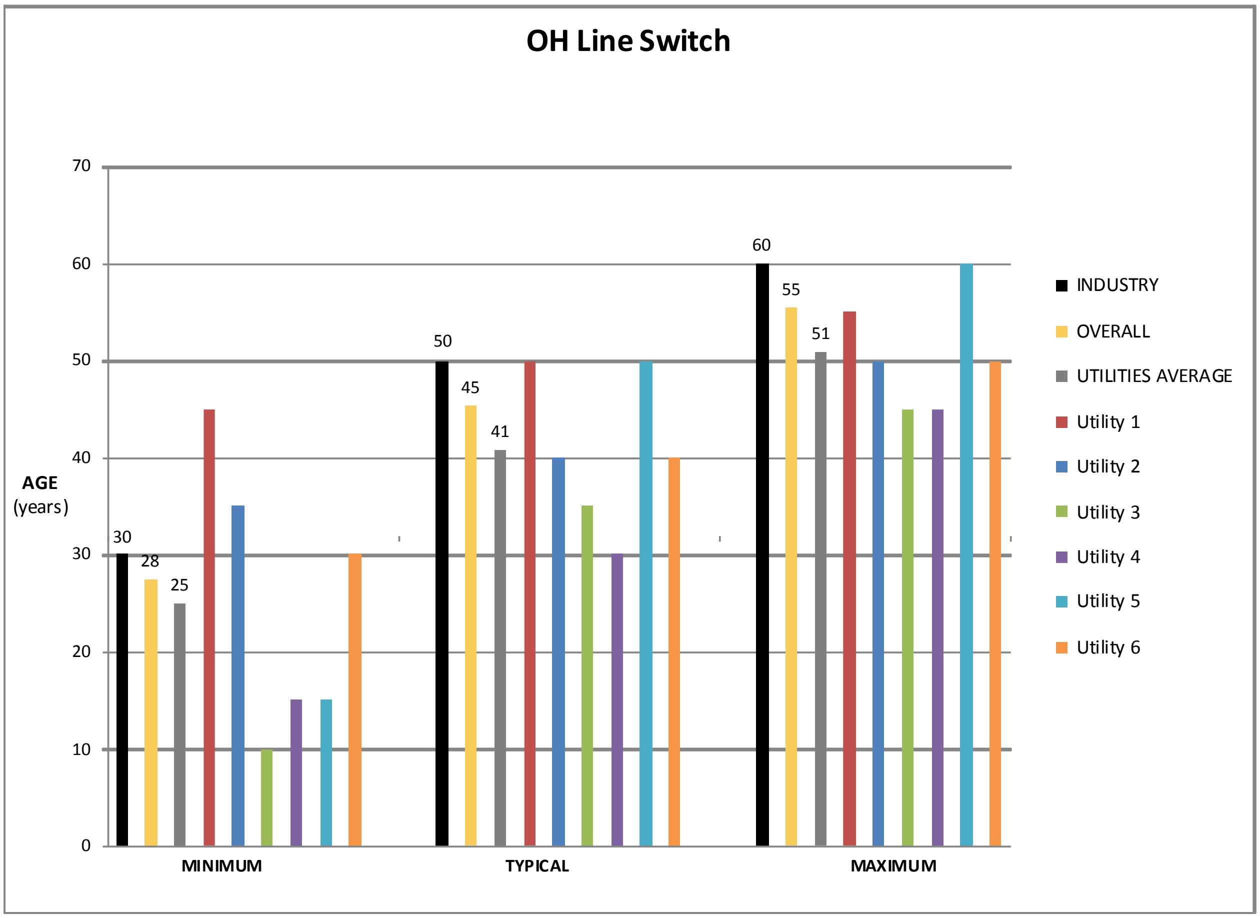


Figure 4-1 Useful Life Values for Overhead Line Switch

4.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Line Switch are displayed in Table 4-2.

Table 4-2 - Composite Score for Overhead Line Switch

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	35%	25%	35%	44%	65%	42%
Overall Rating*	**L**	**L**	**L**	**L**	**M**	**L**

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

4.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Line Switch. All six of the interviewed utilities provided their input regarding the UFs for Overhead Line Switches (Figure 1-42).

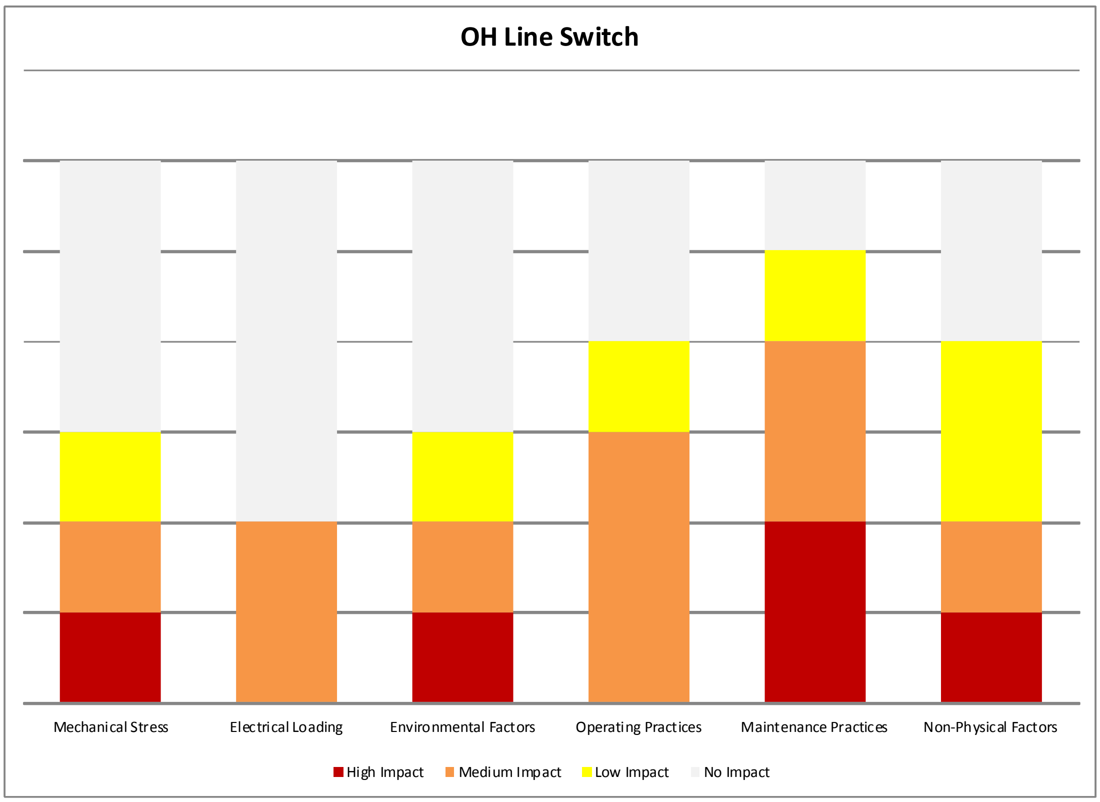


Figure 4-2 Impact of Utilization Factors on the Useful Life of Overhead Line Switch

5. Overhead Line Switch Motor

5.1 Asset Description

This asset class consists of the motor component of overhead line three-phase, gang operated switches. The primary function of switches is to allow for isolation of line sections or equipment for maintenance, safety or other operating requirements. .

5.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Line Switch Motor asset category has not been componentized.

5.1.2 System Hierarchy

Overhead Line Switch Motor is considered to be a part of the Overhead Lines asset grouping.

5.2 Degradation Mechanism

The main degradation processes associated with local motor for operating overhead switches include the following:

- Corrosion of the housing
- Mechanical deterioration of linkages and bearings
- Loose connections
- Winding deterioration

The rate and severity of degradation are a function on operating duties and environment.

5.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Line Switch Motor are displayed in Table 5-1.

Table 5-1 Useful Life Values for Overhead Line Switch Motor

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Line Switch Motor	15	25	25

5.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Line Switch Motor. Four of the interviewed utilities gave Minimum and Maximum Useful Life (Min UL and MAX UL) Values and five of the interviewed utilities gave TUL Values for Overhead Line Switch Motor (Figure 5-1).

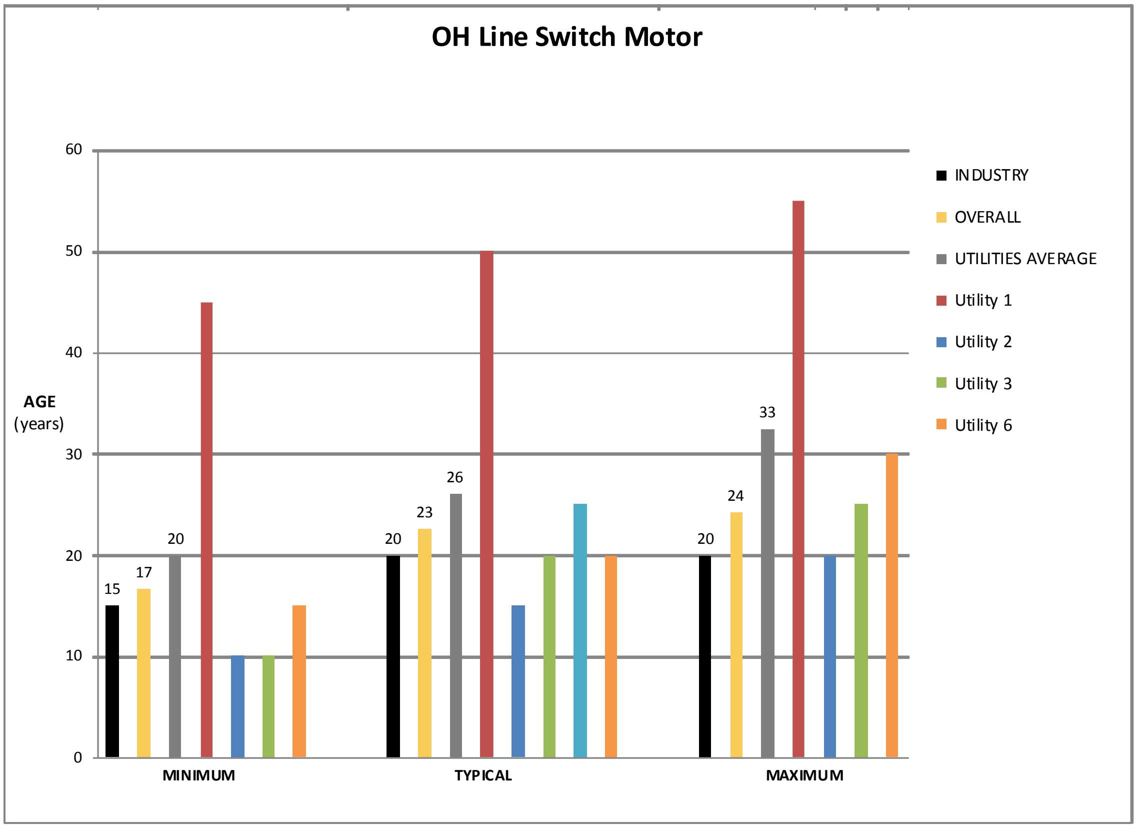


Figure 5-1 Useful Life Values for Overhead Line Switch Motor

5.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Line Switch Motor are displayed in Table 5-2.

Table 5-2 - Composite Score for Overhead Line Switch Motor

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	35%	0%	20%	30%	50%	33%
Overall Rating*	**L**	**NI**	**L**	**L**	**M**	**L**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

5.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Line Switch Motor. Five of the interviewed utilities provided their input regarding the UFs for Overhead Line Switch Motors (Figure 1-42).

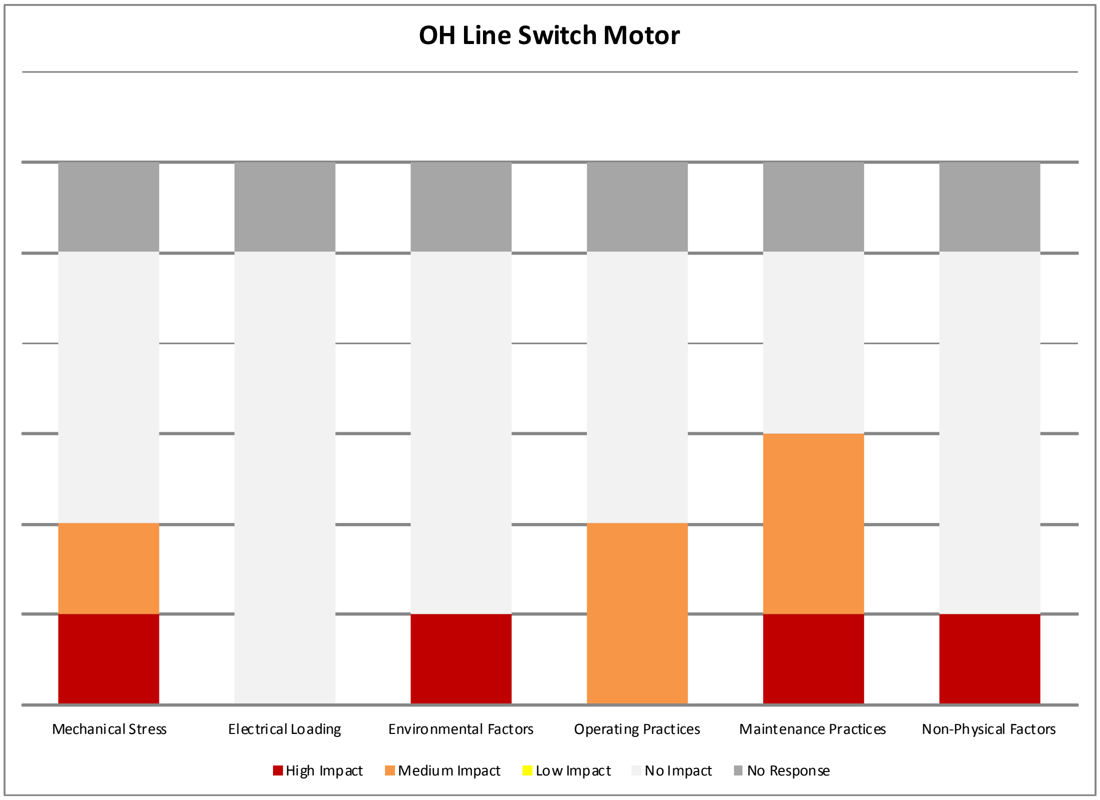


Figure 5-2 Impact of Utilization Factors on the Useful Life of Overhead Line Switch Motor

6. Overhead Line Switch Remote Terminal Unit

6.1 Asset Description

This asset class consists of remote terminal unit (RTU) component of overhead line three-phase, gang operated switches. The primary function of switches is to allow for isolation of line sections or equipment for maintenance, safety or other operating requirements.

6.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Line Switch Remote Terminal Unit asset category has not been componentized.

6.1.2 System Hierarchy

Overhead Line Switch Remote Terminal Unit is considered to be a part of the Overhead Lines asset grouping.

6.2 Degradation Mechanism

The main degradation processes associated with the remote terminal units include the following:

- Corrosion of the housing
- Contamination of the circuitry
- Loose connections
- Failure of electronic components

The rate and severity of degradation are a function on operating duties and environment.

6.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Line Switch Remote Terminal Unit are displayed in Table 6-1.

Table 6-1 Useful Life Values for Overhead Line Switch Remote Terminal Unit

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Line Switch RTU	15	20	20

6.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Line Switch Remote Terminal Unit. Four of the interviewed utilities gave Typical and Maximum Useful Life (TUL and MAX UL) Values and five of the interviewed utilities gave MIN UL Values for Overhead Line Switch Remote Terminal Unit (Table 6-1).

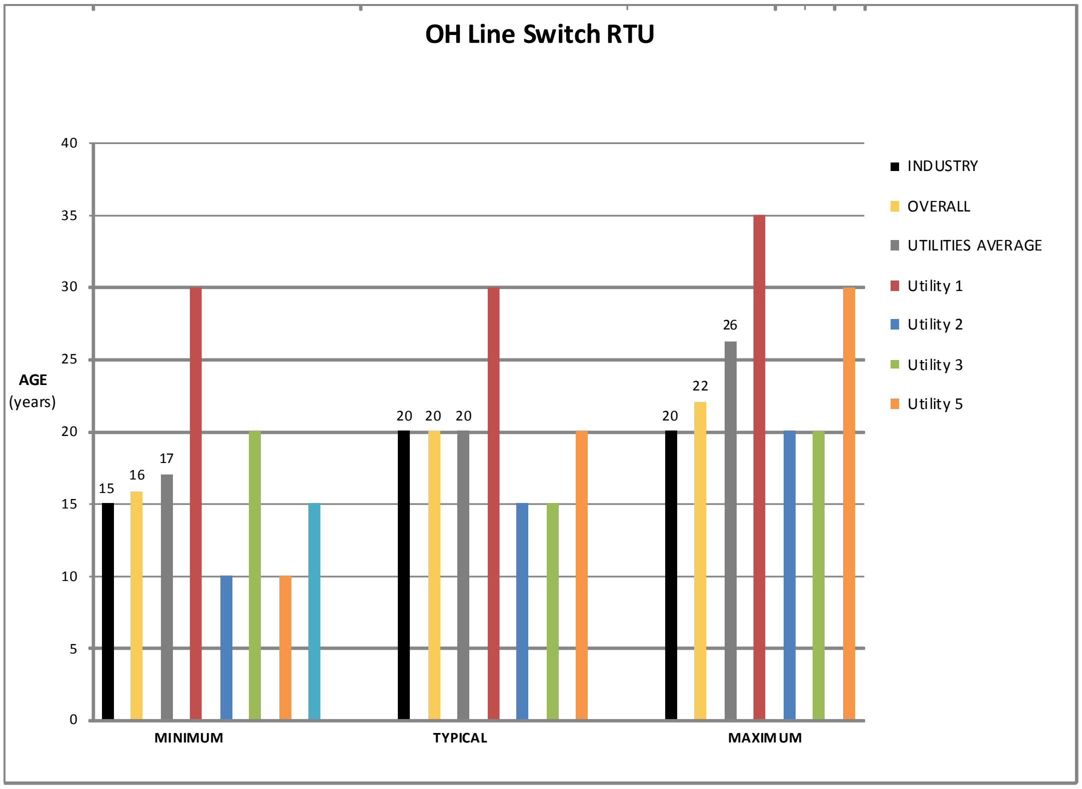


Figure 6-1 Useful Life Values for Overhead Line Switch Remote Terminal Unit

6.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Line Switch Remote Terminal Unit are displayed in Table 6-2.

Table 6-2 - Composite Score for Overhead Line Switch Remote Terminal Unit

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	0%	0%	28%	15%	30%	75%
Overall Rating*	**NI**	**NI**	**L**	**L**	**L**	**M**

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

6.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Line Switch Remote Terminal Unit. Five of the interviewed utilities provided their input regarding the UFs for Overhead Line Switch RTUs (Figure 1-4).

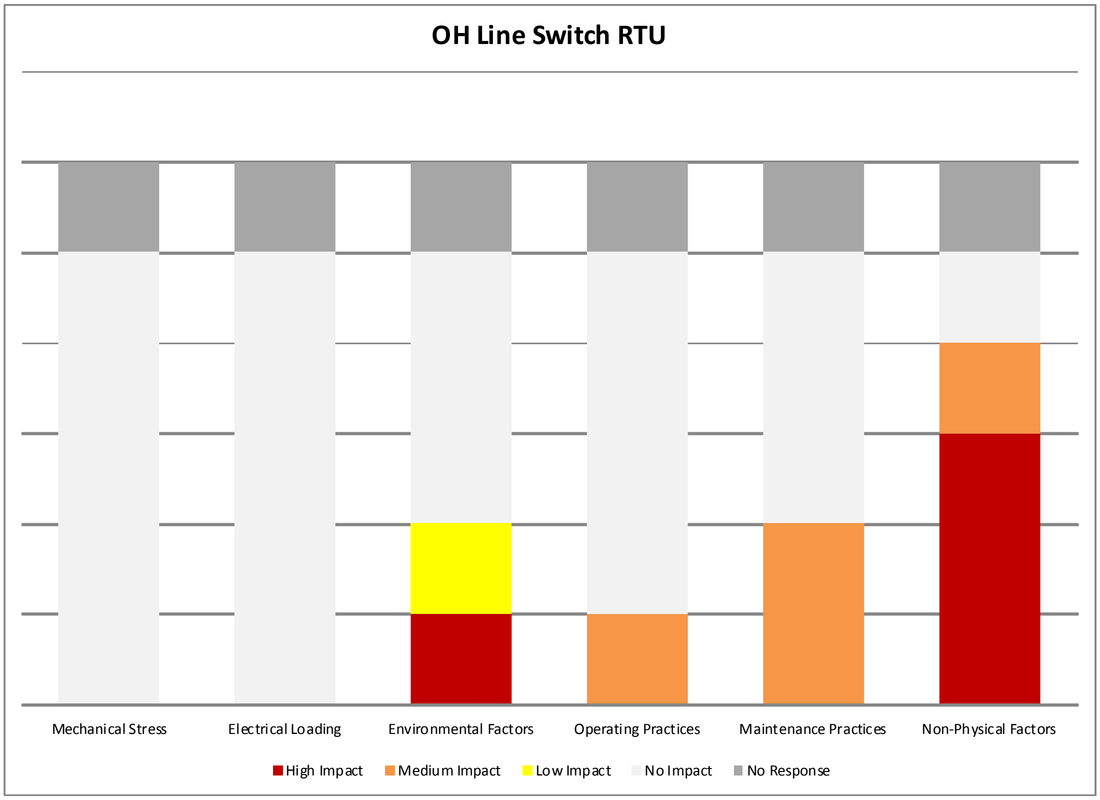


Figure 6-2 Impact of Utilization Factors on the Useful Life of Overhead Line Switch Remote Terminal Unit

7. Overhead Integral Switch

7.1 Asset Description

This asset class consists of integral switches. Integral switches are considered to be overhead line switches with integrated remotely operable opening and closing mechanisms and communication capability that can receive signals from and be monitored by a SCADA system. These units include the switch, communications, and RTU. As with other line switches, this asset allows for the isolation of overhead line sections or equipment for maintenance, safety, and any other operating requirements.

7.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Integral Switch asset category has not been componentized.

7.1.2 System Hierarchy

Overhead Integral Switch is considered to be a part of the Overhead Lines asset grouping.

7.2 Degradation Mechanism

The main degradation processes associated with line switches include those associated with the switch, motor and communication circuitry:

- Corrosion of the housing, hardware and linkages
- Mechanical deterioration of linkages and bearings
- Loose connections
- Motor winding deterioration
- Contamination of the circuitry
- Failure of electronic components
- Switch blades falling out of alignment
- Insulators damage

7.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Integral Switch are displayed in Table 7-1.

Table 7-1 Useful Life Values for Overhead Integral Switch

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Integral Switches	35	45	60

7.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Integral Switch. Three of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Integral Switch (Figure 7-1).

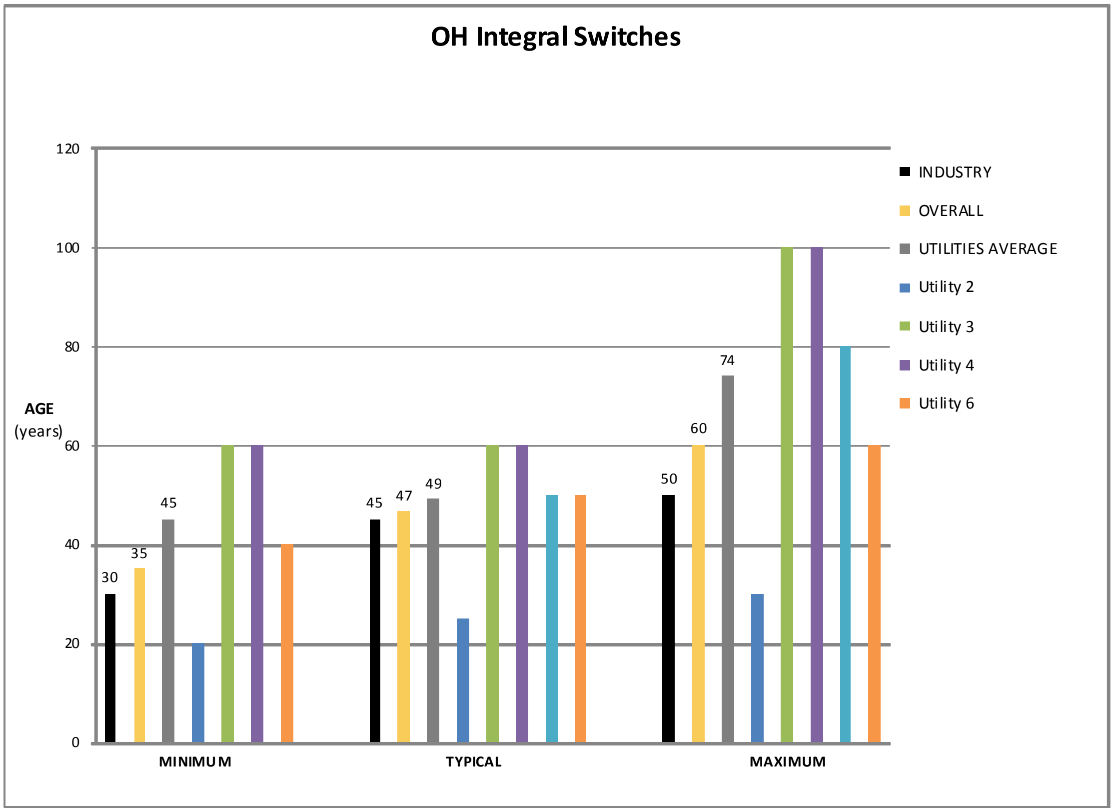


Figure 7-1 Useful Life Values for Overhead Integral Switch

7.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Integral Switch are displayed in Table 7-2.

Table 7-2 - Composite Score for Overhead Integral Switch

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	13%	50%	46%	67%	25%	100%
Overall Rating*	**L**	**M**	**M**	**M**	**L**	**H**

* H = High Impact   M = Medium Impact   L = Low Impact   NI = No Impact

7.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Integral Switch. Three of the interviewed utilities provided their input regarding the UFs for Overhead Integral Switches (Figure 1-42).

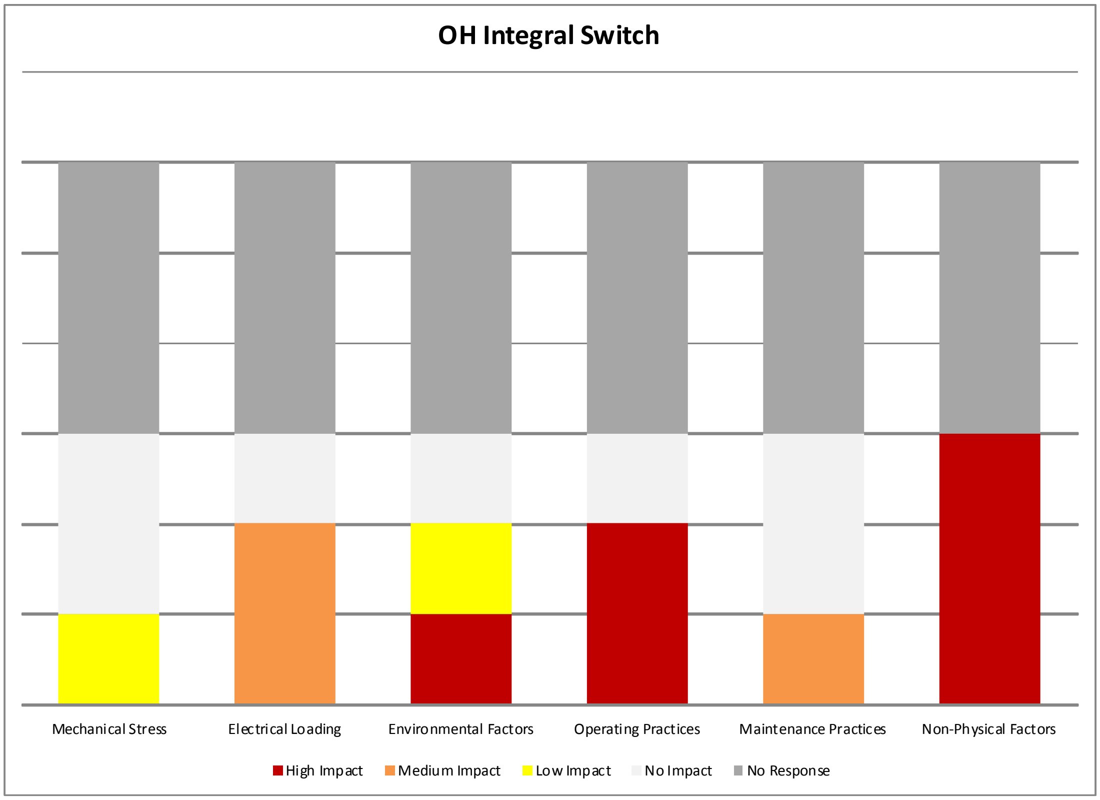


Figure 7-2 Impact of Utilization Factors on the Useful Life of Overhead Integral Switch

8. Overhead Conductors

8.1 Asset Description

Overhead conductors along with structures that support them constitute overhead lines or feeders that distribute electrical energy to customers from the distribution or transmission station. These conductors are sized to carry a specified maximum current and to meet other design criteria, i.e. mechanical loading.

8.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Conductors asset category has not been componentized.

8.1.2 Design Configuration

There are several types of Overhead Line Switches. For the purposes of this report, the types are aluminum conductor steel reinforced (ACSR), all aluminum conductor (AAC), and copper.

8.1.3 System Hierarchy

Overhead Conductors is considered to be a part of the Overhead Lines asset grouping.

8.2 Degradation Mechanism

To function properly, conductors must retain both their conductive properties and mechanical (i.e. tensile) strength. Aluminum conductors have three primary modes of degradation: corrosion, fatigue and creep. The rate of each degradation mode depends on several factors, including the size and construction of the conductor, as well as environmental and operating conditions. Most utilities find that corrosion and fatigue present the most critical forms of degradation.

Generally, corrosion represents the most critical life-limiting factor for aluminum-based conductors. Visual inspection cannot detect corrosion readily in conductors. Environmental conditions affect degradation rates from corrosion. Both aluminum and zinc-coated steel core conductors are particularly susceptible to corrosion from chlorine-based pollutants, even in low concentrations.

Fatigue degradation presents greater detection and assessment challenges than corrosion degradation. In extreme circumstances, under high tensions or inappropriate vibration or galloping control, fatigue can occur in very short timeframes. However, under normal operating conditions, with proper design and application of vibration control, fatigue degradation rates are relatively slow. Under normal circumstances, widespread fatigue degradation is not commonly seen in conductors less than 70 years of age. Also, in many cases detectable indications of fatigue may only exist during the last 10% of a conductor’s life.

In designing distribution lines, engineers ensure that conductors have adequate rated tensile strength (RTS) to withstand the heaviest anticipated weather loads. The tensile strength of conductors gradually decreases over time. When conductors experience unexpectedly large mechanical loads and tensions, they begin to undergo permanent stretching with noticeable increases in sagging.

Overloading lines beyond their thermal capacity causes elevated operating temperatures. When operating at elevated temperatures, aluminum conductors begin to anneal and lose tensile strength. Each elevated temperature event adds further damage to the conductor. After a loss of 10% of a conductor’s RTS, significant sag occurs, requiring either re-sagging or replacement of the conductor.

Phase to phase power arcs can result from conductor galloping during severe storm events. This can cause localized burning and melting of a conductor’s aluminum strands, reducing strength at those sites and potentially leading to conductor failures. Visual inspection readily detects arcing damage.

Other forms of conductor damage include:

- Broken strands (i.e., outer and inners)
- Strand abrasion
- Elongation (i.e., change in sags and tensions)
- Burn damage (i.e., power arc/clashing)
- Birdcaging

The degradation of copper wire is mostly due to corrosion. Oxidization gives copper a high resistance to corrosion. Derivatives of chlorine and sulfur contained in coastal atmospheres start the oxidation by forming a blackish or greenish film. The film is very dense, has low solubility, high electric resistance and high resistance to chemical attack and to corrosion. Despite this, mechanical vibrations, abrasion, erosion and thermal variations may cause fissures and faults in this layer. When this happens, the metal is uncovered and corrosion may occur. Also electrolytes with low chlorine content could enter, causing a change in the chemical passivity. This may also be the result of a deficit of oxygen which would make the area anodic and rapidly accelerate corrosion.

Note that the weather protection and insulation on the Cables is for improving reliability of the distribution system as opposed to improving the useful life of this asset. The conductive properties of the wire are what degradation impacts, although Utilities may choose to replace weather protected cables if called for by their own system reliability practices.

8.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Conductors are displayed in Table 8-1.

Table 8-1 Useful Life Values for Overhead Conductors

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Conductors	50	60	75

8.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Conductors. Four of the interviewed utilities gave Minimum (Min UL) Values and five of the interviewed utilities gave TUL and MAX UL Values for Overhead Conductors (Figure 8-1).

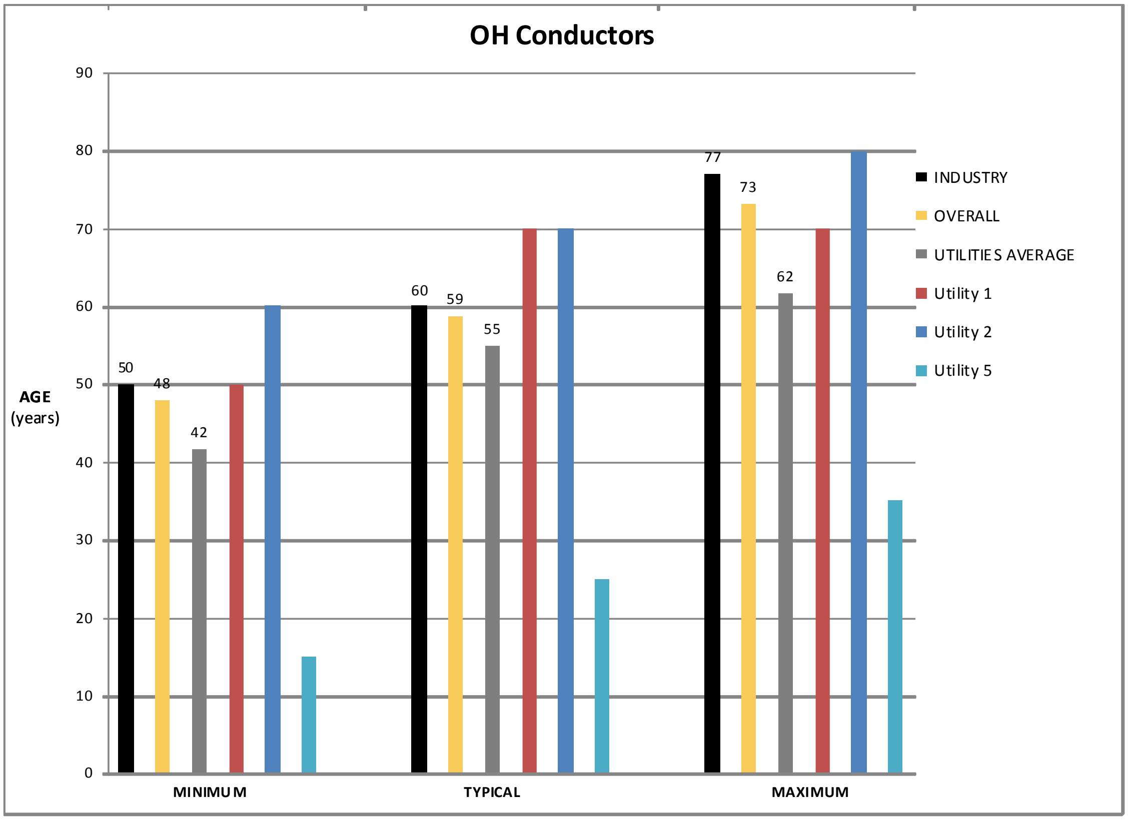


Figure 8-1 Useful Life Values for Overhead Conductors

8.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Conductors are displayed in Table 8-1.

Table 8-2 Composite Score for Overhead Conductors

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	50%	38%	65%	0%	8%	28%
Overall Rating*	M	L	M	NI	NI	L
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

8.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Conductors. Five of the interviewed utilities provided their input regarding the UFs for Overhead Conductors (Figure 1-42).

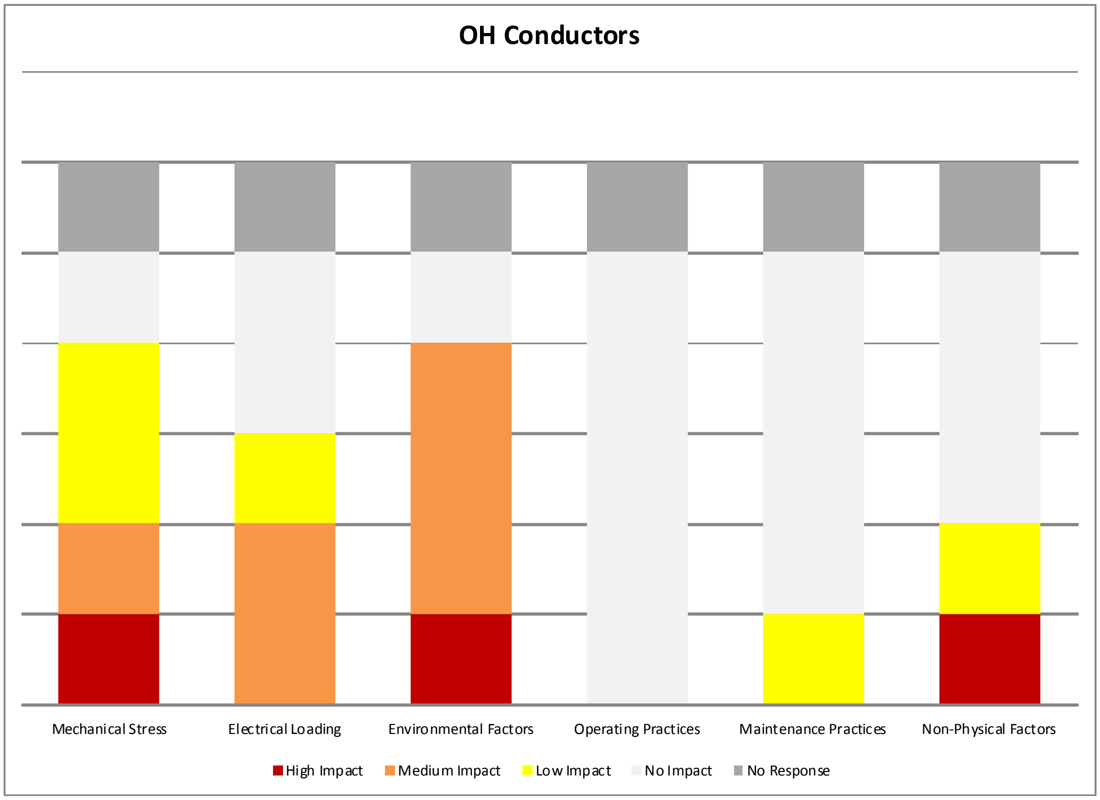


Figure 8-2 Impact of Utilization Factors on the Useful Life of Overhead Conductors

9. Overhead Transformers and Voltage Regulators

9.1 Asset Description

Distribution pole top transformers change sub-transmission or primary distribution voltages to secondary voltages such as 120/240 V or other common voltages for use in residential and commercial applications.

9.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Transformers and Voltage Regulators asset category has not been componentized.

9.1.2 Design Configuration

For the purposes of this report, Overhead Transformers and Voltage Regulators refers to both single phase and three phase Transformers.

9.1.3 System Hierarchy

Overhead Transformers and Voltage Regulators is considered to be a part of the Overhead Lines asset grouping.

9.2 Degradation Mechanism

It has been demonstrated that the life of the transformer's internal insulation is related to temperature-rise and duration. Therefore, transformer life is affected by electrical loading profiles and length of time in service. Other factors such as mechanical damage, exposure to corrosive salts, and voltage and current surges also have a strong effect. Therefore, a combination of condition, age and load based criteria is commonly considered in determining the useful remaining life of distribution transformers.

The impacts of loading profiles, load growth, and ambient temperature on asset condition, loss-of-life, and life expectancy can be assessed using methods outlined in ANSI/IEEE Loading Guides. This also provides an initial baseline for the size of transformer that should be selected for a given number and type of end users to obtain optimal life.

The life of the voltage regulator's internal insulation is related to temperature-rise and duration. Therefore, voltage regulator life is affected by electrical loading profiles and length of time in service. Other factors such as mechanical damage, exposure to corrosive salts, and voltage and current surges also have a strong effect. Therefore, a combination of condition, age and load based criteria is commonly considered in determining the useful remaining life of voltage regulators.

The impacts of loading profiles, load growth, and ambient temperature on asset condition, loss-of-life, and life expectancy can be assessed. There is also the operating practice affect on voltage regulators in terms of the number of operations that it is required to perform on a daily basis.

9.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Transformers and Voltage Regulators are displayed in Table 9-1.

Table 9-1 Useful Life Values for Overhead Transformers and Voltage Regulators

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Transformers	30	40	60

9.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Transformers and Voltage Regulators. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Transformers and Voltage Regulators (Figure 9-1).

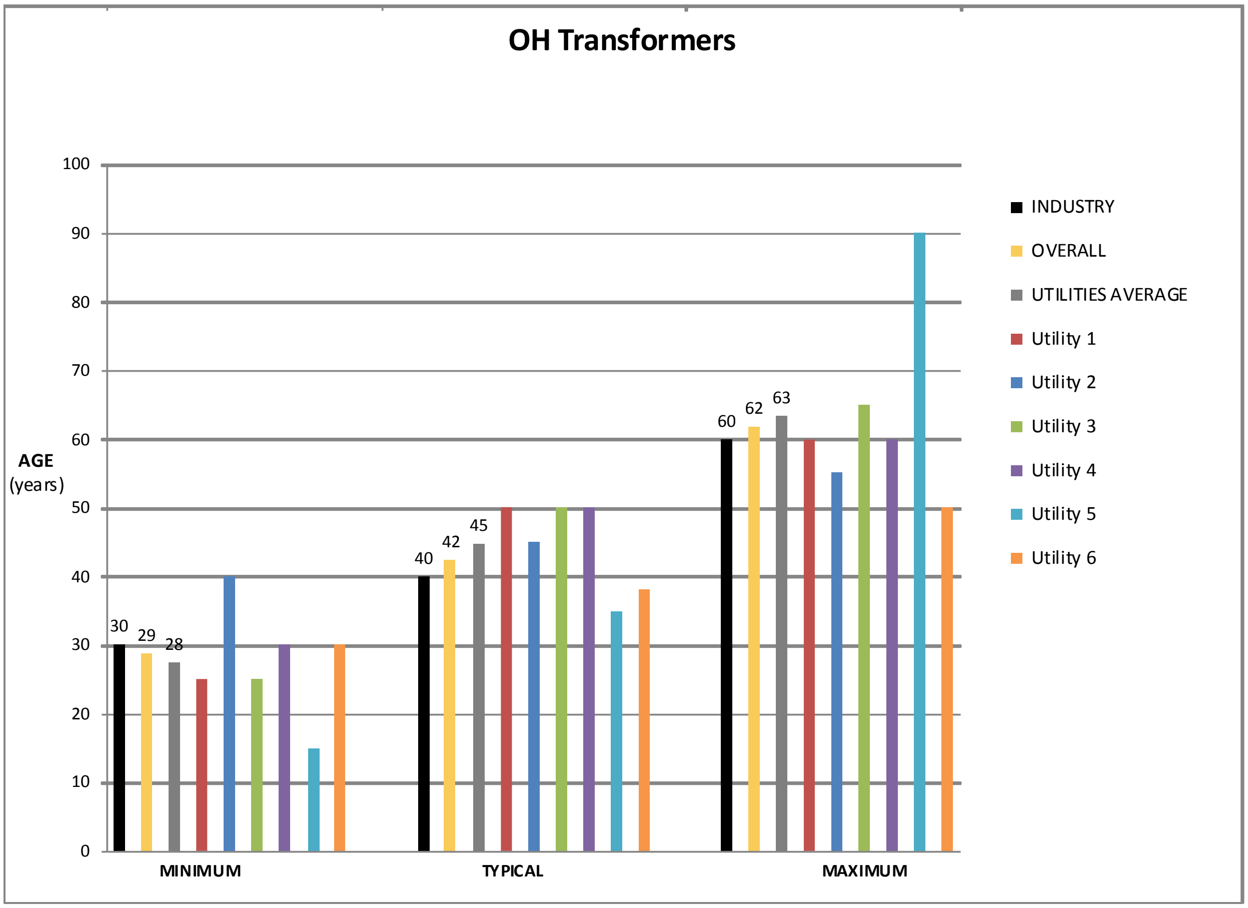


Figure 9-1 Useful Life Values for Overhead Transformers and Voltage Regulators

9.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Transformers and Voltage Regulators are displayed in Table 9-2.

Table 9-2 - Composite Score for Overhead Transformers and Voltage Regulators

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	13%	65%	56%	0%	6%	58%
Overall Rating*	**L**	**M**	**M**	**NI**	**NI**	**M**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

9.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Transformers and Voltage Regulators. All six of the interviewed utilities provided their input regarding the UFs for Overhead Transformers (Figure 1-42).

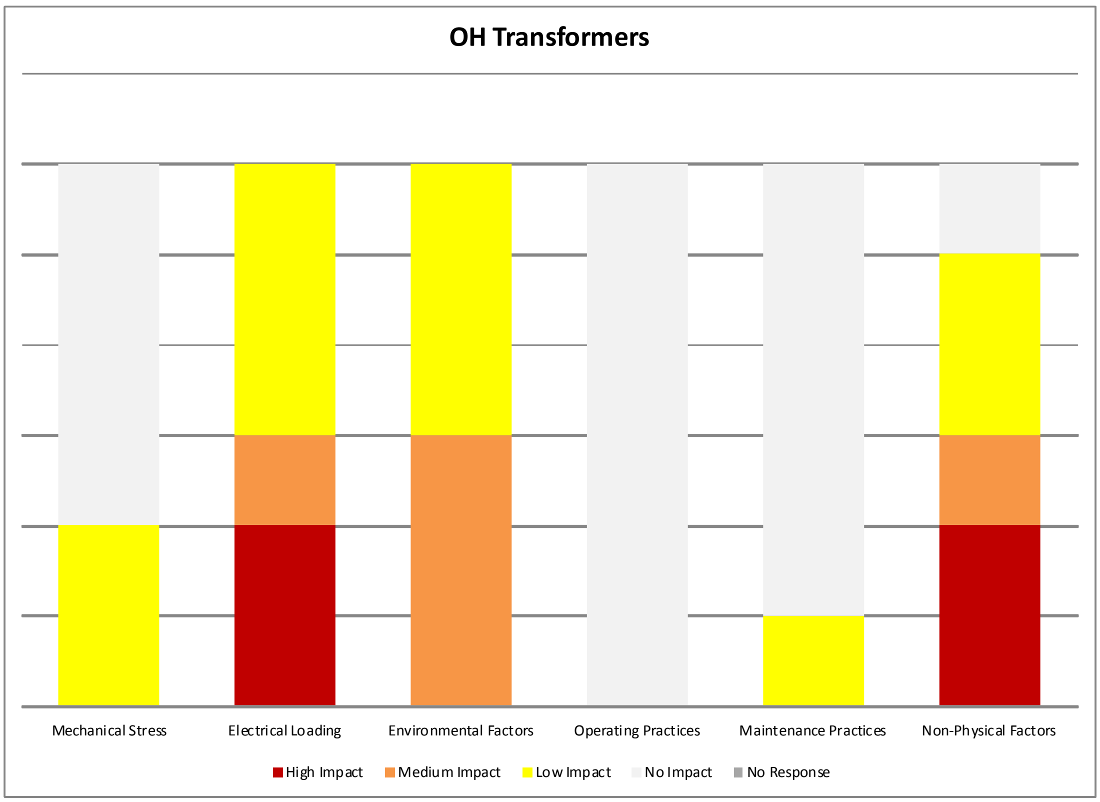


Figure 9-2 Impact of Utilization Factors on the Useful Life of Overhead Transformers and Voltage Regulators

10. Overhead Shunt Capacitor Banks

10.1 Asset Description

This asset category refers to pole mounted shunt capacitor banks and their supporting hardware. The capacitor bank also includes the control switches and devices, fuse cutout, surge arrester and in some cases current-limiting fuses. Shunt capacitors regulate voltage in distribution systems, and provide reactive compensation.

10.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Shunt Capacitor Banks asset category has not been componentized.

10.1.2 System Hierarchy

Overhead Shunt Capacitor Banks is considered to be a part of the Overhead Lines asset grouping.

10.2 Degradation Mechanism

The major degradation of overhead capacitor banks is related to the capacitors themselves. They are exposed to detrimental environmental factors including: extreme temperatures, contamination, birds etc. They also experience steady state, transient and dynamic over voltage conditions. The switching devices add an additional stress to the capacitors. These environmental conditions, electrical loading and operating practices cause non-reversible degradation of the insulation in capacitor units and external insulation.

Fuse and bushing degradation result primarily from the failure of seals (hence moisture seeps in). Based on the surrounding environmental conditions this may cause corrosion of the capacitor units and support frame. Internal degradation can also occur in insulators.

10.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Shunt Capacitor Banks are displayed in Table 10-1 Useful Life Values for Overhead Shunt Capacitor Banks

Table 10-1 Useful Life Values for Overhead Shunt Capacitor Banks

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Shunt Capacitor Banks	25	30	40

10.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Shunt Capacitor Banks. None of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Shunt Capacitor Banks (Figure 10-1).

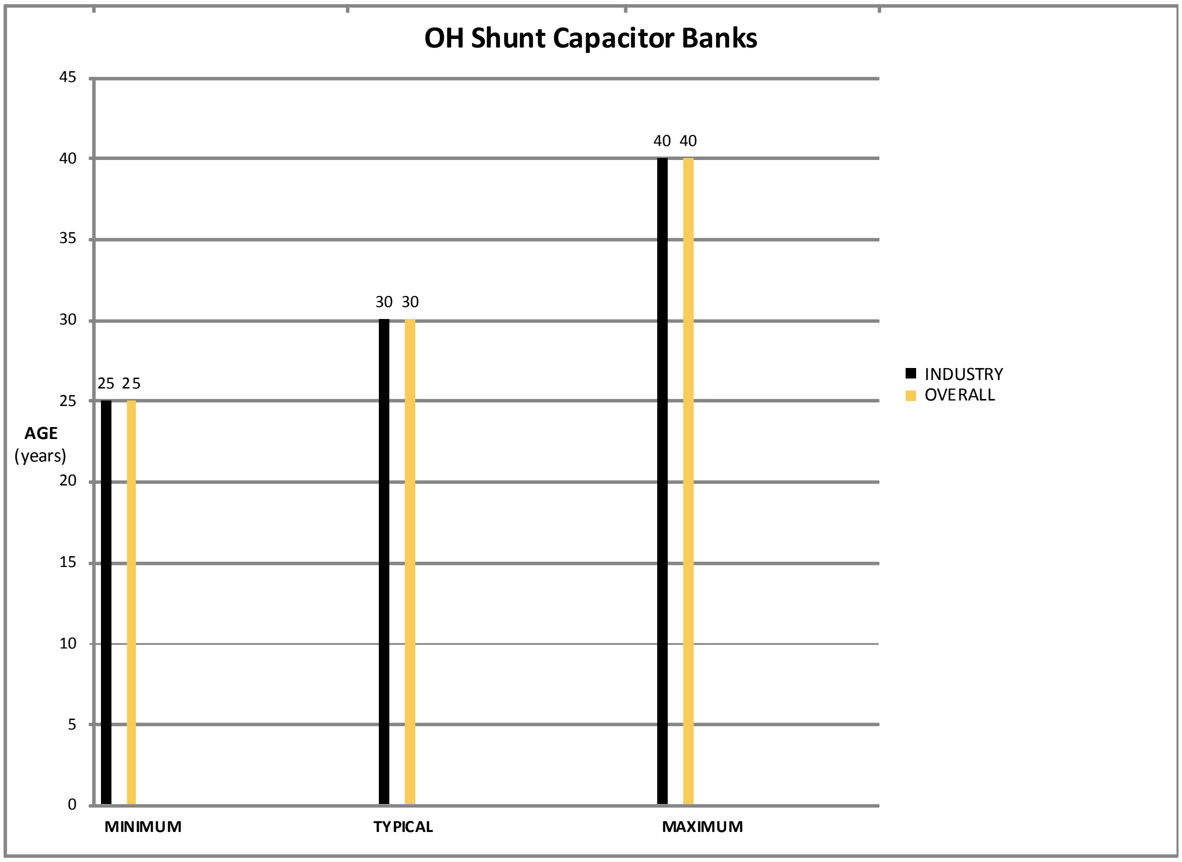


Figure 10-1 Useful Life Values for Overhead Shunt Capacitor Banks

10.4 Impact of Utilization Factors

No Impact of Utilization Factors Data was available from the Utility Interviews.

11. Reclosers

11.1 Asset Description

This asset class consists of reclosers which are light duty circuit breakers equipped with control units. The recloser unit accomplishes the breaking and making of fault current. The interrupters use oil or vacuum as the insulating agent. The controllers are either integral hydraulic or local electric units. Reclosers are designed for either single phase or three phase use.

11.1.1 Componentization Assumptions

For the purposes of this report, the Reclosers asset category has not been componentized.

11.1.2 Design Configuration

There are several circuit breakers types associated with reclosers. For the purposes of this report, the breaker types are oil, gas (SF6) and vacuum.

11.1.3 System Hierarchy

Reclosers are considered to be a part of the Overhead Lines asset grouping.

11.2 Degradation Mechanism

The degradation processes associated with reclosers involves the effects of making and breaking fault current, the mechanism itself and deterioration of components. The effects of making and breaking fault current affect arc suppression devices as well as the contacts, and the oil condition. The degradation of these devices depends on the available fault current, if it is well below the rated capability of the recloser, the deteriorating effects will be small. For the mechanism itself, deterioration or mal-operation of the mechanism causes deterioration during operation. Typically lack of use, corrosion and poor lubrication are the main causes of mechanism malfunction. For deterioration, exposure to weather is a potentially significant degradation process

11.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Reclosers are displayed in Table 11-1.

Table 11-1 Useful Life Values for Reclosers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Reclosers	25	40	55

11.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Reclosers. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Reclosers (Figure 11-1).

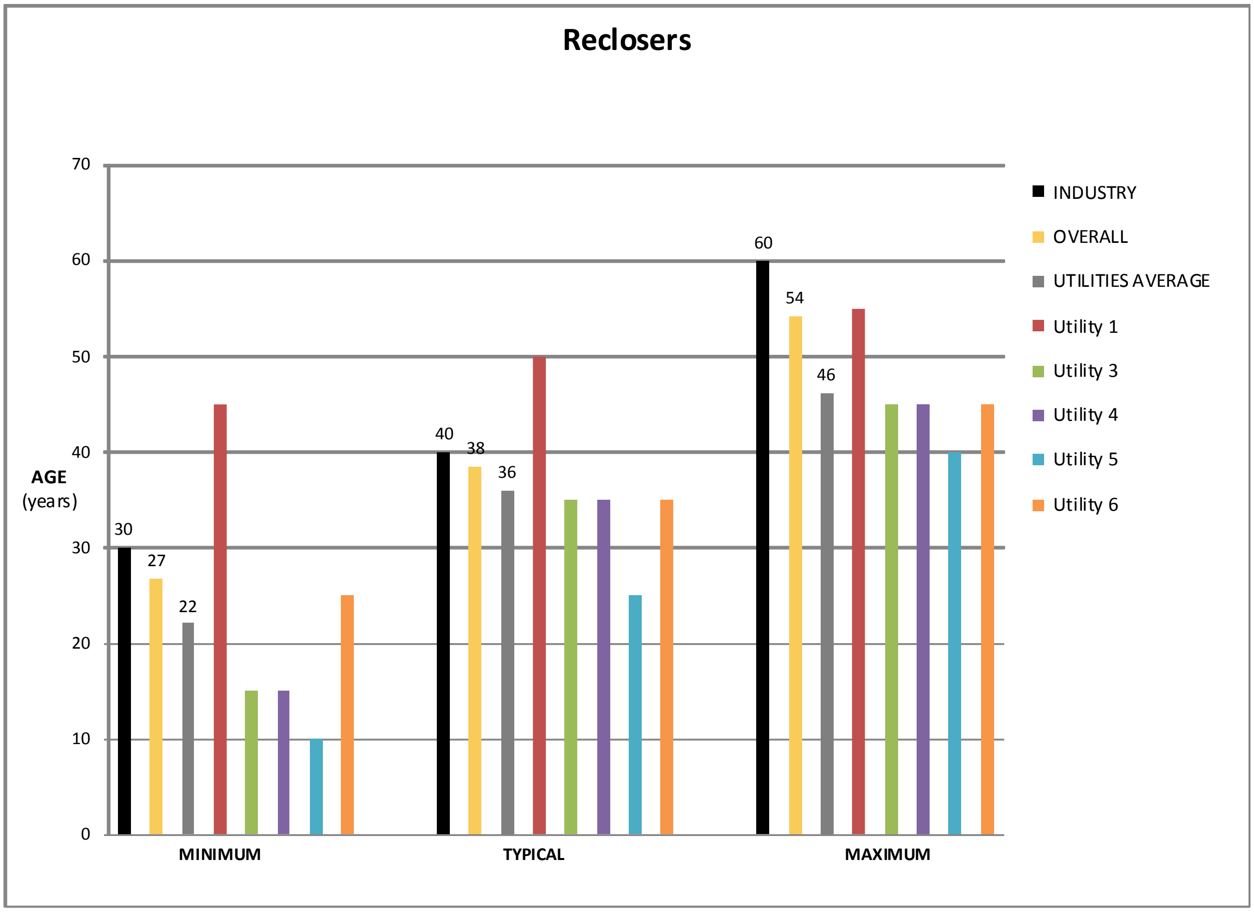


Figure 11-1 Useful Life Values for Reclosers

11.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Reclosers are displayed in Table 11-2.

Table 11-2 - Composite Score for Reclosers

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	15%	38%	38%	53%	23%	55%
Overall Rating*	**L**	**L**	**L**	**M**	**L**	**M**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

11.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Reclosers. Five of the interviewed utilities provided their input regarding the UFs for Reclosers (Figure 1-42).

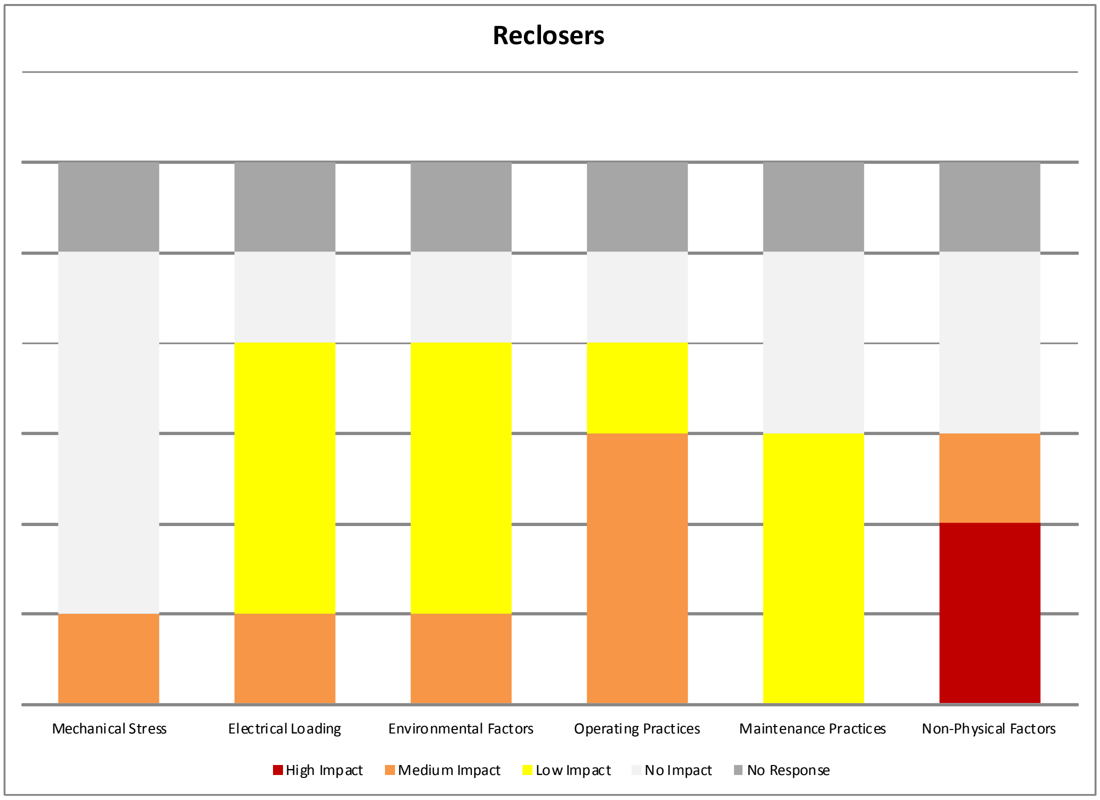


Figure 11-2 Impact of Utilization Factors on the Useful Life of Reclosers

12. Power Transformers

12.1 Asset Description

While power transformers can be employed in either step-up or step-down mode, a majority of the applications in transmission and distribution stations involve step down of the transmission or sub-transmission voltage to distribution voltage levels. Power transformers vary in capacity and ratings over a broad range. There are two general classifications of power transformers: transmission station transformers and distribution station transformers. For transformer stations, when step down from 230kV or 115kV to distribution voltage is required, ratings may range from 30MVA to 125 MVA.

12.1.1 Componentization Assumptions

For the purposes of this report, the Power Transformers asset category has been componentized so that the bushing and tap changer may be regarded as separate components. Therefore the Power Transformer has overall useful life values based on the useful life of the transformer itself and useful life values for the specific components, bushing and tap changer.

12.1.2 System Hierarchy

Power Transformers is considered to be a part of the Transformer and Municipal Stations asset grouping.

12.2 Degradation Mechanism

Transformers operate under many extreme conditions, and both normal and abnormal conditions affect their aging and breakdown. They are subject to thermal, electrical, and mechanical aging. Overloads cause above-normal temperatures, through-faults can cause displacement of coils and insulation, and lightning and switching surges can cause internal localized over-voltages.

For a majority of transformers, end of life is a result of the failure of insulation, more specifically, the failure of pressboard and paper insulation. While the insulating oil can be treated or changed, it is not practical to change the paper and pressboard insulation. The condition and degradation of the insulating oil, however, plays a significant role in aging and deterioration of the transformer, as it directly influences the speed of degradation of the paper insulation. The degradation of oil and paper in transformers is essentially an oxidation process. The three important factors that impact the rate of oxidation of oil and paper insulation are the presence of oxygen, high temperature, and moisture. Particles and acids, as well as static electricity in oil cooled units, also affect the insulation.

Tap changers and bushing are major components of the power transformer. Tap changers are complex mechanical devices and are therefore prone to failure resulting from either mechanical or electrical degradation. Bushings are subject to aging from both electrical and thermal stresses.

12.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Power Transformers are displayed in Table 12-1.

Table 12-1 Useful Life Values for Power Transformers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Overall	30	45	60
Bushing	10	20	30
Tap Changer	20	30	60

12.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Power Transformers. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Power Transformers (Figure 12-1).

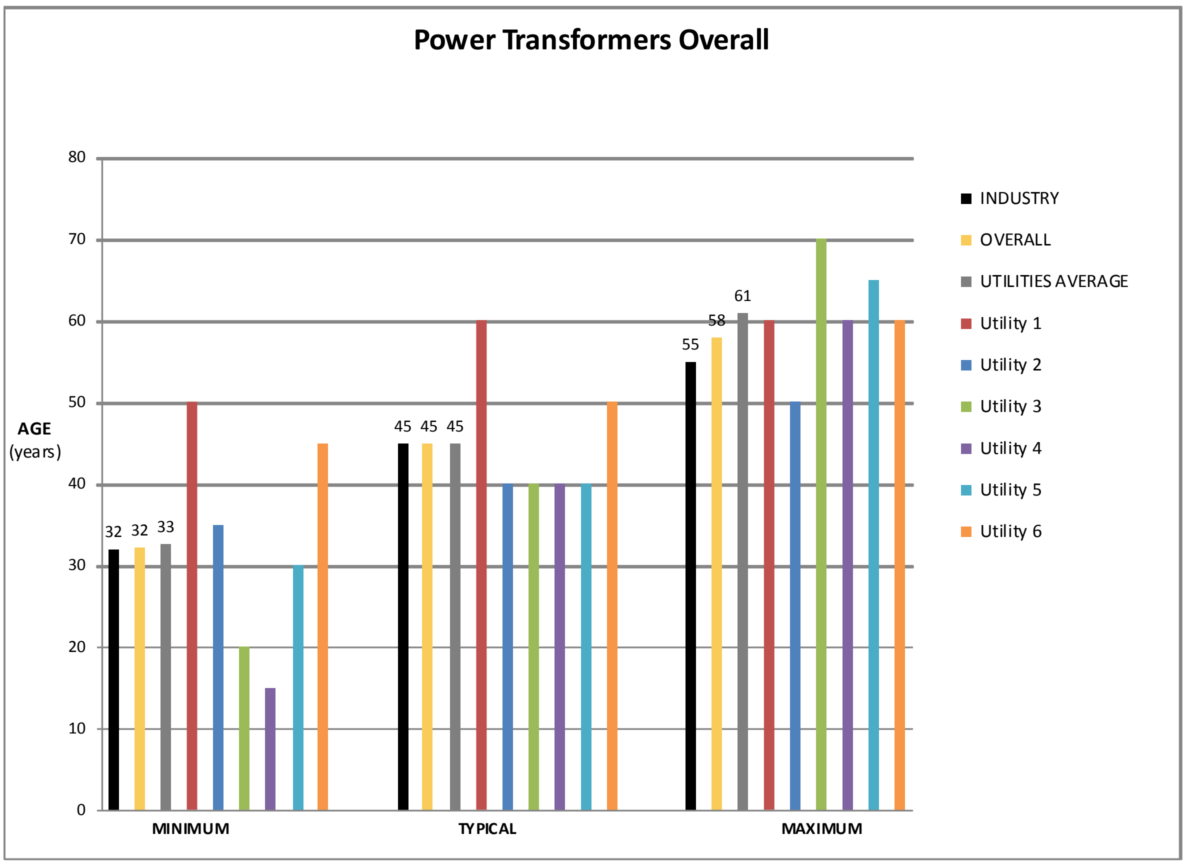


Figure 12-1 Useful Life Values for Power Transformers

12.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Power Transformers are displayed in Table 12-2.

Table 12-2 - Composite Score for Power Transformers

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	0%	75%	50%	44%	42%	0%
Overall Rating*	**NI**	**M**	**M**	**L**	**L**	**NI**

* H = High Impact   M = Medium Impact   L = Low Impact   NI = No Impact

12.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Power Transformers. All six of the interviewed utilities provided their input regarding the UFs for Power Transformers (Figure 12-2).

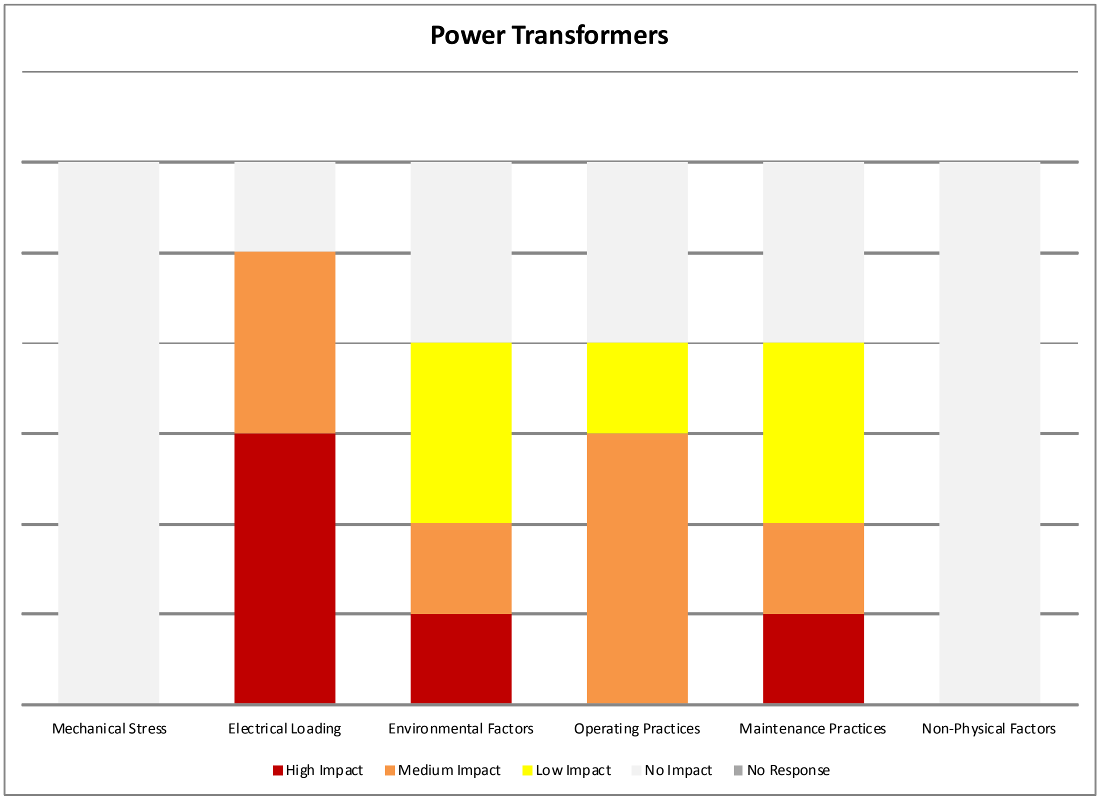


Figure 12-2 Impact of Utilization Factors on the Useful Life of Power Transformers

13. Station Service Transformers

13.1 Asset Description

The station service transformer provides power to the auxiliary equipment, such as fans, pumps, heating, or lighting, in the distribution station. Small power transformers are configured to provide this requirement.

13.1.1 Componentization Assumptions

For the purposes of this report, the Station Service Transformers has not been componentized.

13.1.2 System Hierarchy

Station Service Transformers is considered to be a part of the Transformer and Municipal Stations asset grouping.

13.2 Degradation Mechanism

As with most transformers, end of life is typically a result of insulation failure, particularly paper insulation. The oil and paper insulation degrade as oxidation takes place in the presence of oxygen, high temperature, and moisture. Acids, particles, and static electricity also have degrading effects to the insulation.

13.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Station Service Transformers are displayed in Table 13-1.

Table 13-1 Useful Life Values for Station Service Transformers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Station Service Transformer	30	45	55

13.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Station Service Transformers. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Station Service Transformers (Figure 13-1).

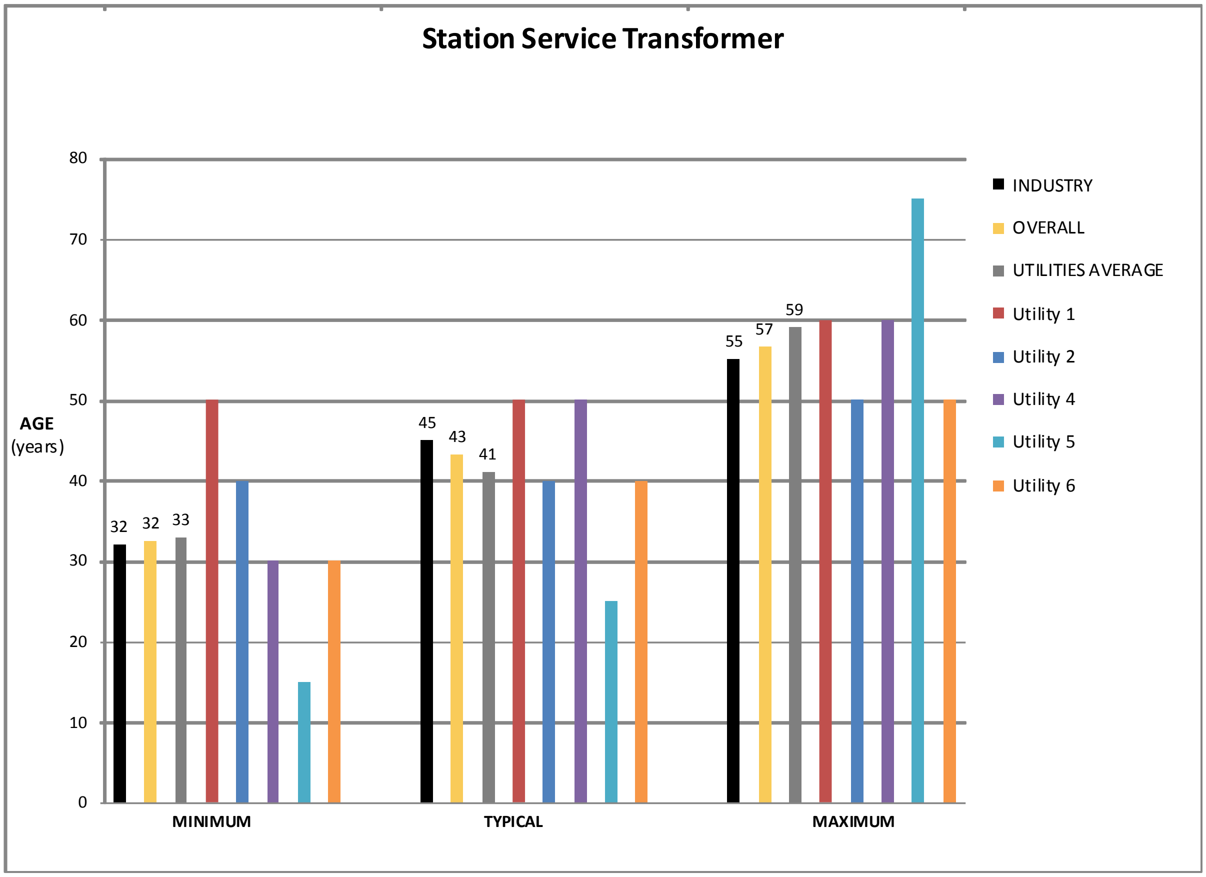


Figure 13-1 Useful Life Values for Station Service Transformers

13.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Station Service Transformers are displayed in Table 13-2.

Table 13-2 - Composite Score for Station Service Transformers

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	0%	35%	65%	15%	8%	40%
Overall Rating*	**NI**	**L**	**M**	**L**	**NI**	**L**
* H = High Impact	M = Medium Impact	L = Low Impact	NI = No Impact			

13.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Station Service Transformers. Five of the interviewed utilities provided their input regarding the UFs for Station Service (Figure 1-42).

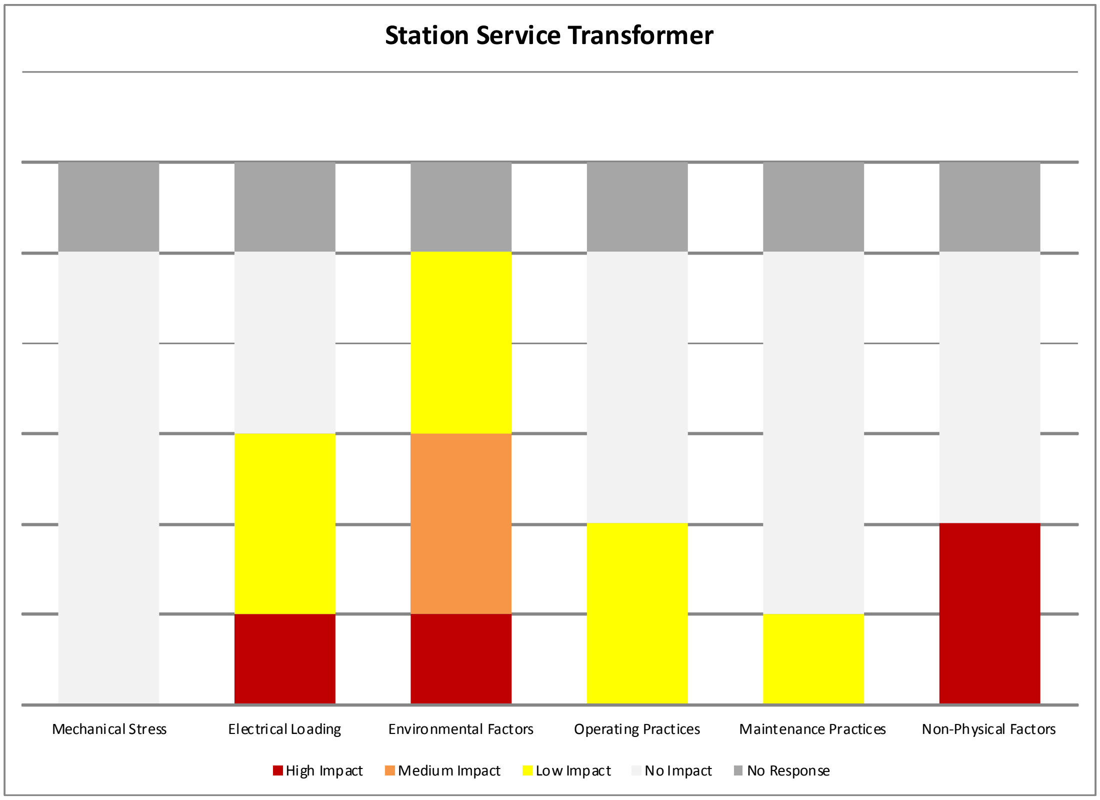


Figure 13-2 Impact of Utilization Factors on the Useful Life of Station Service Transformers

14. Station Grounding Transformers

14.1 Asset Description

Electrical distribution systems can be configured as a grounded or ungrounded system. A grounded system has an electrical connection generally between star-point of a wye configured transformer and the earth, whereas an ungrounded system has no intentional connection. Sometimes it is necessary to create a virtual ground on an ungrounded system for safety or to aid in protective relaying applications. Grounding transformers, smaller transformers similar in construction to power transformers, are used in this application.

14.1.1 Componentization Assumptions

For the purposes of this report, the Station Grounding Transformers has not been componentized.

14.1.2 System Hierarchy

Station Grounding Transformers is considered to be a part of the Transformer and Municipal Stations asset grouping.

14.2 Degradation Mechanism

Like a majority of transformers, the end of life for this asset is a result of insulation degradation, more specifically, the failure of pressboard and paper insulation. Degradation of the insulating oil, and more significantly, paper insulation, typically results in end of life. Insulation degradation is a result of oxidation, a process that occurs in the presence of oxygen, high temperature, and moisture. For oil cooled transformers, particles, acids, and static electricity will also deteriorate the insulation.

14.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Station Grounding Transformers are displayed in Table 14-1.

Table 14-1 Useful Life Values for Station Grounding Transformers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Station Grounding Transformer	30	40	40

14.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Station Grounding Transformers. None of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Station Grounding Transformers (Figure 14-1).

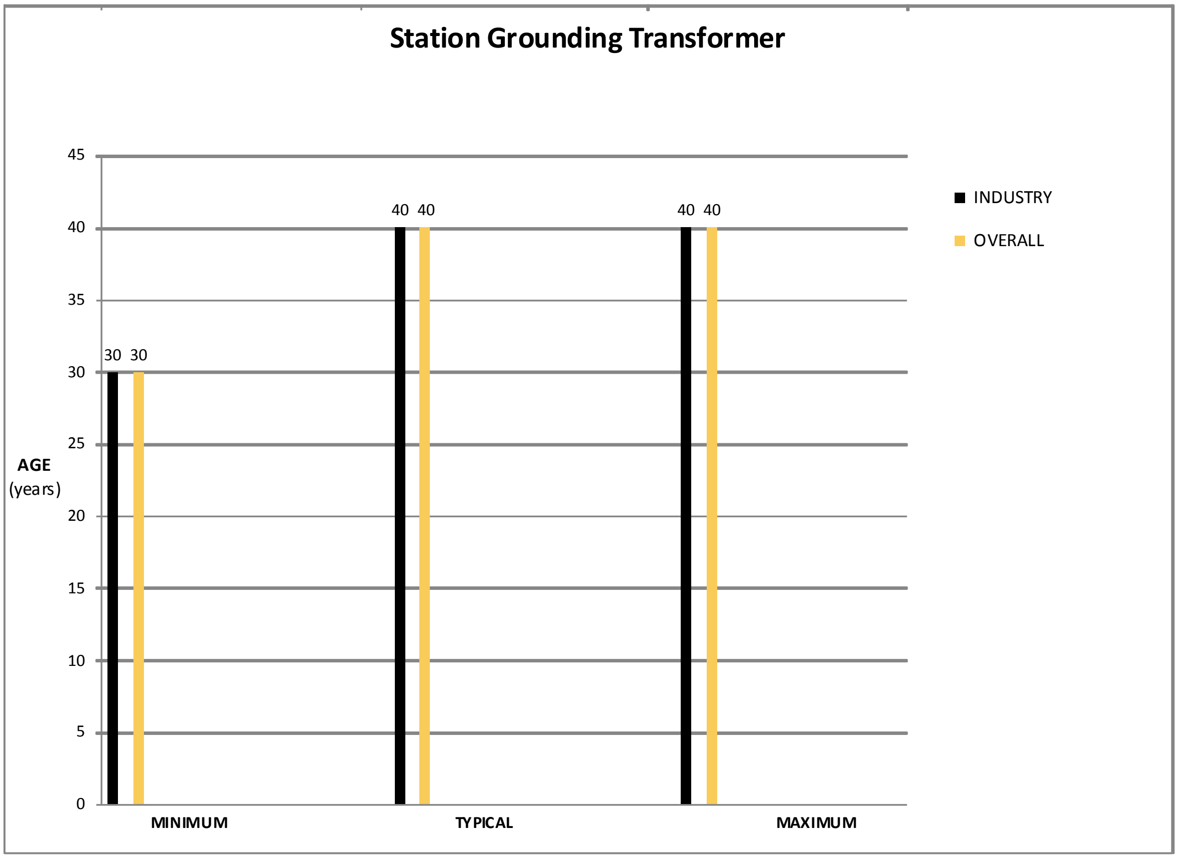


Figure 14-1 Useful Life Values for Station Grounding Transformers

14.4 Impact of Utilization Factors

No Impact of Utilization Factors Data was available from the Utility Interviews.

15. Station Direct Current System

15.1 Asset Description

Station direct current (DC) systems are the critical supply for station protection and control equipment and other auxiliary devices such as transformer cooling. This asset category has been componentized into batteries, chargers and other DC distribution equipment. Maintaining batteries in a condition capable of delivering the necessary energy as required is essential.

Batteries consist of multiple individual cells. For the purposes of this report, these are lead-acid battery banks. Battery chargers are relatively simple electronic devices that have a high degree of reliability and a significantly longer lifetime than the battery banks.

15.1.1 Componentization Assumptions

For the purposes of this report, the Station Direct Current System has been componentized so that the battery bank and charger are regarded as separated components. Therefore the Station Direct Current System has overall useful life values based and useful life values for the specific components, battery bank and charger.

15.1.2 System Hierarchy

Station Direct Current System is considered to be a part of the Transformer and Municipal Stations asset grouping.

15.2 Degradation Mechanism

The deterioration of a battery from an apparently healthy condition to a functional failure can be rapid. This makes condition assessment very difficult. However, careful inspection and testing of individual cells often enables the identification of high risk units in the short term.

Although battery deterioration is difficult to detect, any changes in the electrical characteristics or observation of significant internal damage can be used as sensitive measures of impending failure. While the significant deterioration/failure of an individual cell may be an isolated incident, detection of deterioration in a number of cells in a battery is usually the precursor to widespread failure and functional failure of the total battery. The ability to detect significant deterioration and pre-empt battery failure is especially critical if monitoring and alarm systems are not installed.

Historically, battery end-of-life was determined mainly by a number of factors including age, appearance (indication of physical deterioration) and the history of specific gravity and cell voltage measurements. Presently, the battery load test is now considered the “best” indicator of battery condition. This test is now used to identify and confirm the condition of suspect batteries identified from the preceding tests.

Battery chargers are also critical to the satisfactory performance of the whole battery system. As with other electronic devices, it is difficult to detect deterioration prior to failure. It is normal practice during the regular maintenance and inspection process to check the functionality of the battery chargers, in particular the charging rates. Where any functional failures are detected it would be normal to replace the battery charger.

For battery chargers, diagnostic testing programs are coordinated with the battery maintenance program. This involves a number of functional tests and each test has a defined test passed/test failed (TP/TF) criteria. Failure of any functional test may lead to further investigations or consideration of replacement.

Due to the critical functionality of batteries, most utilities take a conservative approach towards battery replacement: any significant evidence of battery deterioration usually leads to decisions to replace the battery.

15.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Station Direct Current System are displayed in Table 15-1.

Table 15-1 Useful Life Values for Station Direct Current System

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Overall	10	20	30
Battery bank	10	15	15
Charger	20	20	30

15.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Station Direct Current System. Four of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Station Direct Current System (Figure 15-1).

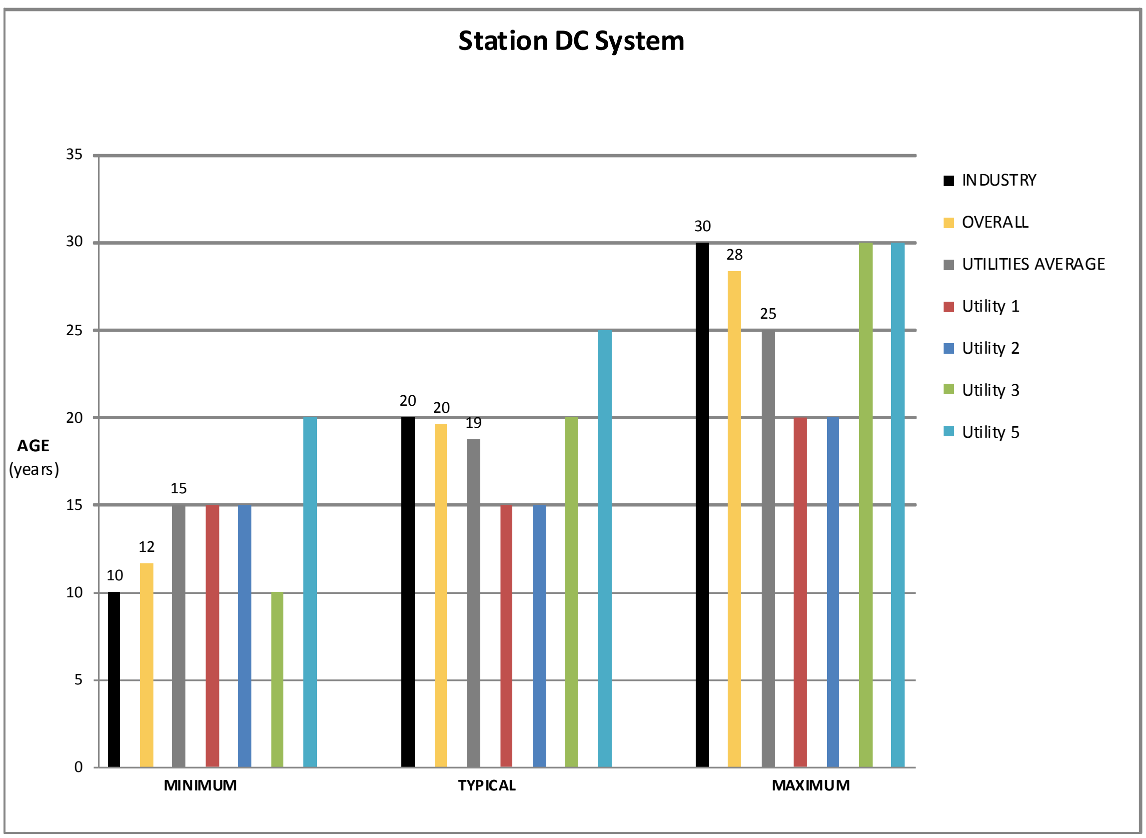


Figure 15-1 Useful Life Values for Station Direct Current System

15.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Station Direct Current System are displayed in Table 15-2.

Table 15-2 - Composite Score for Station Direct Current System

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	8%	50%	15%	23%	52%	53%
Overall Rating*	**NI**	**M**	**L**	**L**	**M**	**M**
* H = High Impact	M = Medium Impact	L = Low Impact	NI = No Impact			

15.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Station Direct Current System. Five of the interviewed utilities provided their input regarding the UFs for Station Direct Current System (Figure 15-2).

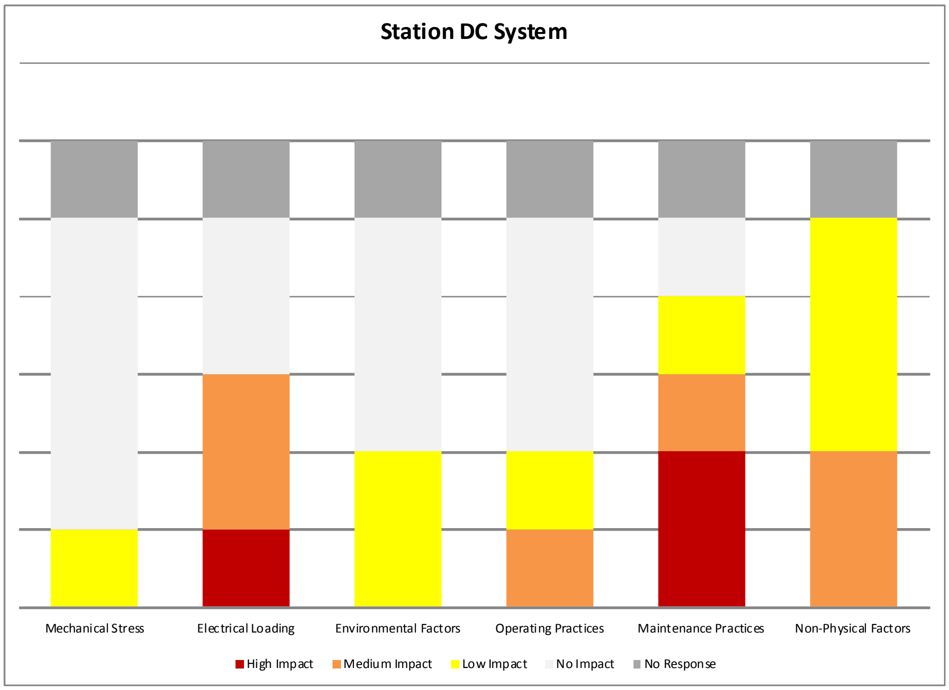


Figure 15-2 Impact of Utilization Factors on the Useful Life of Station Direct Current System

16. Station Metal Clad Switchgear

16.1 Asset Description

Station Metal Clad Switchgear comprises the metal enclosure, the circuit breakers and the associated protection and control devices. Metal clad switchgear is used for protection and switching of distribution system circuits.

16.1.1 Componentization Assumptions

For the purposes of this report, the Station Metal Clad Switchgear has been componentized so that the removable breaker may be regarded as a separate component. Therefore the Station Metal Clad Switchgear has overall useful life values based and useful life values for the specific component, the removable breaker.

16.1.2 Design Configuration

For the purposes of this report, station metal clad switchgear asset category can be classified in two types: gas insulated and air insulated switchgear. There are also several interrupting mediums associated with the removable breaker component of station metal clad switchgear. For the purposes of this report, the types are oil, air, gas (SF6) and vacuum.

16.1.3 System Hierarchy

Station Metal Clad Switchgear is considered to be a part of the Transformer and Municipal Stations asset grouping.

16.2 Degradation Mechanism

Switchgear degradation is a function of a number of different factors: mechanism operation and performance, degradation of solid insulation, general degradation/corrosion, environmental factors, or post fault maintenance (condition of contacts and arc control devices).

16.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Station Metal Clad Switchgear are displayed in Table 16-1.

Table 16-1 Useful Life Values for Station Metal Clad Switchgear

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Overall	30	40	60
Removable Breaker	25	40	60

16.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Station Metal Clad Switchgear. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Station Metal Clad Switchgear (Figure 16-1).

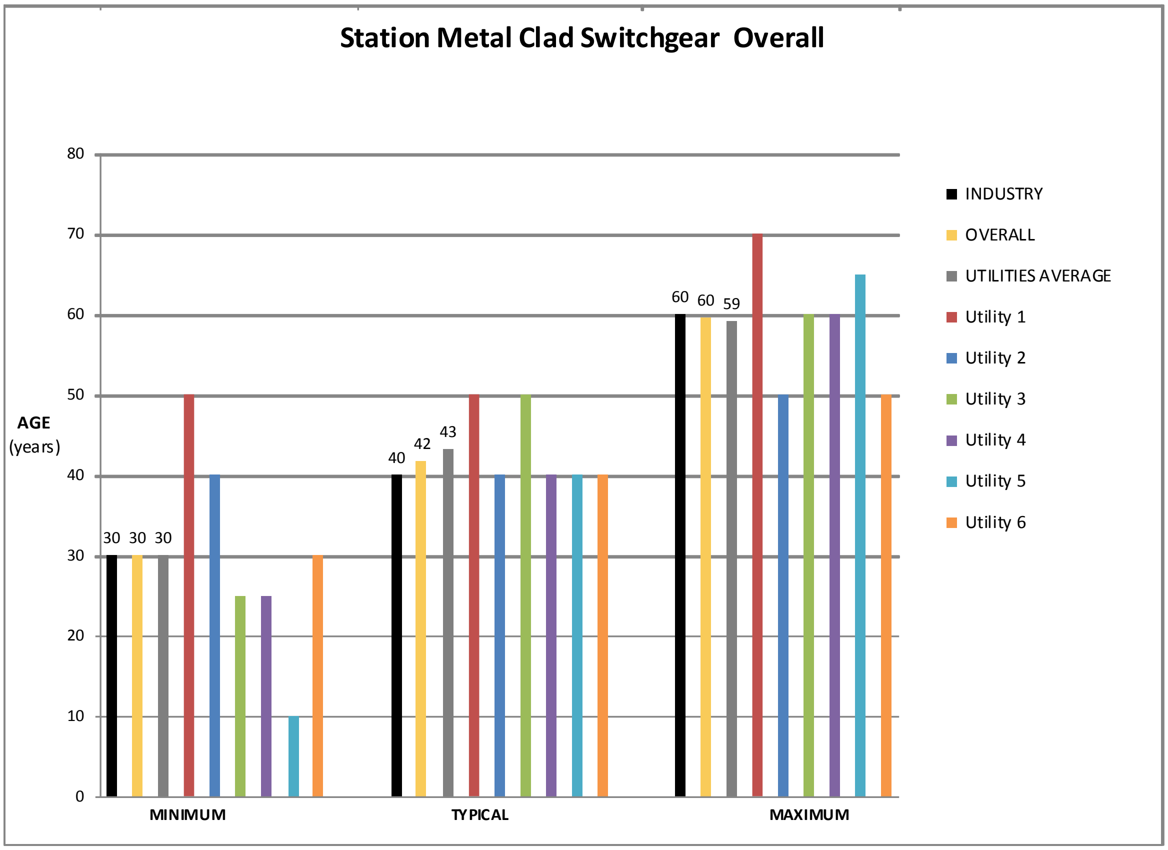


Figure 16-1 Useful Life Values for Station Metal Clad Switchgear

16.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Station Metal Clad Switchgear are displayed in Table 16-2.

Table 16-2 - Composite Score for Station Metal Clad Switchgear

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	31%	44%	48%	56%	69%	50%
Overall Rating*	L	L	M	M	M	M

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

16.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Station Metal Clad Switchgear. All six of the interviewed utilities provided their input regarding the UFs for Station Metal Clad Switchgear (Figure 15-2).

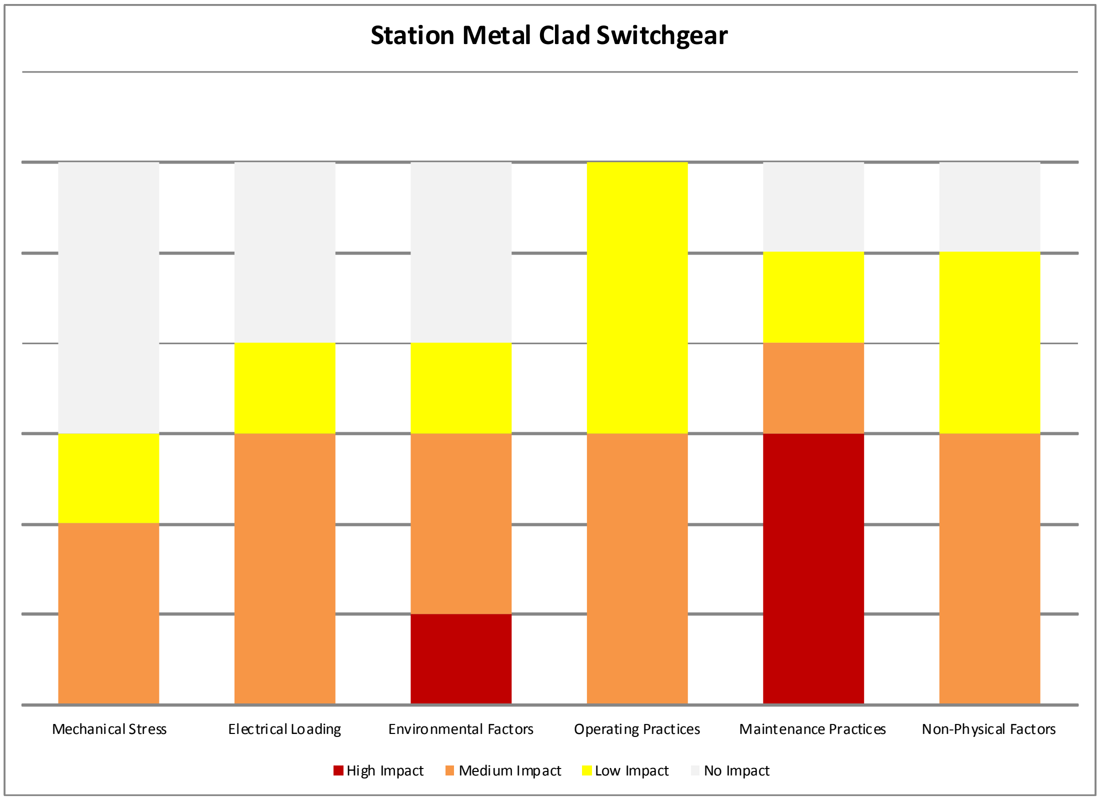


Figure 16-2 Impact of Utilization Factors on the Useful Life of Station Metal Clad Switchgear

17. Station Independent Breakers

17.1 Asset Description

Circuit breakers are automated switching devices that can make, carry and interrupt electrical currents under normal and abnormal conditions. Breakers are required to operate infrequently, however, when an electrical fault occurs, breakers must operate reliably and with adequate speed to minimize damage. This asset category refers to five types of independent station circuit breakers: oil, gas (SF6), air magnetic, air blast and vacuum.

17.1.1 Componentization Assumptions

For the purposes of this report, the Station Independent Breakers has not been componentized.

17.1.2 Design Configuration

For the purposes of this report, the independent breakers could be either indoor or outdoor. The breaker types are oil, gas (SF6), air magnetic, air blast and vacuum.

The oil circuit breaker (OCB) is the oldest type of breaker design and has been in use for over 70 years. Two types of designs exist among OCBs: bulk oil breakers (in which oil serves as the insulating and arc quenching medium) and minimum oil breakers (in which oil provides the arc quenching function only).

Gas, sulfur hexafluoride (SF6) insulated equipment is a relatively young technology. The first SF6 equipment was developed in the late 1960s. After some initial design and manufacturing problems equipment was increasingly used to replace oil filled equipment with widespread adoption and utilization since the mid 1980s. One of the more remarkable features of SF6 is its performance when subjected to an arc, or during a fault operation. SF6 is extremely stable and even at the high temperatures associated with an arc, limited breakdown occurs. Furthermore, most of the products of the breakdown recombine to form SF6. Consequently, SF6 circuit breakers can operate under fault conditions many more times than oil breakers before requiring maintenance.

In air magnetic circuit breakers, magnetic blowout coils are used to create a strong magnetic field that draws the arc into specially designed arc chutes. The breaker current flows through the blowout coils and produces a magnetic flux. This magnetic field drives the arc against barriers built perpendicular to the length of the arc. The cross sectional area of the arc is thereby reduced, and its resistance is considerably increased. The surface of the barriers cool and de-ionize the arc, thus collaborating to extinguish the arc.

Air-blast breakers use compressed air as the quenching, insulating and actuating medium. In normal operation, a blast of compressed air carries the arc into an arc chute where it is quickly extinguished. A combination cooler-muffler is often provided to cool ionized exhaust gases before they pass out into the atmosphere and to reduce noise during operation.

Vacuum Breakers consist of fixed and moving butt type contacts in small evacuated chambers (i.e. bottles). A bellows attached to the moving contact permits the required short stroke to occur with no vacuum losses. Arc interruption occurs at current zero after withdrawal of the moving contact. Current medium voltage vacuum breakers require low mechanical drive energy, have high endurance, can interrupt fully rated short circuits up to 100 times, and operate reliably over 30,000 or more switching operations. Vacuum breakers also are safe and protective of the environment.

17.1.3 System Hierarchy

Station Independent Breakers is considered to be a part of the Transformer and Municipal Stations asset grouping.

17.2 Degradation Mechanism

Circuit breakers have many moving parts that are subject to wear and stress. They frequently “make” and “break” high currents and experience the arcing accompanying these operations. All circuit breakers undergo some contact degradation every time they open to interrupt an arc. Also, arcing produces heat and decomposition products that degrade surrounding insulation materials, nozzles, and interrupter chambers. The mechanical energy needed for the high contact velocities of these assets adds mechanical deterioration to their degradation processes.

The rate and severity of degradation depends on many factors, including insulating and conducting materials, operating environments, and a breaker’s specific duties. The following additional factors could lead to end-of-life for this asset class:

- Decreasing reliability, availability and maintainability
- High maintenance and operating costs
- Changes in operating conditions, rendering the existing asset obsolete
- Maintenance overhaul requirements

Many of the earlier breakers relied on hydraulic or pneumatic assisted mechanisms. These have proved problematic in some cases and contributed significantly to the higher failure rates associated with this generation of equipment. More recent equipment usually utilize spring assisted mechanisms that have proved more reliable and require less maintenance.

17.2.1 Oil Breakers

For oil type circuit breakers the key degradation processes associated is as follows:

- Corrosion
- Effects of moisture
- Mechanical
- Bushing deterioration

The rate and severity of these degradation processes is dependent on a number of inter-related factors, in particular the operating duties and environment in which the equipment is installed. Often the critical degradation process is either corrosion or moisture ingress or a combination of the two, resulting in degradation to internal insulation, deterioration of the mechanism affecting the critical performance of the breaker, damage to major components such as bushings or widespread degradation to oil seals and structurally components.

A significant area of concern is barrier-bushing deterioration resulting from moisture ingress. The Synthetic Resin Bonded Paper (SRBP) insulation absorbs the moisture, which can result in discharge tracking across its surface leading to eventual failure of the bushing. Oil impregnated paper bushings are particularly sensitive to moisture. Once moisture finds its way into the oil and then into the paper insulation, it is very difficult to remove and can eventually lead to failure. Significant levels of moisture in the main tank can lead to general degradation of internal components and in acute cases free water can collect at the bottom of the tank. This creates a condition where a catastrophic failure could occur during operation.

Corrosion of the main tank and other structural components is also a concern. One area that is particularly susceptible to corrosion is underneath the main tank on the “bell end”, this problem is common to both single and three tank circuit breakers.

Corrosion of the mechanical linkages associated with the oil circuit breaker operating mechanism is also a widespread problem that can lead to the eventual seizure of the links.

A lesser mode of degradation, although still serious in certain circumstances, is pollution of bushings, particularly where the equipment is located by the sea or in a heavy industrial area.

Other areas of degradation include:

- Deterioration of contacts
- Wear of mechanical components such as bearings
- Loose primary connections
- Deterioration of concrete plinth affecting stability of the circuit breaker

17.2.2 Gas (SF6) Breakers

Failures relating to internal degradation and ultimate breakdown of insulation are limited to early life failures where design or manufacture led to specific problems. There is virtually no experience of failures resulting from long term degradation within the SF6 chambers. Failures and incorrect operations are primarily related to gas leaks and problems with the mechanism and other ancillary systems. Gas seals and valves are a potential weak point. Clearly, loss of SF6 or ingress of moisture and air compromise the performance of the breaker. As would be expected the earlier SF6 equipment was more prone to these problems. Seals and valves have progressively been improved in more modern equipment.

17.2.3 Air Blast Breakers

The air blast circuit breaker has a similar degradation to other types of circuit breakers. The key degradation processes associated with air blast circuit breakers are:

- Corrosion
- Effects of moisture
- Bushing/insulator deterioration
- Mechanical

Severity and rate are dependent on factors such as operating duty and environment. Corrosion is a problem for most types of breakers. It can degrade internal insulators, performance mechanisms, major components (e.g. bushings), structural components, and oil seals. Moisture causes degradation of the insulating system. Mechanical degradation presents greater end-of-life concerns than electrical degradation. Generally, operating mechanisms, bearings, linkages, and drive rods represent components that experience most mechanical degradation problems. Contacts, nozzles, and highly stressed components can also experience electrical-related degradation and deterioration. Other defects that arise with aging include:

- Loose primary and grounding connections
- Oil contamination and/or leakage
- Deterioration of concrete foundation affecting stability of breakers

17.2.4 Air Magnetic Breakers

Air magnetic breakers have a similar degradation mechanism to other breakers in that corrosion; moisture, bushing/insulator deterioration, and mechanical degradation are factors.

17.2.5 Vacuum Breakers

The vacuum breakers in this asset class have a similar degradation mechanism to other breakers, where corrosion, moisture, bushing/insulator deterioration, and mechanical degradation are factors.

17.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Station Independent Breakers are displayed in Table 17-1.

Table 17-1 Useful Life Values for Station Independent Breakers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Station Independent Breakers	35	45	65

17.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Station Independent Breakers. One of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and three of the interviewed utilities gave TUL and MAX UL Values for Station Independent Breakers (Figure 17-1).

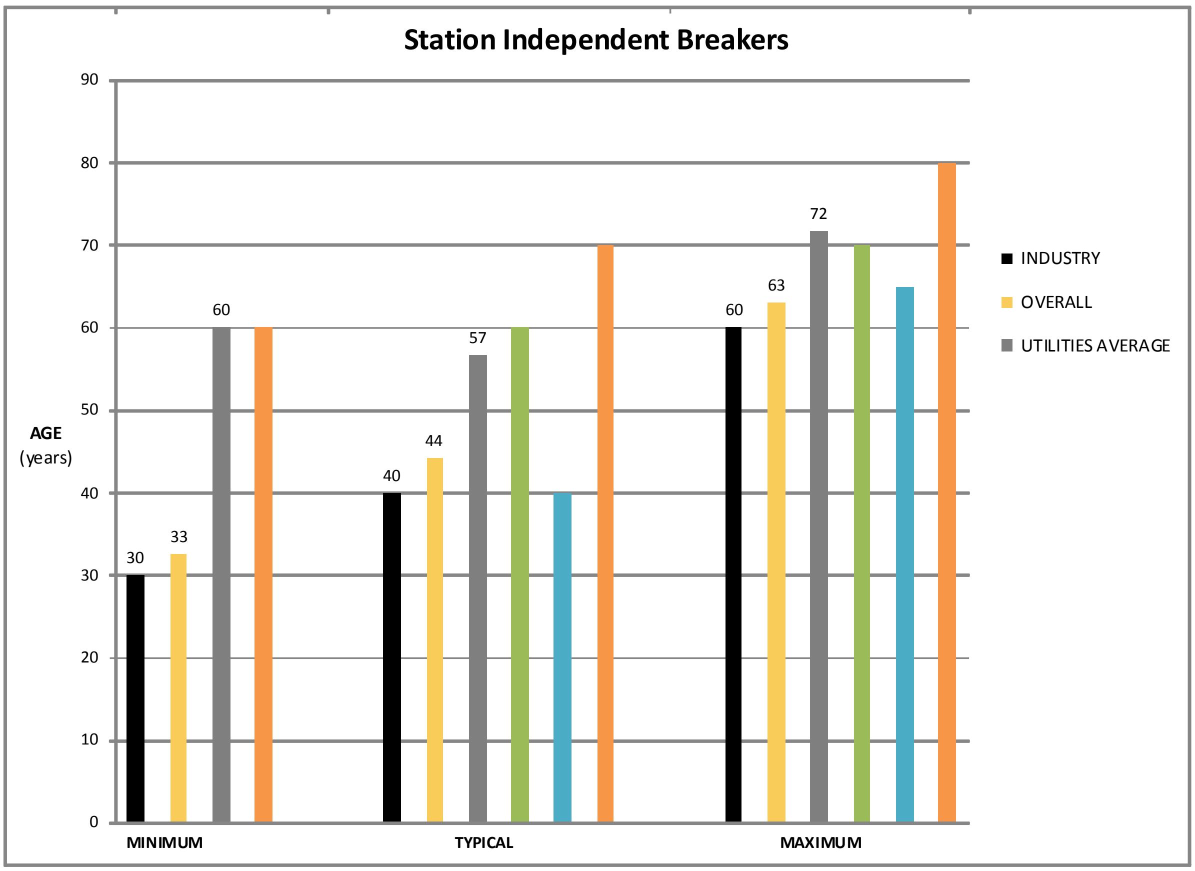


Figure 17-1 Useful Life Values for Station Independent Breakers

17.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Station Independent Breakers are displayed in Table 17-2.

Table 17-2 - Composite Score for Station Independent Breakers

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	58%	63%	50%	63%	50%	67%
Overall Rating*	**M**	**M**	**M**	**M**	**M**	**M**

* H = High Impact   M = Medium Impact   L = Low Impact   NI = No Impact

17.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Station Independent Breakers. Three of the interviewed utilities provided their input regarding the UFs for Station Independent Breakers (Figure 17-2).

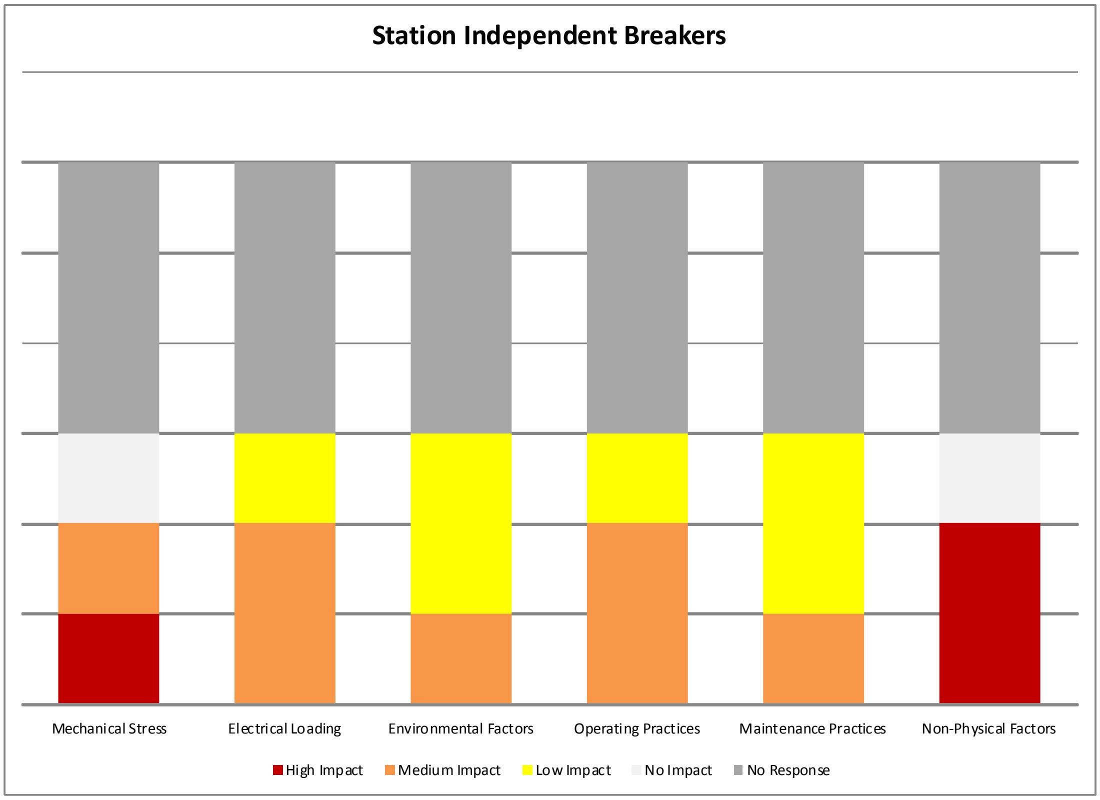


Figure 17-2 Impact of Utilization Factors on the Useful Life of Station Independent Breakers

18. Station Switch

18.1 Asset Description

This asset class consists of the station switches used to physically and electrically isolate sections of the power system for the purposes of maintenance, safety, and other operational requirements. Station switches typically consist of manual or motor operated isolating devices mounted on support insulators and metal support structures. Many high voltage station switches (e.g. line and transformer isolating switches) have motor-operators and the capability of remote-controlled operation. These switches are normally operated when there is no current through the switch, unless specifically designed to be capable of operating under load.

18.1.1 Componentization Assumptions

For the purposes of this report, the Station Switch has not been componentized.

18.1.2 Design Configuration

For the purposes of this report, the station switch refers to both insulting and load interrupting switches. The types included are oil, air magnetic, air blast, gas (SF6) and vacuum.

18.1.3 System Hierarchy

Station Switch is considered to be a part of the Transformer and Municipal Stations asset grouping.

18.2 Degradation Mechanism

Disconnect switches have many moving parts that are subject to wear and operational stress. Except for parts contained in motor-operator cabinets, switch components are exposed to the ambient environment. Thus, environmental factors, along with operating conditions, vintage, design, and configuration all contribute to switch degradation. Critical degradation processes include corrosion, moisture ingress, and ice formation. A combination of these factors that may result in permanent damage to major components such as contacts, blades, bearings, drives and support insulators.

Generally, the following represent key end-of-life factors for disconnect switches:

- Decreasing reliability, availability, and maintainability
- High maintenance and operating costs
- Maintenance overhaul requirements
- Obsolete design, lack of parts and service support

Application criticality and manufacturer also play key roles in determining the end-of-life for disconnect switches. Generally, widespread deterioration of live components, support insulators, motor-operators, and drive linkages define the end-of-life for these switches. However, routine maintenance programs usually provide ample opportunity to assess switch condition and viability.

Disconnect switches have components fabricated from dissimilar materials, and use of these different materials influences degradation. For example, blade, hinge and jaw contacts may consist of combinations of copper, aluminum, silver and stainless steel, several of which have tin, silver and chrome plating. Further switch bases may consist of galvanized steel or aluminum.

Most disconnect switches have porcelain support and rotating insulators. The porcelain offers rigidity, strength and dielectric characteristics needed for reliability. However, excessive deflection or deformation of support or rotating stack insulators can cause blade misalignment and other problems, resulting in operational failures.

Disconnect switches must have the ability to open and close properly even with heavy ice build-up on their blades and contacts. However, these switches may sit idle for several months or more. This infrequent operation may lead to corrosion and water ingress damage, increasing the potential for component seizures. Bearings commonly seize from poor lubrication and sealing, despite manufacturers' claims that such components are sealed, greaseless and maintenance-free for life.

Normally, when blades enter or leave jaw contacts, they rotate to clean accumulated ice from contact surfaces. To accomplish this, hinge ends have rotating or other current transfer contacts. These contacts are often simple, long-life copper braids. However, some switches have more complex rotating contacts in grease-filled chambers. Without proper maintenance these more complex switches may degrade, causing blade failures.

18.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Station Switch are displayed in Table 18-1.

Table 18-1 Useful Life Values for Station Switch

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Station Switch	30	50	60

18.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Station Switch. Four of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Station Switch (Figure 18-1).

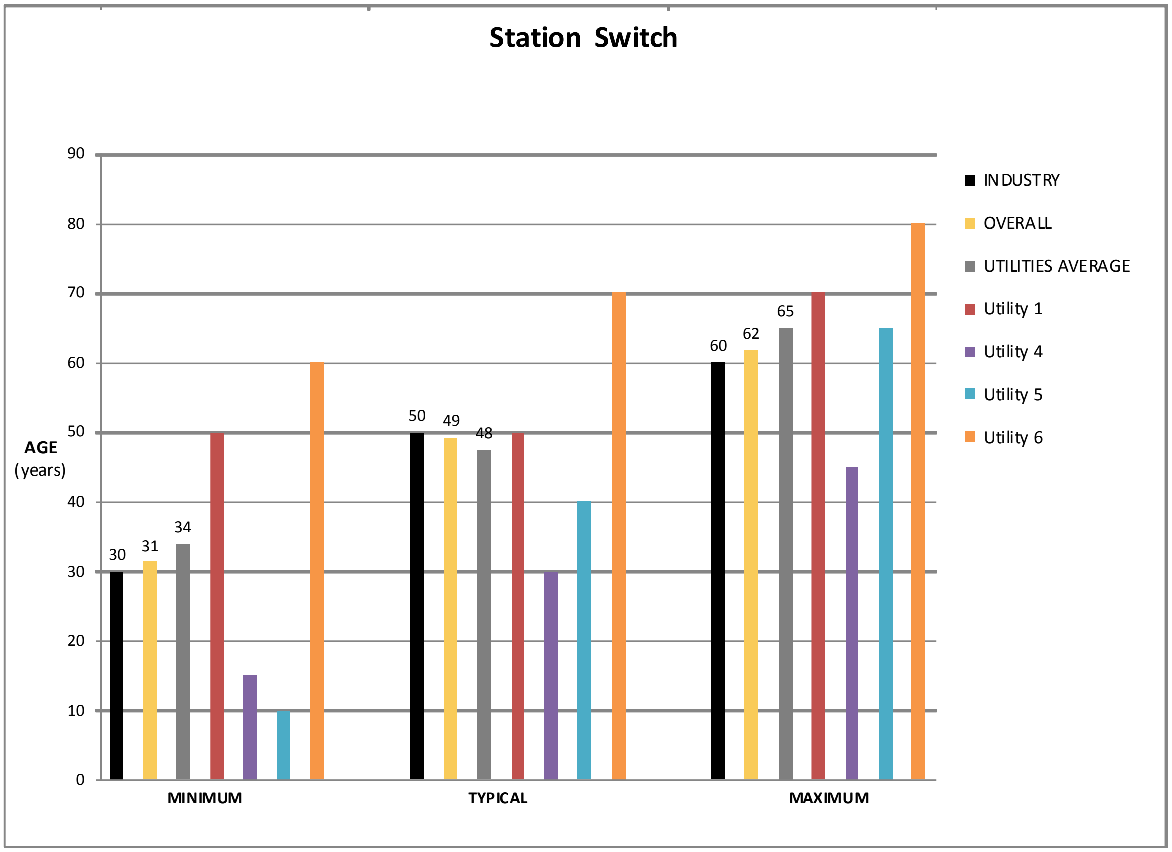


Figure 18-1 Useful Life Values for Station Switch

18.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Station Switch are displayed in Table 18-2.

Table 18-2 - Composite Score for Station Switch

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	47%	38%	72%	47%	53%	19%
Overall Rating*	M	L	M	M	M	L
* H = High Impact	M = Medium Impact	L = Low Impact	NI = No Impact			

18.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Station Switch. Four of the interviewed utilities provided their input regarding the UFs for Station Switch (Figure 18-2).

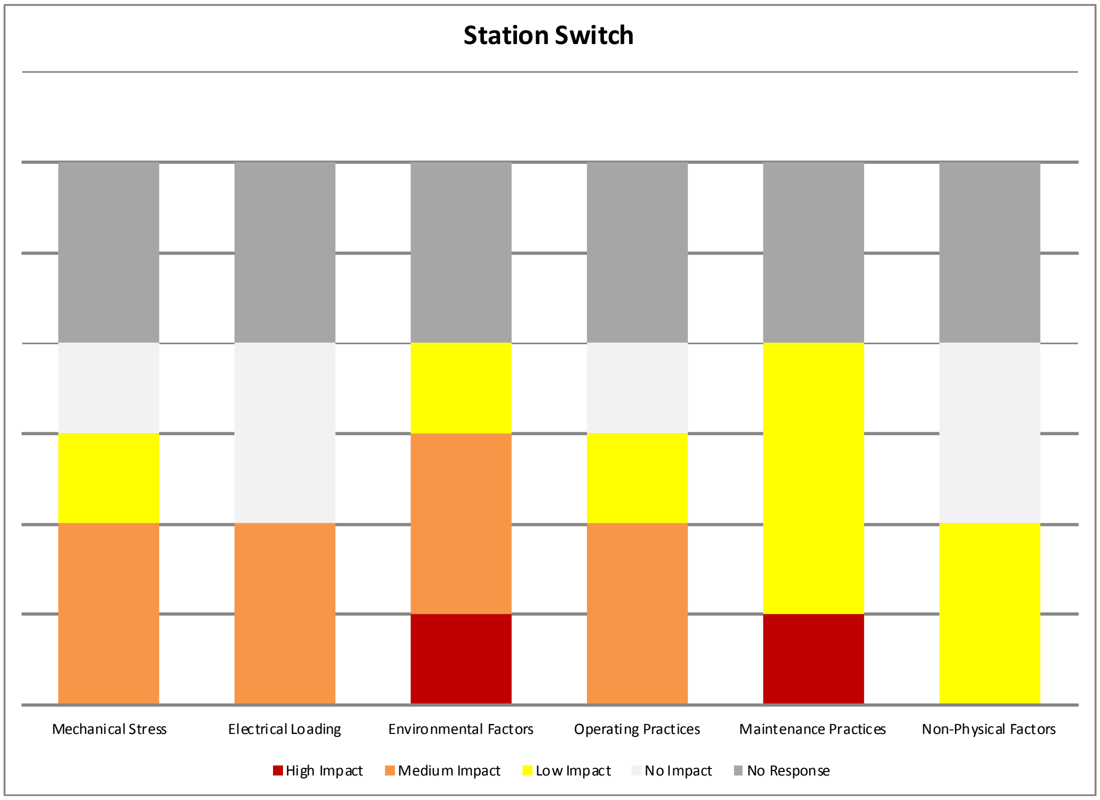


Figure 18-2 Impact of Utilization Factors on the Useful Life of Station Switch

19. Electromechanical Relays

19.1 Asset Description

Protection relays work to detect faults and isolate the system by triggering the opening and closing of the circuit breakers. This asset class includes the older designs of protective relays which had primarily electromechanical mechanisms.

19.1.1 Componentization Assumptions

For the purposes of this report, the Electromechanical Relays has not been componentized.

19.1.2 System Hierarchy

Electromechanical Relays is considered to be a part of the Transformer and Municipal Stations asset grouping.

19.2 Degradation Mechanism

The degradation of electromechanical relays is primarily related to the wear and seizing of the mechanical mechanisms. For instance relay contacts age due to the following factors:

- Contact oxidation
- Contact welding or pitting due to excessive current
- Chemical corrosion

In the case of degradation of relay moving parts, such as wear of moving parts like spring/armature, the major contributing factor is the wear after numerous switching cycles.

Degradation on relay coils is mainly a thermal aging issue due to continuous energization or elevated cabinet temperatures. Excessive heat generated by coil or associated components may cause the coil to burn out or adversely affect other nearby components or components within the relay or nearby (e.g. chemical breakdown of varnishes causing contact contamination, or change in component dimensions).

As a consequence, the failure mode of an electromechanical relay can be:

- Failure to actuate when commanded
- Actuates without command
- Does not make or break current
- Failure to carry current
- High contact resistance
- Set-point shift
- Time delay shift

19.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Electromechanical Relays are displayed in Table 19-1.

Table 19-1 Useful Life Values for Electromechanical Relays

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Electromechanical Relays	25	35	50

19.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Electromechanical Relays. Five of the interviewed utilities gave Minimum Useful Life (MAX UL) Values and all six of the utilities interviewed gave TUL and MAX UL Values for Electromechanical Relays (Figure 19-1).

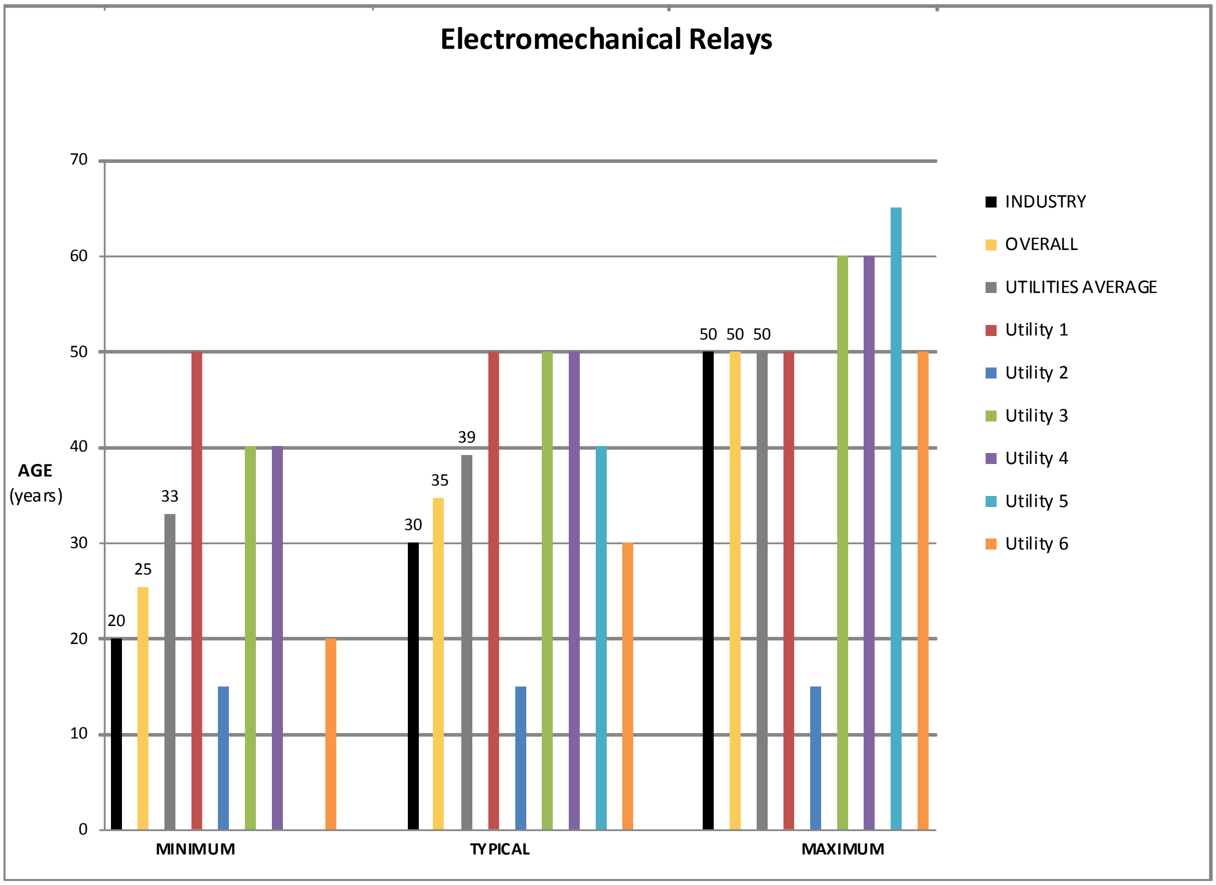


Figure 19-1 Useful Life Values for Electromechanical Relays

19.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Electromechanical Relays are displayed in Table 19-2.

Table 19-2 - Composite Score for Electromechanical Relays

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	6%	6%	6%	6%	6%	100%
Overall Rating*	**NI**	**NI**	**NI**	**NI**	**NI**	**H**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

19.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Electromechanical Relays. All six of the interviewed utilities provided their input regarding the UFs for Electromechanical Relays (Figure 19-2).

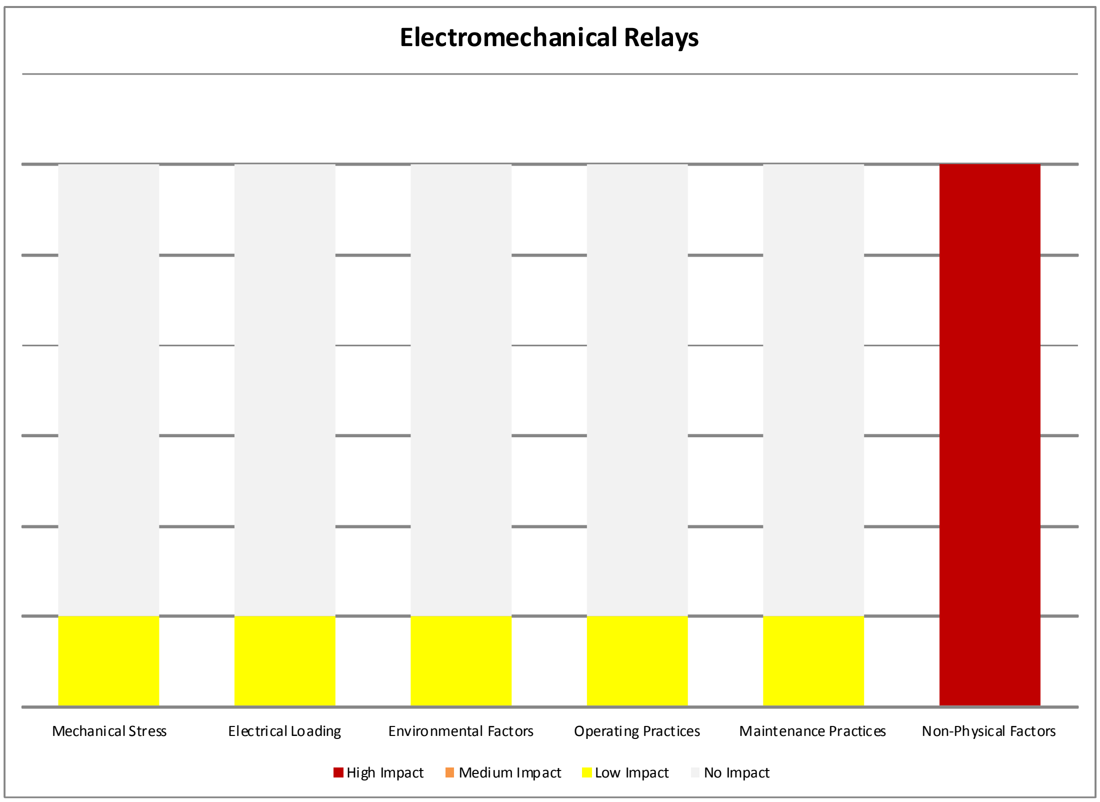


Figure 19-2 Impact of Utilization Factors on the Useful Life of Electromechanical Relays

20. Solid State Relays

20.1 Asset Description

Protection relays work to detect faults and isolate the system by triggering the opening and closing of the circuit breakers. This asset class includes electronic relays that were designed with discrete solid –state components.

20.1.1 Componentization Assumptions

For the purposes of this report, the Solid State Relays has not been componentized.

20.1.2 System Hierarchy

Solid State Relays is considered to be a part of the Transformer and Municipal Stations asset grouping.

20.2 Degradation Mechanism

The degradation of solid state relays is related to the deterioration of contacts and the aging of electronic components. Degradation of relay contacts is due to the following factors:

- Contact oxidation
- Contact welding or pitting due to excessive current
- Chemical corrosion

Degradation on relay coils is mainly a thermal aging issue due to continuous energization or elevated cabinet temperatures. Excessive heat generated by coil or associated components may cause the coil to burn out or adversely affect other nearby components or components within the relay or nearby (e.g. chemical breakdown of varnishes causing contact contamination, or change in component dimensions).

Physical degradation of a solid state relay is particularly sensitive to ambient environmental conditions.

20.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Solid State Relays are displayed in Table 20-1.

Table 20-1 Useful Life Values for Solid State Relays

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Solid State Relays	10	30	45

20.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Solid State Relays. Two of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Solid State Relays (Figure 20-1).

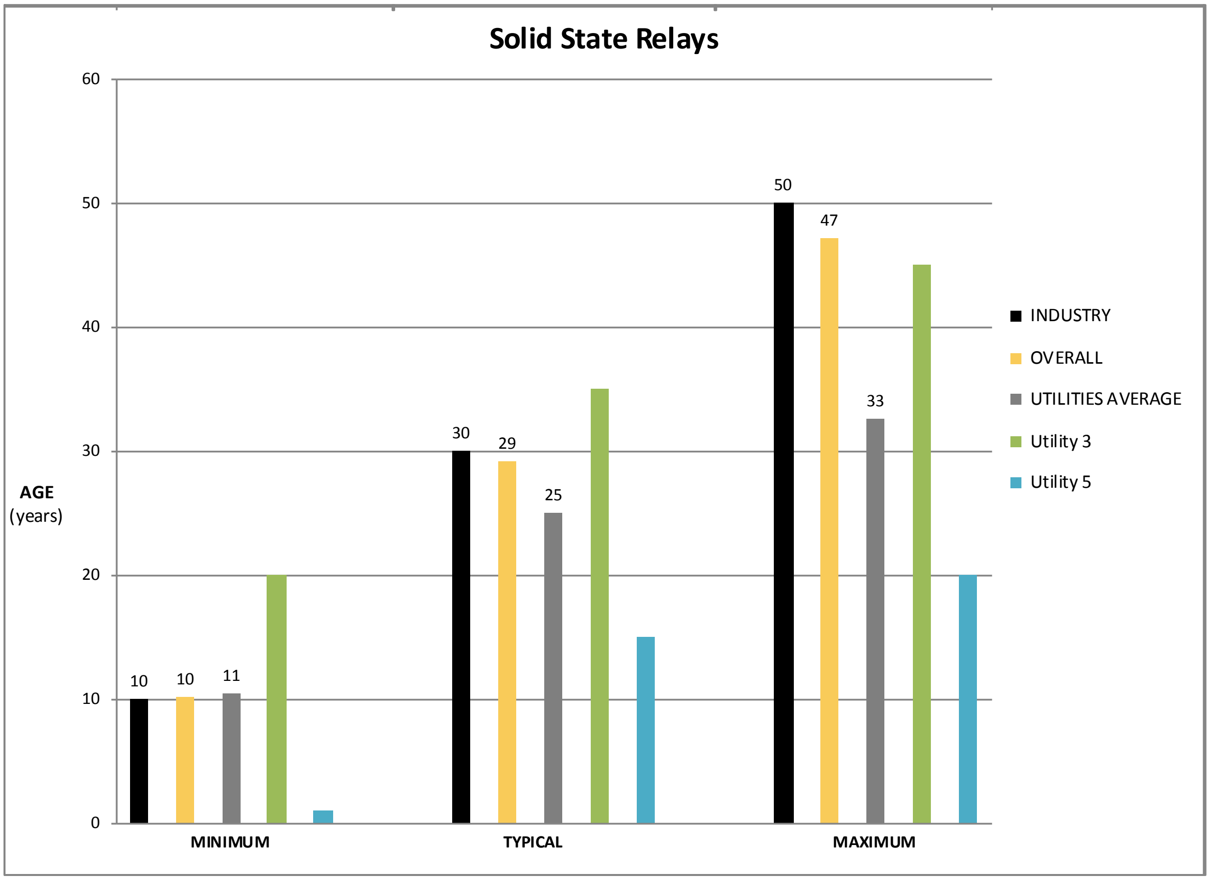


Figure 20-1 Useful Life Values for Solid State Relays

20.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Solid State Relays are displayed in Table 20-2.

Table 20-2 - Composite Score for Solid State Relays

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	0%	0%	0%	0%	0%	100%
Overall Rating*	NI	NI	NI	NI	NI	H
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

20.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Solid State Relays. Two of the interviewed utilities provided their input regarding the UFs for Solid State Relays (Figure 20-2).

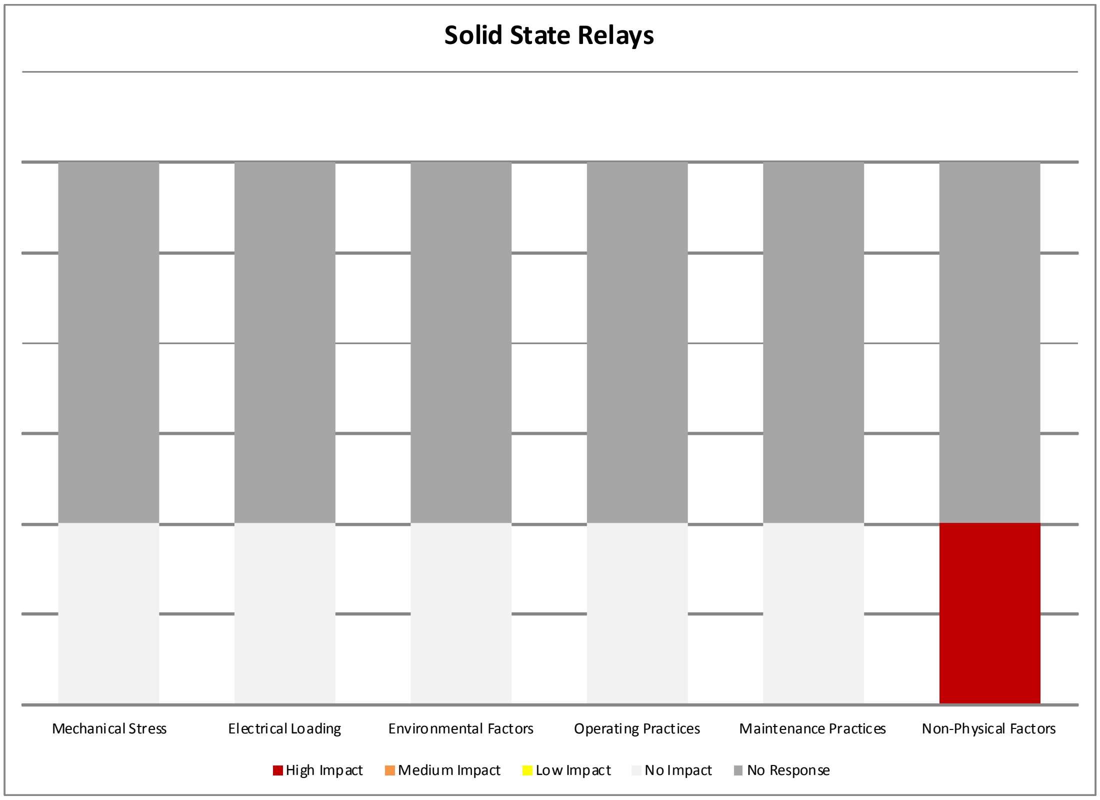


Figure 20-2 Impact of Utilization Factors on the Useful Life of Solid State Relays

21. Digital Microprocessor Relays

21.1 Asset Description

Protection relays work to detect faults and isolate the system by triggering the opening and closing of the circuit breakers. This asset class includes microprocessor based digital relays that have been used in recent years.

21.1.1 Componentization Assumptions

For the purposes of this report, the Digital Microprocessor Relays has not been componentized.

21.1.2 System Hierarchy

Digital Microprocessor Relays is considered to be a part of the Transformer and Municipal Stations asset grouping.

21.2 Degradation Mechanism

The degradation of microprocessor based relays is primarily related to the deterioration of electronic components.

Physical degradation of microprocessor relays is sensitive to ambient environmental conditions.

21.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Digital Microprocessor Relays are displayed in Table 21-1.

Table 21-1 Useful Life Values for Digital Microprocessor Relays

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Digital & Numeric Relays	15	20	20

21.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Digital Microprocessor Relays. Three of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and four of the interviewed utilities gave TUL and MAX UL Values for Digital Microprocessor Relays (Figure 21-1).

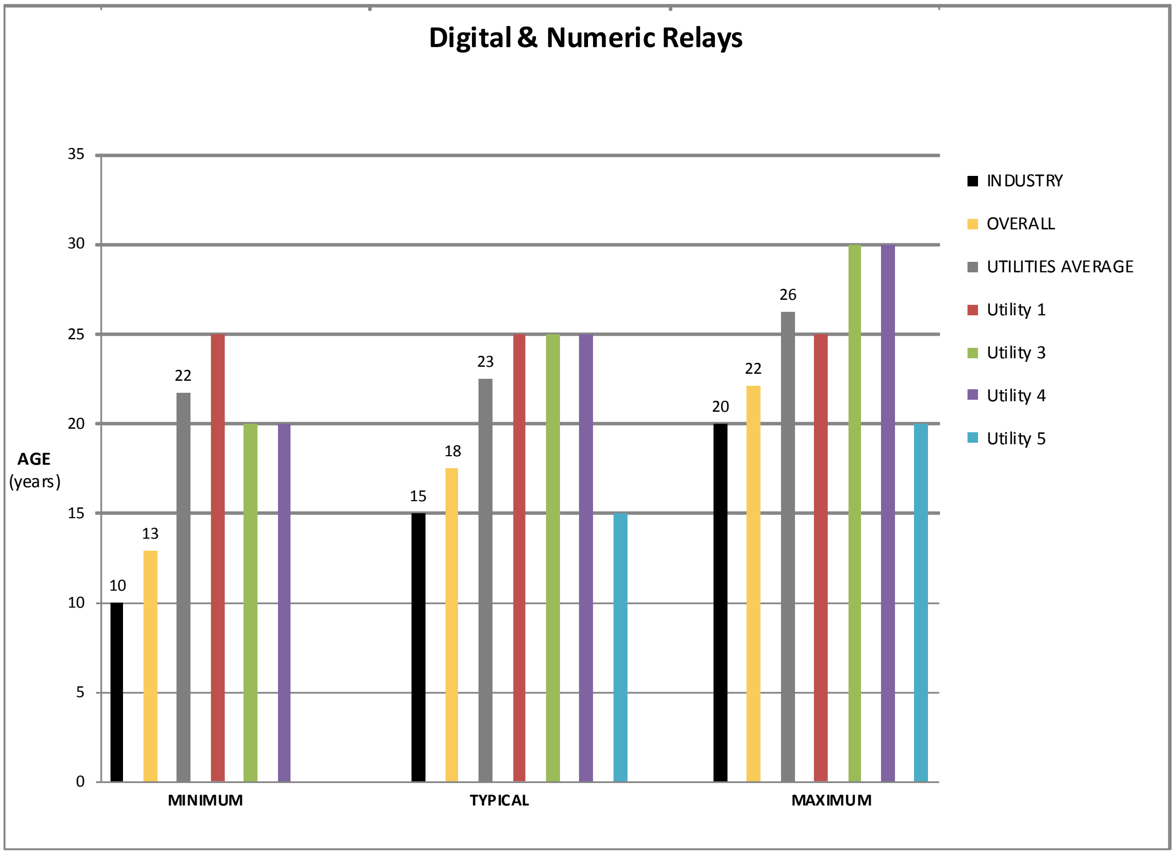


Figure 21-1 Useful Life Values for Digital Microprocessor Relays

21.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Digital Microprocessor Relays are displayed in Table 21-2.

Table 21-2 - Composite Score for Digital Microprocessor Relays

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	0%	0%	0%	0%	0%	100%
Overall Rating*	**NI**	**NI**	**NI**	**NI**	**NI**	**H**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

21.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Digital Microprocessor Relays. Five of the interviewed utilities provided their input regarding the UFs for Digital Microprocessor Relays (Figure 21-2).

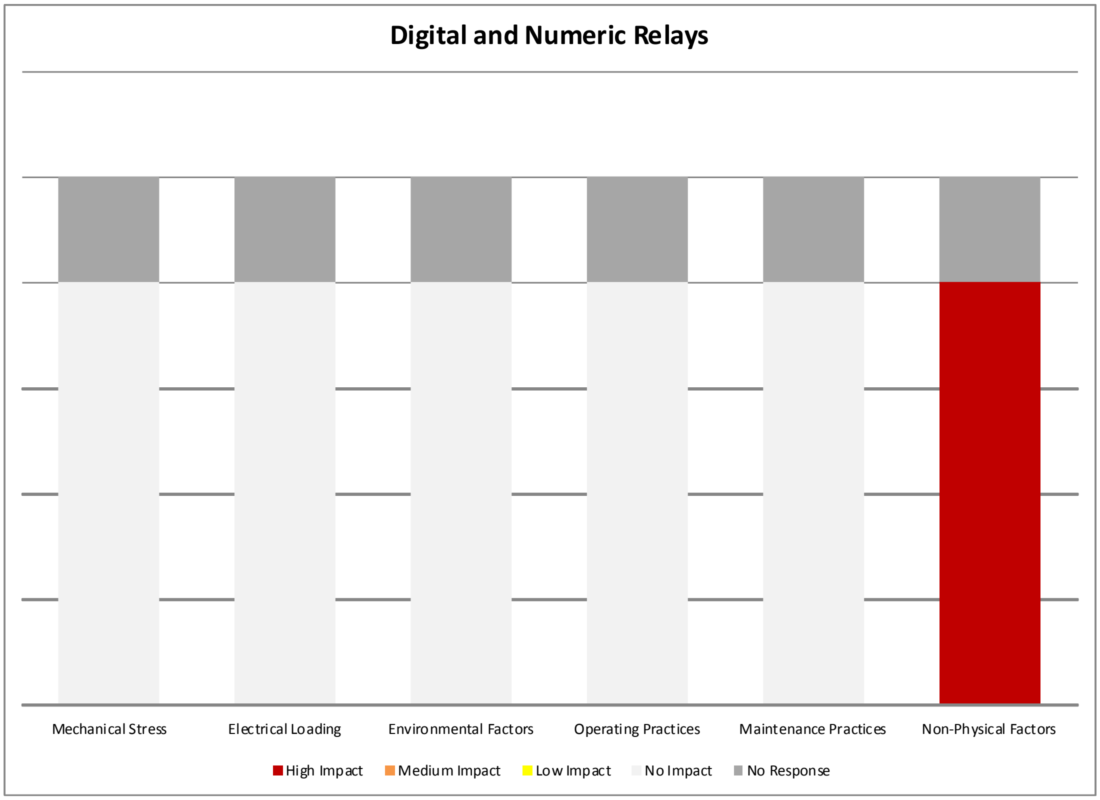


Figure 21-2 Impact of Utilization Factors on the Useful Life of Digital Microprocessor Relays

22. Rigid Busbars

22.1 Asset Description

This asset class includes the current carrying bus in the station. The buses are generally fashioned from aluminum or copper tube or bar.

22.1.1 Componentization Assumptions

For the purposes of this report, the Rigid Busbars has not been componentized.

22.1.2 System Hierarchy

Rigid Busbars is considered to be a part of the Transformer and Municipal Stations asset grouping.

22.2 Degradation Mechanism

Degradation of busbars can result from environmentally induced chemical corrosion, electrical overheating or mechanical damage.

22.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Rigid Busbars are displayed in Table 22-1.

Table 22-1 Useful Life Values for Rigid Busbars

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Rigid Busbars	30	55	60

22.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Rigid Busbars. Three of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and four of the interviewed utilities gave TUL and MAX UL Values for Rigid Busbars (Figure 22-1).

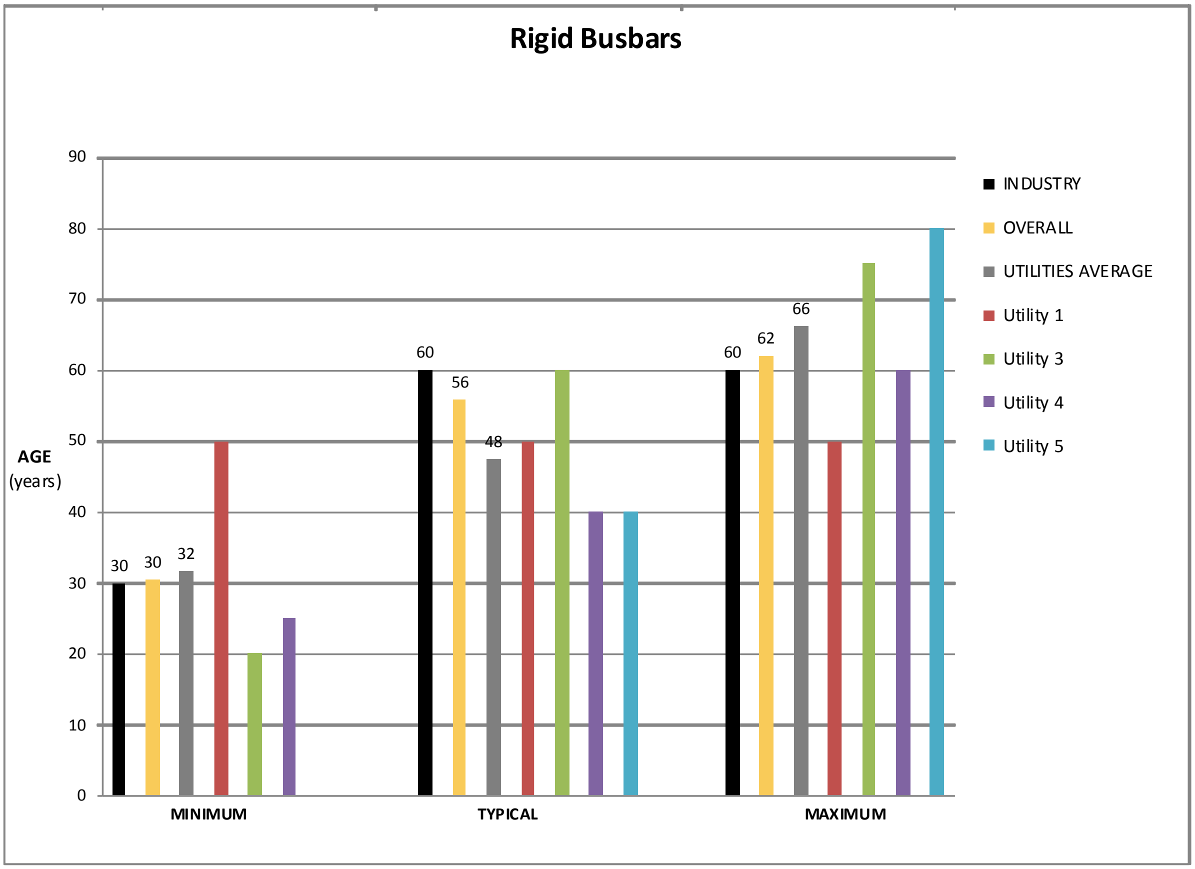


Figure 22-1 Useful Life Values for Rigid Busbars

22.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Rigid Busbars are displayed in Table 22-2.

Table 22-2 - Composite Score for Rigid Busbars

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	19%	34%	44%	0%	9%	25%
Overall Rating*	**L**	**L**	**L**	**NI**	**NI**	**L**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

22.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Rigid Busbars. Four of the interviewed utilities provided their input regarding the UFs for Rigid Busbars (Figure 22-2).

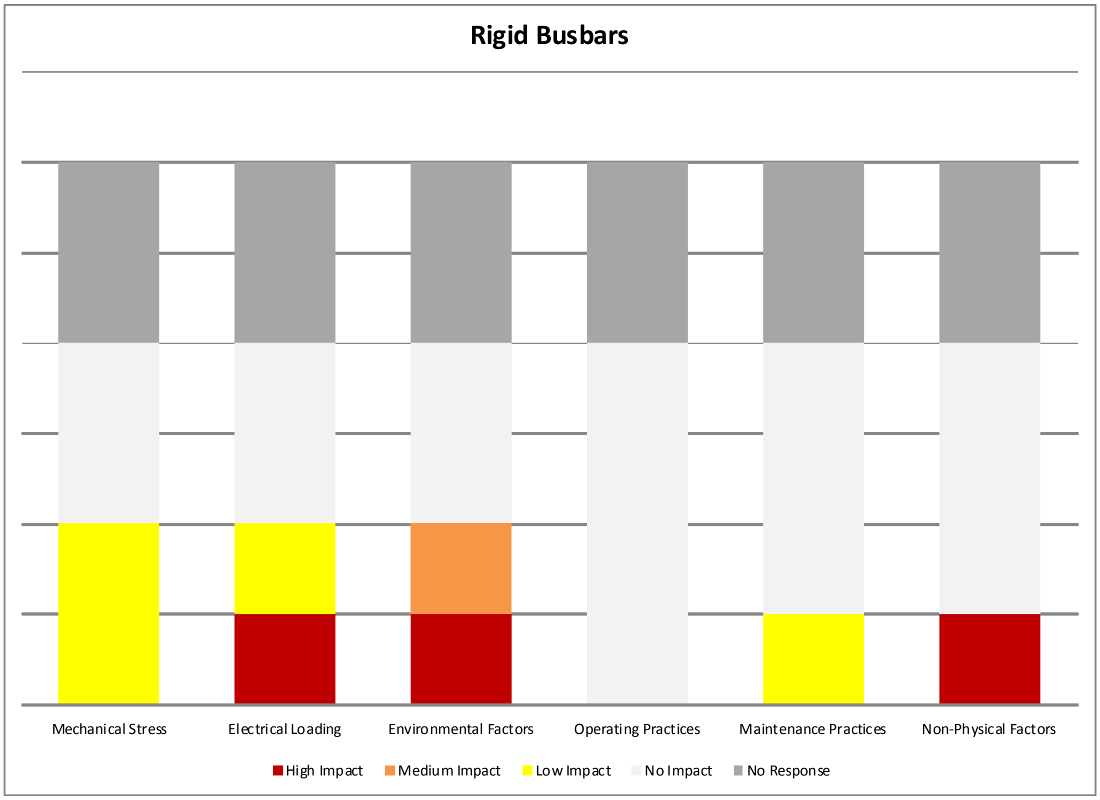


Figure 22-2 Impact of Utilization Factors on the Useful Life of Rigid Busbars

23. Steel Structure

23.1 Asset Description

There are a number of different types of structures at distribution stations for supporting bus and equipment. The predominant types are galvanized steel, either lattice or hollow sections.

23.1.1 Componentization Assumptions

For the purposes of this report, the Steel Structure has not been componentized.

23.1.2 System Hierarchy

Steel Structure is considered to be a part of the Transformer and Municipal Stations asset grouping.

23.2 Degradation Mechanism

Degradation or reduction in strength of steel structures can result from corrosion, structural fatigue, or gradual deterioration of foundation components.

Corrosion of lattice steel members and hardware reduces their cross-sectional area causing a reduction in strength. Similarly, corrosion of tubular steel poles reduces the effectiveness of the tubular walls. Rates of corrosion may vary, depending upon environmental and climatic conditions (e.g., the presence of salt spray in coastal areas or heavy industrial pollution).

Structural fatigue results from repeated structural loading and unloading of support members. Temperature variations, plus wind and ice loadings lead to changes in conductor tension. Tension changes result in structural load variations on angle and dead end towers. Other changes such as foundation displacements and breaks in wires, guys and anchors may result in abnormal tower loading.

Typically, steel pole foundations are cylindrical steel reinforced concrete structures with anchor bolts connecting the pole to its base. Common degradation processes include corrosion of foundation rebar, concrete spalling and storm damage.

23.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Steel Structure are displayed in Table 23-1.

Table 23-1 Useful Life Values for Steel Structure

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Steel Structure	35	50	90

23.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Steel Structure. Four of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and five of the interviewed utilities gave TUL and MAX UL Values for Steel Structure (Figure 23-1).

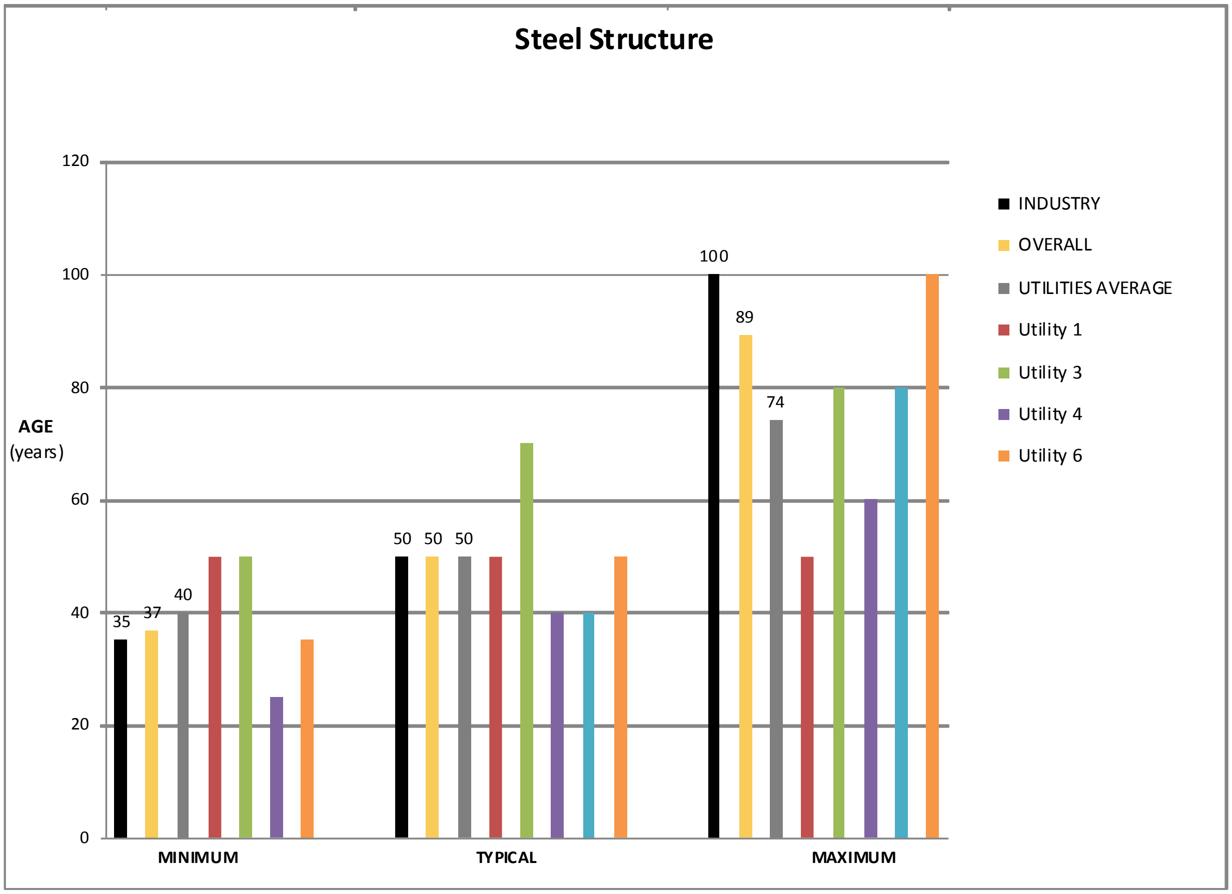


Figure 23-1 Useful Life Values for Steel Structure

23.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Steel Structure are displayed in Table 23-2.

Table 23-2 - Composite Score for Steel Structure

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	35%	0%	55%	8%	8%	28%
Overall Rating*	**L**	**NI**	**M**	**NI**	**NI**	**L**

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

23.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Steel Structure. Five of the interviewed utilities provided their input regarding the UFs for Steel Structure (Figure 23-2).

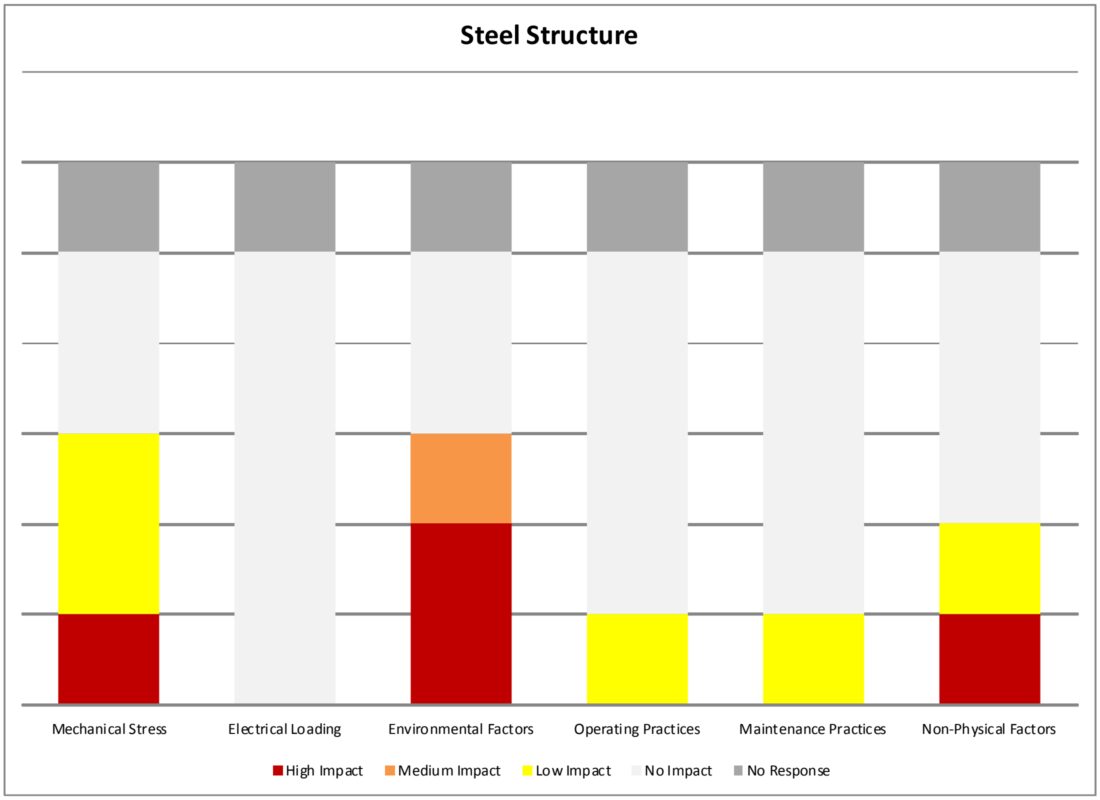


Figure 23-2 Impact of Utilization Factors on the Useful Life of Steel Structure

24. Primary Paper Insulated Lead Covered Cables

24.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. This asset group includes paper insulated lead covered cables.

24.1.1 Componentization Assumptions

For the purposes of this report, the Primary Paper Insulated Lead Covered Cables has not been componentized.

24.1.2 System Hierarchy

Primary Paper Insulated Lead Covered Cables is considered to be a part of the Underground Systems asset grouping.

24.2 Degradation Mechanism

For Paper Insulated Lead Covered (PILC) cables, the two significant long-term degradation processes are corrosion of the lead sheath and dielectric degradation of the oil impregnated paper insulation. Isolated sites of corrosion resulting in moisture penetration or isolated sites of dielectric deterioration resulting in insulation breakdown can result in localized failures. However, if either of these conditions becomes widespread there will be frequent cable failures and the cable can be deemed to be at effective end-of-life.

24.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Primary Paper Insulated Lead Covered Cables are displayed in Table 24-1.

Table 24-1 Useful Life Values for Primary Paper Insulated Lead Covered Cables

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Primary Paper Insulated Lead Covered (PILC) Cables	60	65	75

24.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Primary Paper Insulated Lead Covered Cables. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Primary Paper Insulated Lead Covered Cables (Figure 24-1).

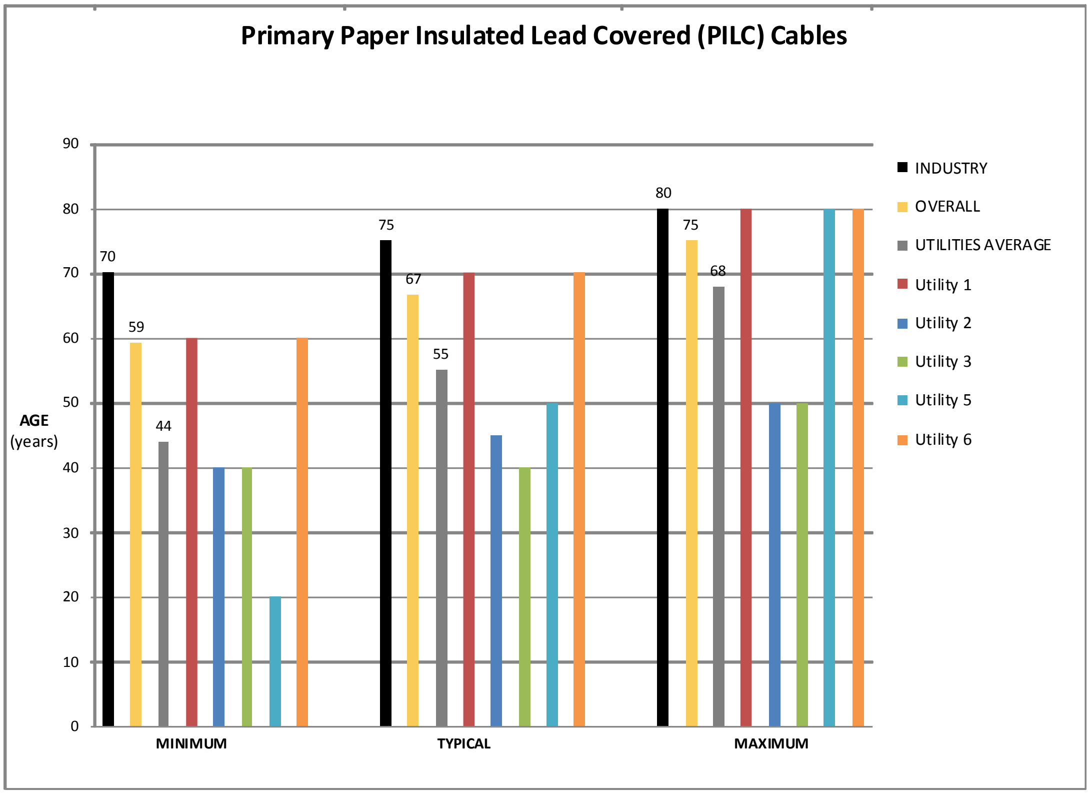


Figure 24-1 Useful Life Values for Primary Paper Insulated Lead Covered Cables

24.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Primary Paper Insulated Lead Covered Cables are displayed in Table 24-2.

Table 24-2 - Composite Score for Primary Paper Insulated Lead Covered Cables

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	23%	44%	65%	15%	0%	75%
Overall Rating*	**L**	**L**	**M**	**L**	**NI**	**M**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

24.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Primary Paper Insulated Lead Covered Cables. Five of the interviewed utilities provided their input regarding the UFs for Primary Paper Insulated Lead Covered Cables (Figure 24-2).

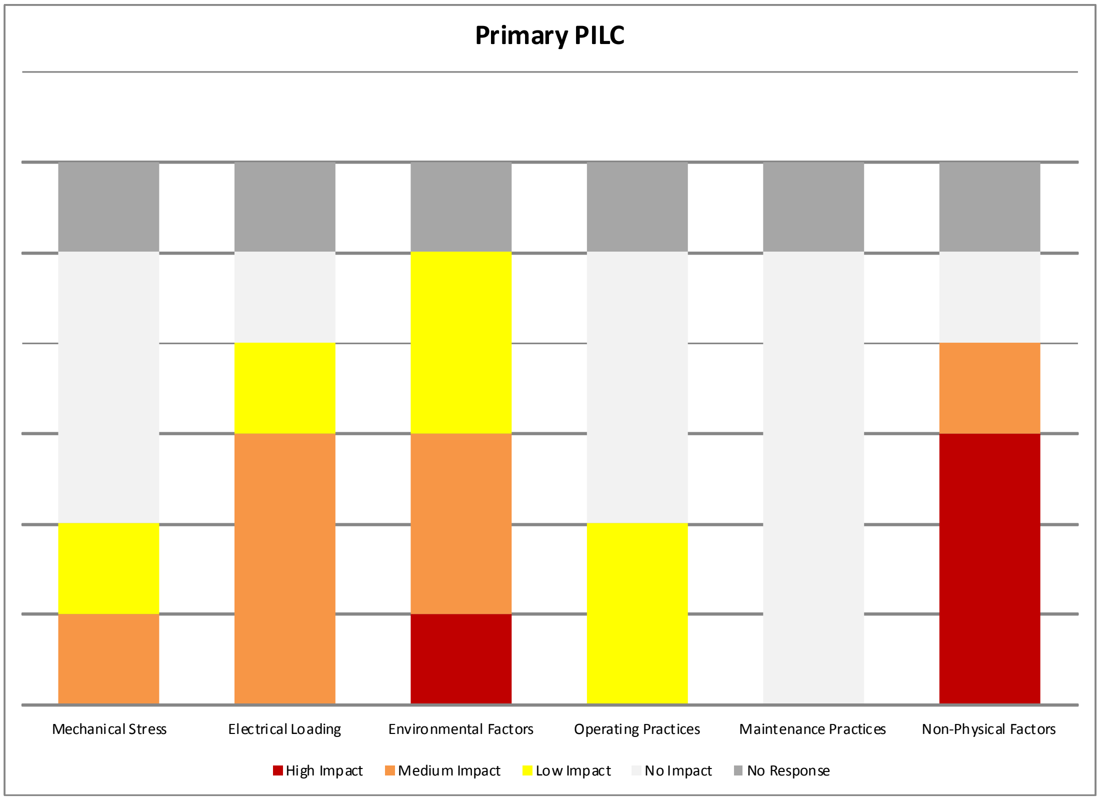


Figure 24-2 Impact of Utilization Factors on the Useful Life of Primary Paper Insulated Lead Covered Cables

25. Primary Ethylene-Propylene Rubber Cables

25.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. This asset group includes ethylene-propylene rubber insulated cables.

25.1.1 Componentization Assumptions

For the purposes of this report, the Primary Ethylene-Propylene Rubber Cables has not been componentized.

25.1.2 System Hierarchy

Primary Ethylene-Propylene Rubber Cables is considered to be a part of the Underground Systems asset grouping.

25.2 Degradation Mechanism

For Ethylene-Propylene Rubber Cables (EPR) cables long term degradation can occur due to mechanical damage, overheating, or the impact of moisture ingress and chemical deterioration.

25.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Primary Ethylene-Propylene Rubber Cables are displayed in Table 25-1.

Table 25-1 Useful Life Values for Primary Ethylene-Propylene Rubber Cables

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Primary Ethylene-Propylene Rubber (EPR) Cables	20	25	25

25.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Primary Ethylene-Propylene Rubber Cables. One of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Primary Ethylene-Propylene Rubber Cables (Figure 25-1).

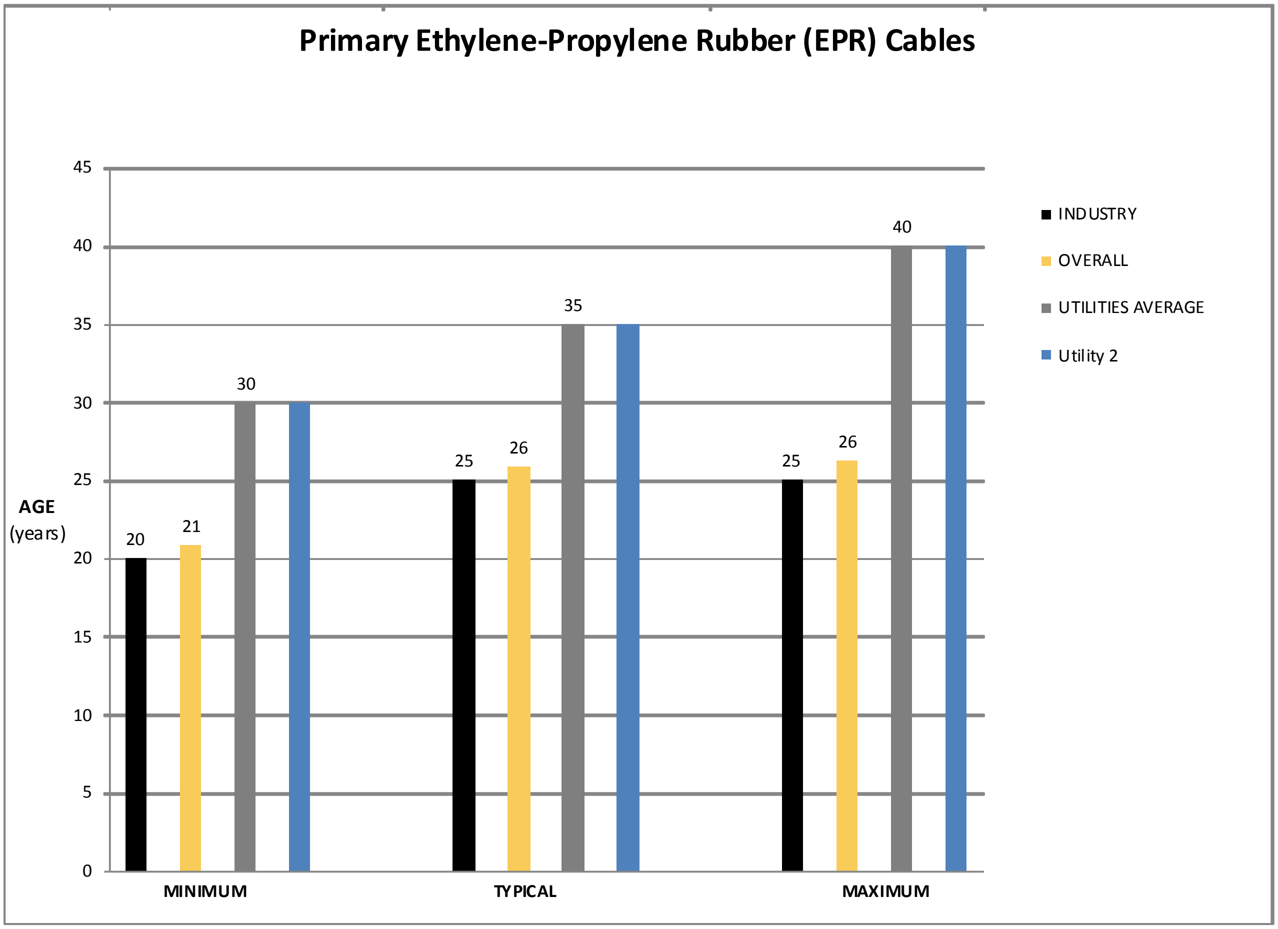


Figure 25-1 Useful Life Values for Primary Ethylene-Propylene Rubber Cables

25.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Primary Ethylene-Propylene Rubber Cables are displayed in Table 25-2.

Table 25-2 - Composite Score for Primary Ethylene-Propylene Rubber Cables

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	0%	75%	38%	0%	0%	0%
Overall Rating*	**NI**	**M**	**L**	**NI**	**NI**	**NI**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

25.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Primary Ethylene-Propylene Rubber Cables. One of the interviewed utilities provided their input regarding the UFs for Primary Ethylene-Propylene Rubber Cables (Figure 25-2).

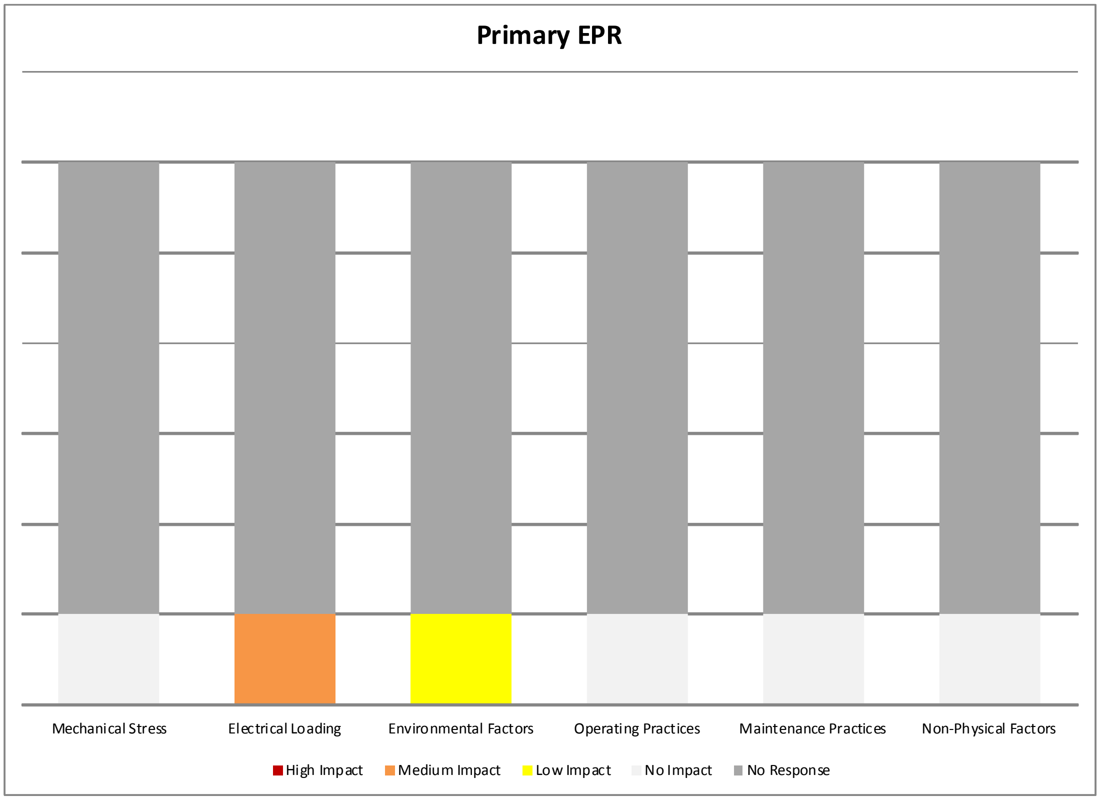


Figure 25-2 Impact of Utilization Factors on the Useful Life of Primary Ethylene-Propylene Rubber Cables

26. Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

26.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. This asset group includes directly buried non-tree retardant cross linked polyethylene insulated cables with copper or aluminum conductor.

26.1.1 Componentization Assumptions

For the purposes of this report, the Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried has not been componentized.

26.1.2 System Hierarchy

Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried is considered to be a part of the Underground Systems asset grouping.

26.2 Degradation Mechanism

Over the past 30 years XLPE insulated cables have all but replaced paper-insulated cables. These cables can be manufactured by a simple extrusion of the insulation over the conductor and therefore are much more economic to produce. In normal cable lifetime terms XLPE cables are still relatively young. Therefore, failures that have occurred can be classified as early life failures. Certainly in the early days of polymeric insulated cables their reliability was questionable. Many of the problems were associated with joints and accessories or defects introduced in the manufacturing process. Over the past 30 years many of these problems have been addressed and modern XLPE cables and accessories are generally very reliable.

Polymeric insulation is very sensitive to discharge activity. It is therefore very important that the cable, joints and accessories are discharge free when installed. Discharge testing is, therefore, an important factor for these cables. This type of testing is conducted during commissioning and is not typically used for detection of deterioration of the insulation. These commissioning tests are an area of some concern for polymeric cables because the tests themselves are suspected of causing permanent damage and reducing the life of polymeric cables.

26.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried are displayed in Table 26-1.

Table 26-1 Useful Life Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Primary Non-Tree Retardant (TR) Cross Linked Polyethylene (XLPE) Cables - Direct Buried	20	25	30

26.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried (Figure 26-1).

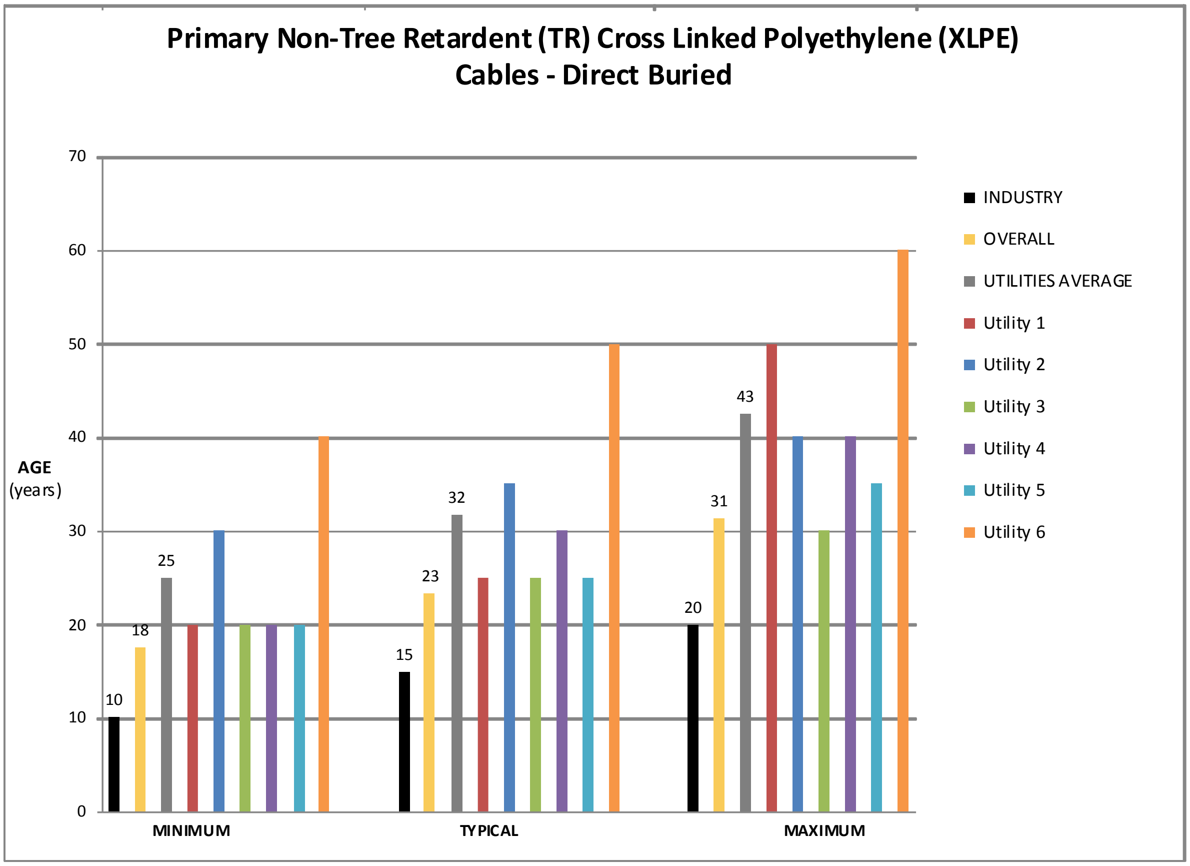


Figure 26-1 Useful Life Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

26.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried are displayed in Table 26-2

Table 26-2 - Composite Score for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	54%	60%	71%	29%	19%	33%
Overall Rating*	**M**	**M**	**M**	**L**	**L**	**L**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

26.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried. All six of the interviewed utilities provided their input regarding the UFs for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried (Figure 26-2).

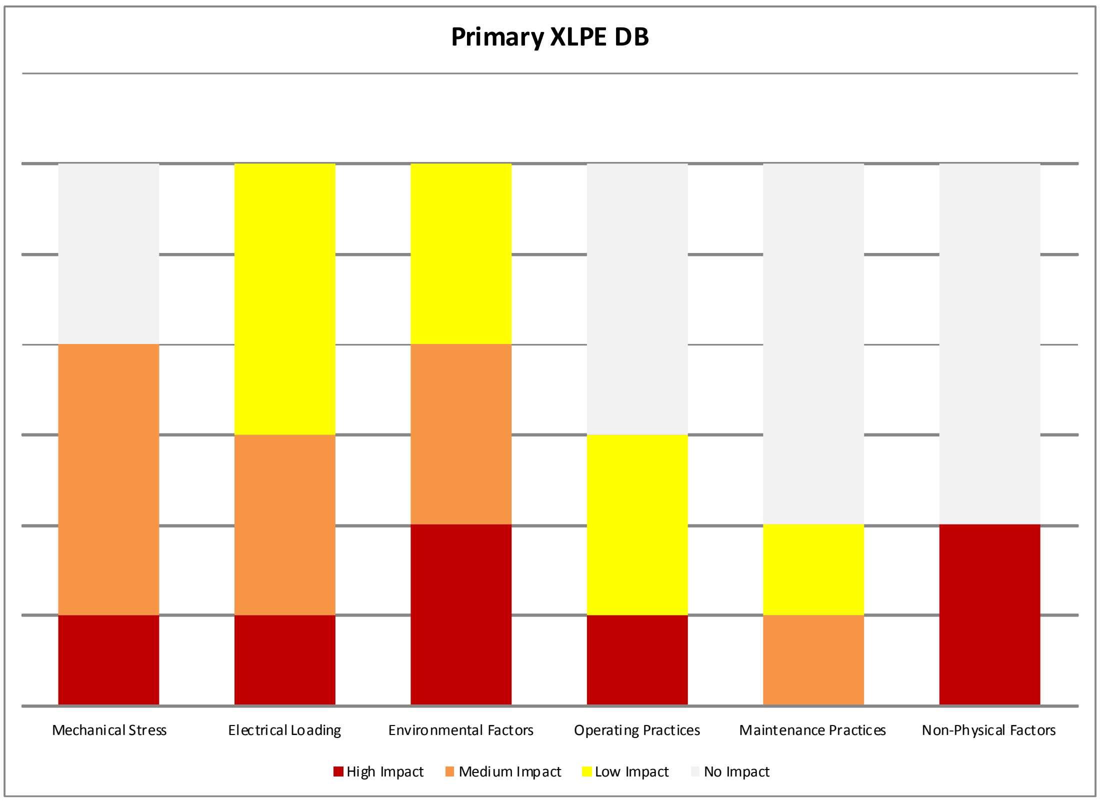


Figure 26-2 Impact of Utilization Factors on the Useful Life of Primary Non-Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

27. Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct

27.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. This asset group includes non-tree retardant cross linked polyethylene insulated cables with copper or aluminum conductor installed in duct.

27.1.1 Componentization Assumptions

For the purposes of this report, the Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct has not been componentized.

27.1.2 System Hierarchy

Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct is considered to be a part of the Underground Systems asset grouping.

27.2 Degradation Mechanism

Over the past 30 years XLPE insulated cables have all but replaced paper-insulated cables. These cables can be manufactured by a simple extrusion of the insulation over the conductor and therefore are much more economic to produce. In normal cable lifetime terms XLPE cables are still relatively young. Therefore, failures that have occurred can be classified as early life failures. Certainly in the early days of polymeric insulated cables their reliability was questionable. Many of the problems were associated with joints and accessories or defects introduced in the manufacturing process. Over the past 30 years many of these problems have been addressed and modern XLPE cables and accessories are generally very reliable.

Polymeric insulation is very sensitive to discharge activity. It is therefore very important that the cable, joints and accessories are discharge free when installed. Discharge testing is, therefore, an important factor for these cables. This type of testing is conducted during commissioning and is not typically used for detection of deterioration of the insulation. These commissioning tests are an area of some concern for polymeric cables because the tests themselves are suspected of causing permanent damage and reducing the life of polymeric cables.

27.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct are displayed in Table 27-1.

Table 27-1 Useful Life Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Primary Non-TR XLPE Cables - In Duct	20	25	30

27.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct. Three of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct (Figure 27-1).

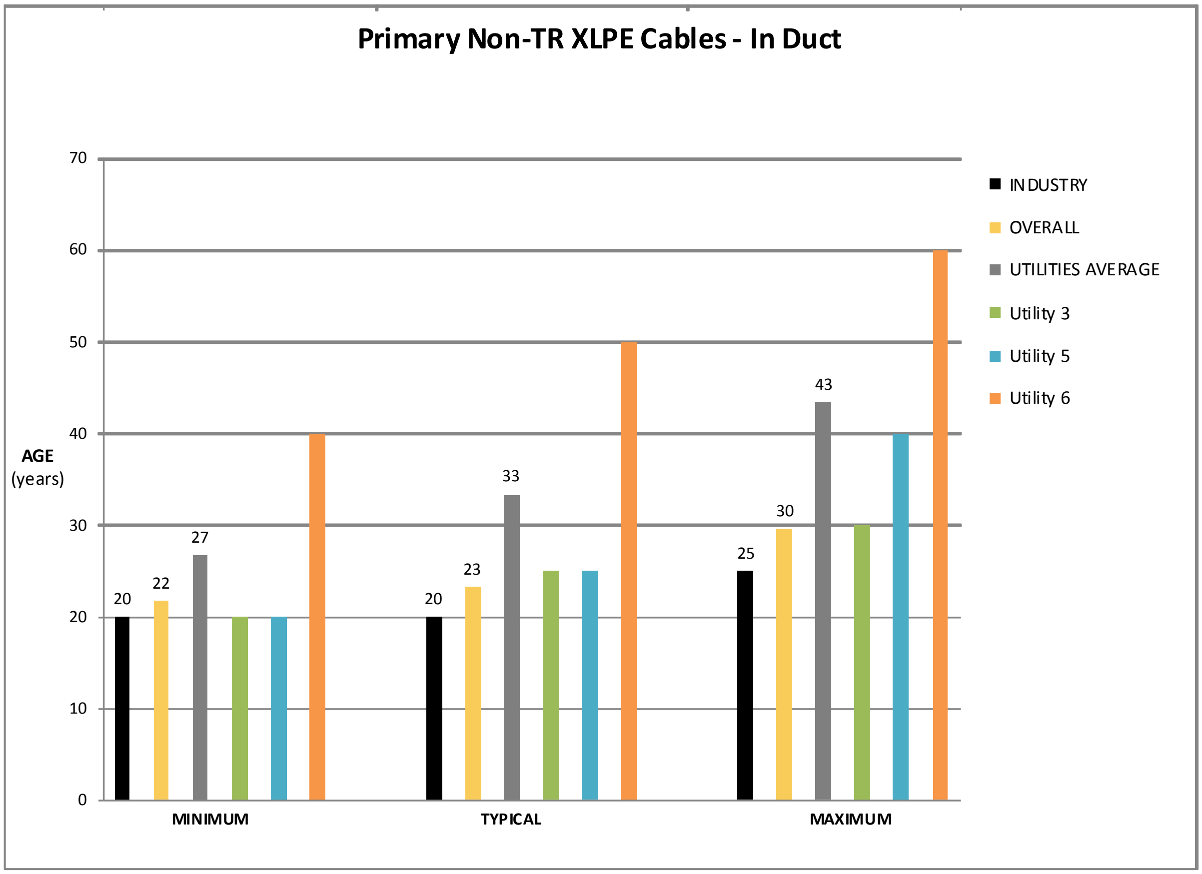


Figure 27-1 Useful Life Values for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct

27.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct are displayed in Table 27-2.

Table 27-2 - Composite Score for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	71%	71%	71%	25%	38%	67%
Overall Rating*	**M**	**M**	**M**	**L**	**L**	**M**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

27.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct. Three of the interviewed utilities provided their input regarding the UFs for Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct (Figure 27-2).

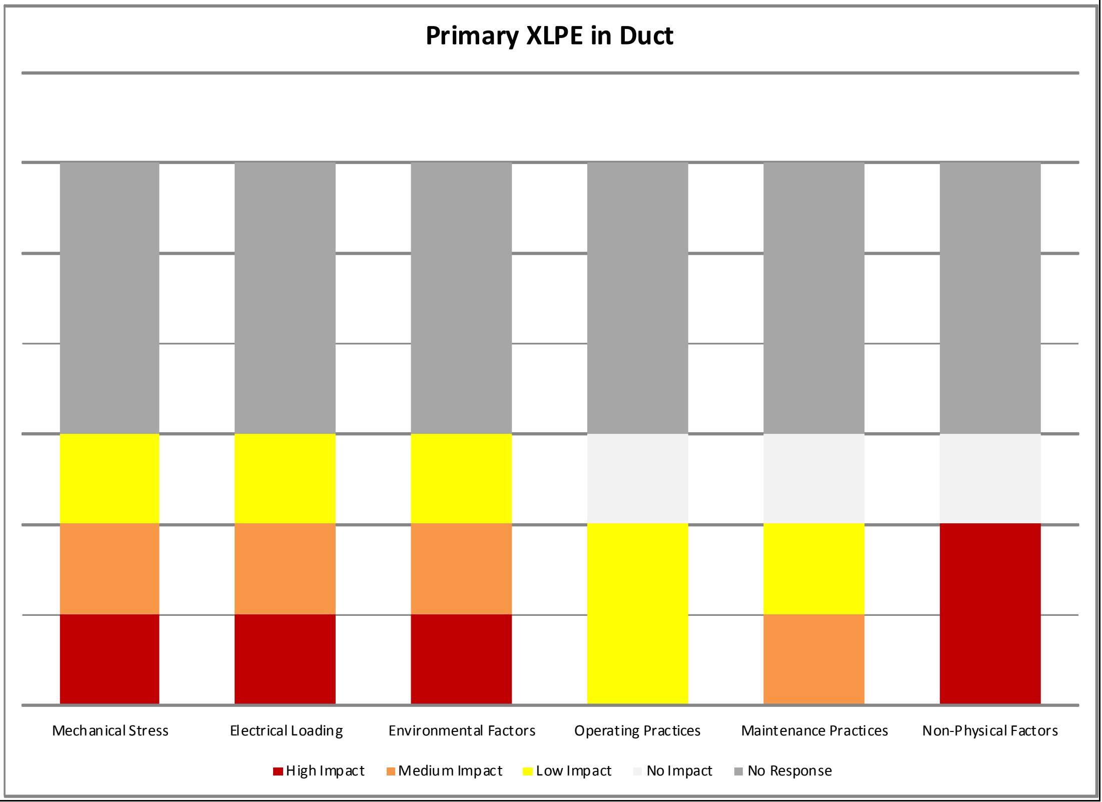


Figure 27-2 Impact of Utilization Factors on the Useful Life of Primary Non-Tree Retardant Cross Linked Polyethylene Cables – In Duct

28. Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

28.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. This asset group includes direct buried tree retardant cross linked polyethylene insulated cables with copper or aluminum conductor.

28.1.1 Componentization Assumptions

For the purposes of this report, the Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried has not been componentized.

28.1.2 System Hierarchy

Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried is considered to be a part of the Underground Systems asset grouping.

28.2 Degradation Mechanism

Over the past 30 years XLPE insulated cables have all but replaced paper-insulated cables. These cables can be manufactured by a simple extrusion of the insulation over the conductor and therefore are much more economic to produce. In normal cable lifetime terms XLPE cables are still relatively young. Therefore, failures that have occurred can be classified as early life failures. Certainly in the early days of polymeric insulated cables their reliability was questionable. Many of the problems were associated with joints and accessories or defects introduced in the manufacturing process. Over the past 30 years many of these problems have been addressed and modern XLPE cables and accessories are generally very reliable.

Polymeric insulation is very sensitive to discharge activity. It is therefore very important that the cable, joints, splices and terminations are discharge free when installed. Discharge testing is, therefore, an important factor for these cables. This type of testing is conducted during commissioning and is not typically used for detection of deterioration of the insulation. These commissioning tests are an area of some concern for polymeric cables because the tests themselves are suspected of causing permanent damage and reducing the life of polymeric cables.

Water treeing is the most significant degradation process for polymeric cables. The original design of cables with polymeric sheaths allowed water to penetrate and come into contact with the insulation. In the presence of electric fields water migration can result in treeing and ultimately breakdown. The rate of growth of water trees is dependent on the quality of the polymeric insulation and the manufacturing process. Any contamination voids or discontinuities will accelerate degradation. This is assumed to be the reason for poor reliability and relatively short lifetimes of early (non-tree retardant) polymeric cables. As manufacturing processes have improved and tree retardant cables have become the predominant underground cable type, the performance and ultimate life of this type of cable has also improved.

The major degradation problems with the cable terminations concern mostly flashover and tracking associated with the outside and interior surfaces of joints, splices and terminations. . However, there are also problems of overheating at connections and voltage control at the end of the cable shield.

28.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried are displayed in Table 28-1.

Table 28-1 Useful Life Values for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Primary TR XLPE Cables - Direct Buried	25	30	35

28.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried (Figure 28-1).

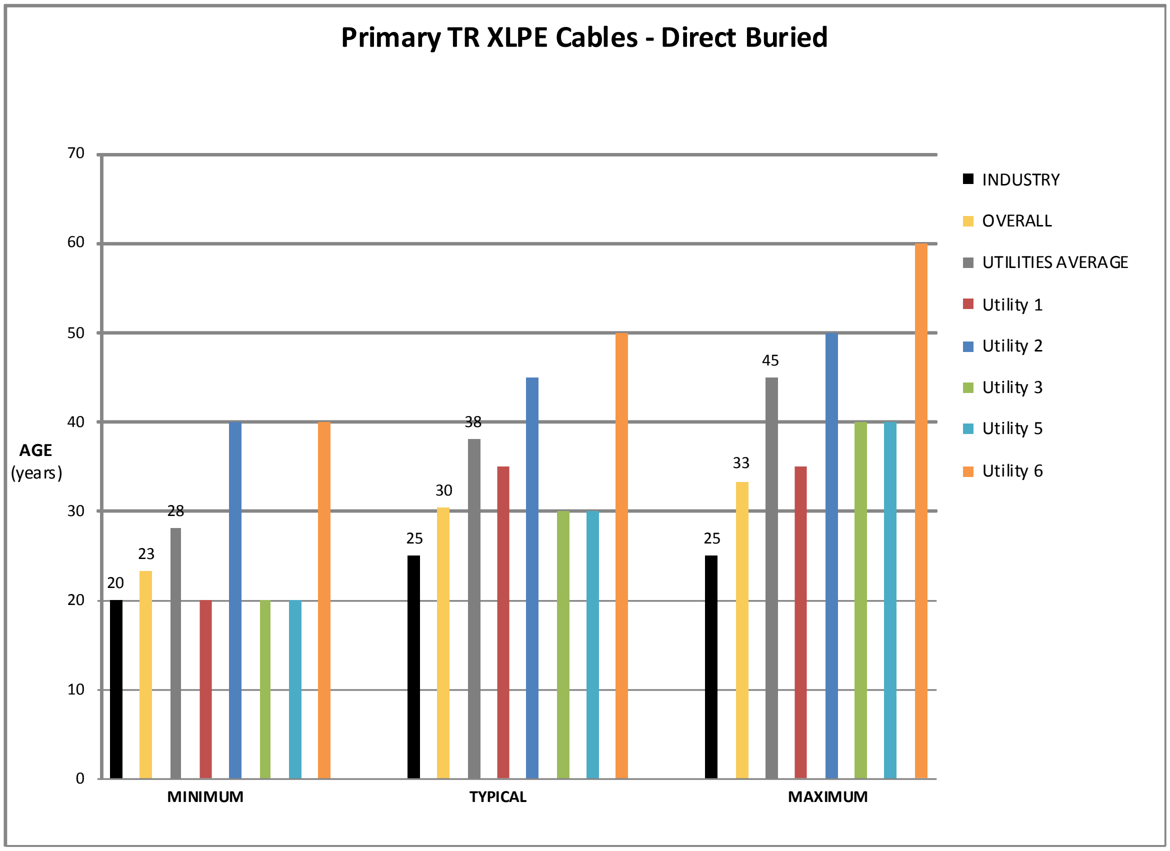


Figure 28-1 Useful Life Values for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

28.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried are displayed in Table 28-2.

Table 28-2 - Composite Score for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	50%	60%	70%	15%	15%	15%
Overall Rating*	**M**	**M**	**M**	**L**	**L**	**L**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

28.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried. Five of the interviewed utilities provided their input regarding the UFs for Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried (Figure 28-2).

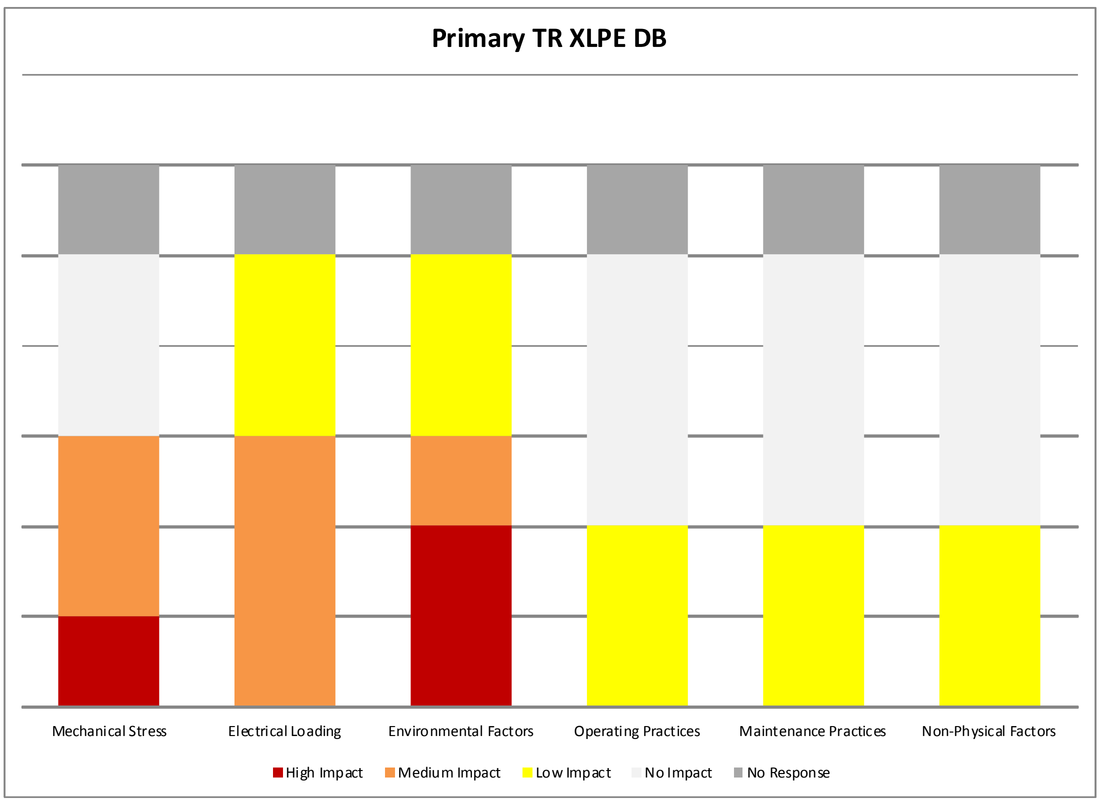


Figure 28-2 Impact of Utilization Factors on the Useful Life of Primary Tree Retardant Cross Linked Polyethylene Cables – Direct Buried

29. Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct

29.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. This asset group includes tree retardant cross linked polyethylene insulated cables with copper or aluminum conductor installed in duct.

29.1.1 Componentization Assumptions

For the purposes of this report, the Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct has not been componentized.

29.1.2 System Hierarchy

Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct is considered to be a part of the Underground Systems asset grouping.

29.2 Degradation Mechanism

Over the past 30 years XLPE insulated cables have all but replaced paper-insulated cables. These cables can be manufactured by a simple extrusion of the insulation over the conductor and therefore are much more economic to produce. In normal cable lifetime terms XLPE cables are still relatively young. Therefore, failures that have occurred can be classified as early life failures. Certainly in the early days of polymeric insulated cables their reliability was questionable. Many of the problems were associated with joints and accessories or defects introduced in the manufacturing process. Over the past 30 years many of these problems have been addressed and modern XLPE cables and accessories are generally very reliable.

Polymeric insulation is very sensitive to discharge activity. It is therefore very important that the cable, joints and accessories are discharge free when installed. Discharge testing is, therefore, an important factor for these cables. This type of testing is conducted during commissioning and is not typically used for detection of deterioration of the insulation. These commissioning tests are an area of some concern for polymeric cables because the tests themselves are suspected of causing permanent damage and reducing the life of polymeric cables.

Water treeing is the most significant degradation process for polymeric cables. The original design of cables with polymeric sheaths allowed water to penetrate and come into contact with the insulation. In the presence of electric fields water migration can result in treeing and ultimately breakdown. The rate of growth of water trees is dependent on the quality of the polymeric insulation and the manufacturing process. Any contamination voids or discontinuities will accelerate degradation. This is assumed to be the reason for poor reliability and relatively short lifetimes of early (non-tree retardant) polymeric cables. As manufacturing processes have improved and tree retardant cables have become the predominant underground cable type, the performance and ultimate life of this type of cable has also improved.

The major degradation problems with the cable terminations concern mostly flashover and tracking associated with the outside and interior surfaces of the accessory. However, there are also problems of overheating at connections and voltage control at the end of the cable shield.

29.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct are displayed in Table 29-1.

Table 29-1 Useful Life Values for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Primary TR XLPE Cables - In Duct	35	40	55

29.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct (Figure 29-1).

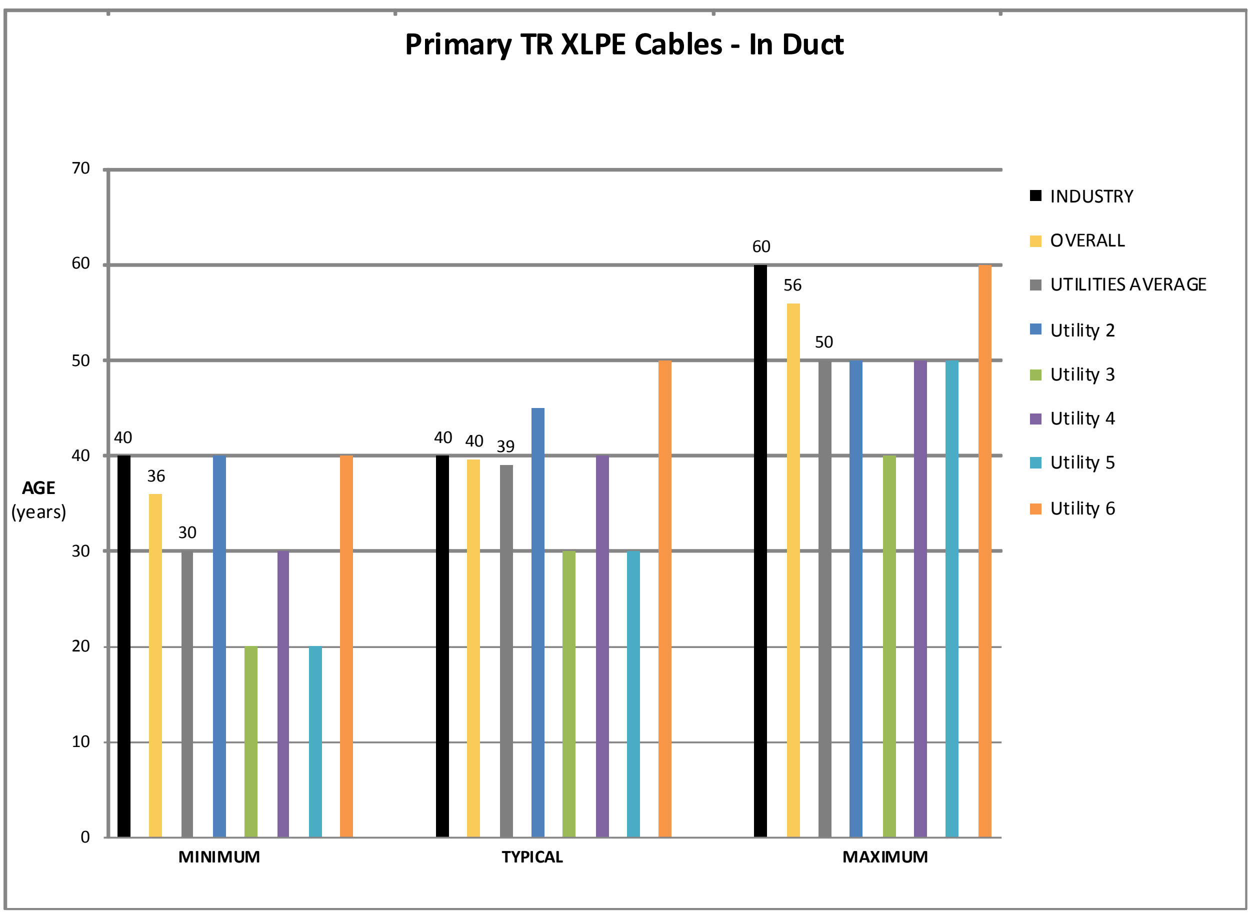


Figure 29-1 Useful Life Values for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct

29.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct are displayed in Table 29-2.

Table 29-2 - Composite Score for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	58%	56%	54%	35%	15%	15%
Overall Rating*	M	M	M	L	L	L
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

29.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct. All six of the interviewed utilities provided their input regarding the UFs for Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct (Figure 29-2).

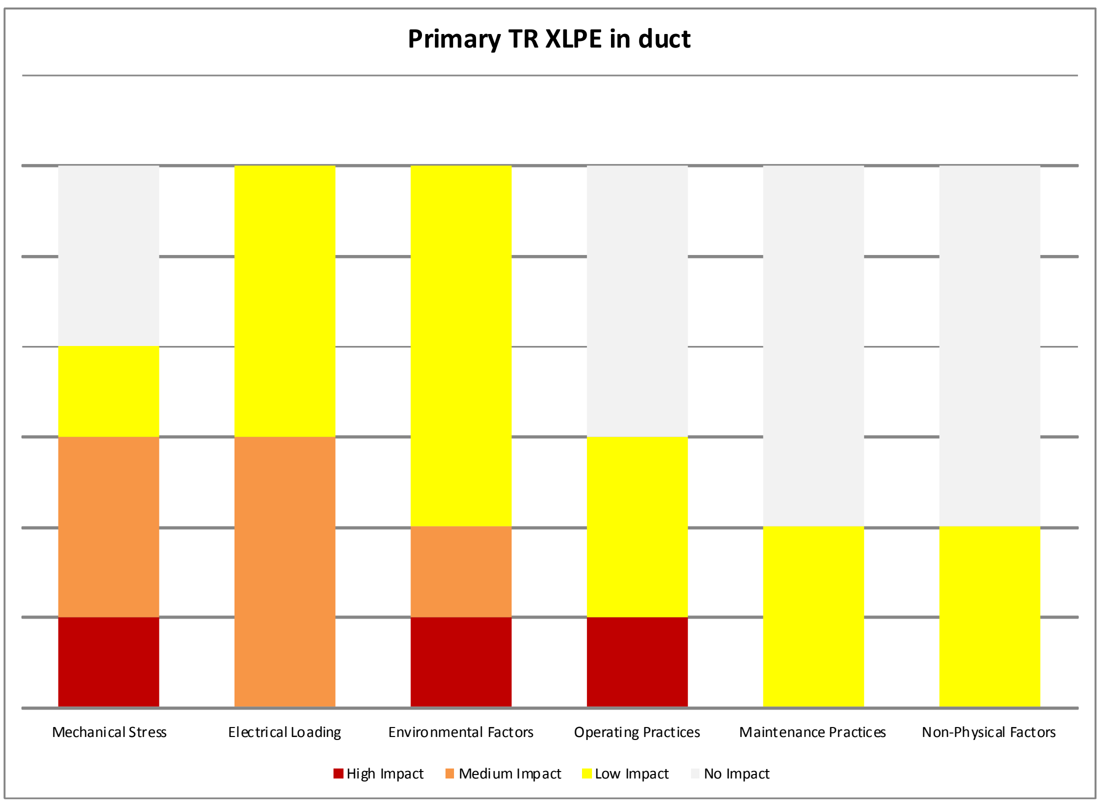


Figure 29-2 Impact of Utilization Factors on the Useful Life of Primary Tree Retardant Cross Linked Polyethylene Cables – In Duct

30. Secondary Paper Insulated Lead Covered Cables

30.1 Asset Description

Distribution underground cables are mainly used in urban areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental and safety reasons. Secondary underground cables are used to supply customer premises.

30.1.1 Componentization Assumptions

For the purposes of this report, the Secondary Paper Insulated Lead Covered Cables has not been componentized.

30.1.2 System Hierarchy

Secondary Paper Insulated Lead Covered Cables is considered to be a part of the Underground Systems asset grouping.

30.2 Degradation Mechanism

For Paper Insulated Lead Covered (PILC) cables, the two significant long-term degradation processes are corrosion of the lead sheath and dielectric degradation of the oil impregnated paper insulation. Isolated sites of corrosion resulting in moisture penetration or isolated sites of dielectric deterioration resulting in insulation breakdown can result in localized failures. However, if either of these conditions becomes widespread there will be frequent cable failures and the cable can be deemed to be at effective end-of-life.

30.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Secondary Paper Insulated Lead Covered Cables are displayed in Table 30-1.

Table 30-1 Useful Life Values for Secondary Paper Insulated Lead Covered Cables

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Secondary PILC Cables	70	75	80

30.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Secondary Paper Insulated Lead Covered Cables. None of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Secondary Paper Insulated Lead Covered Cables (Figure 30-1).

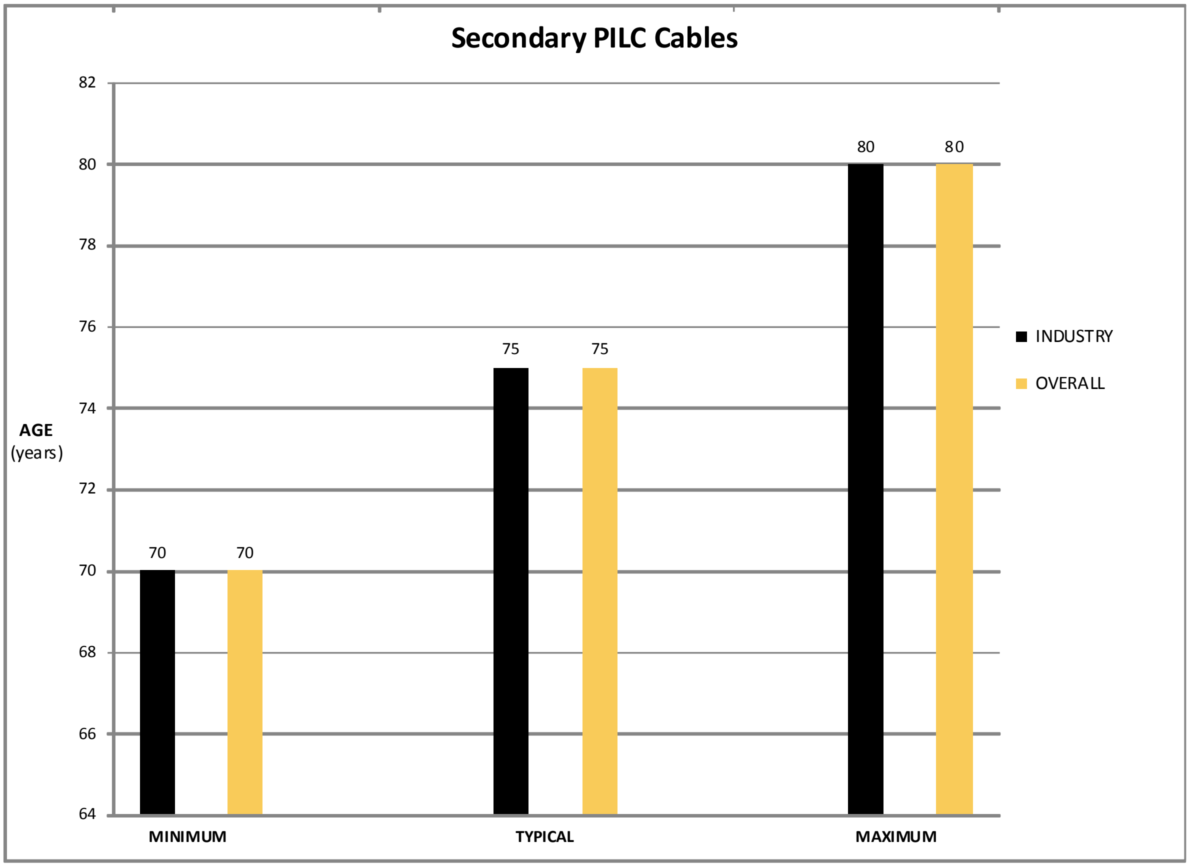


Figure 30-1 Useful Life Values for Secondary Paper Insulated Lead Covered Cables

30.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high, medium, low), if any, of each factor on the typical useful life of Secondary Paper Insulated Lead Covered Cables are displayed in Table 30-2.

Table 30-2 - Composite Score for Secondary Paper Insulated Lead Covered Cables

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	0%	38%	38%	0%	0%	100%
Overall Rating*	**NI**	**L**	**L**	**NI**	**NI**	**H**

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

30.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Secondary Paper Insulated Lead Covered Cables. One of the interviewed utilities provided their input regarding the UFs for Secondary Paper Insulated Lead Covered Cables (Figure 30-2).

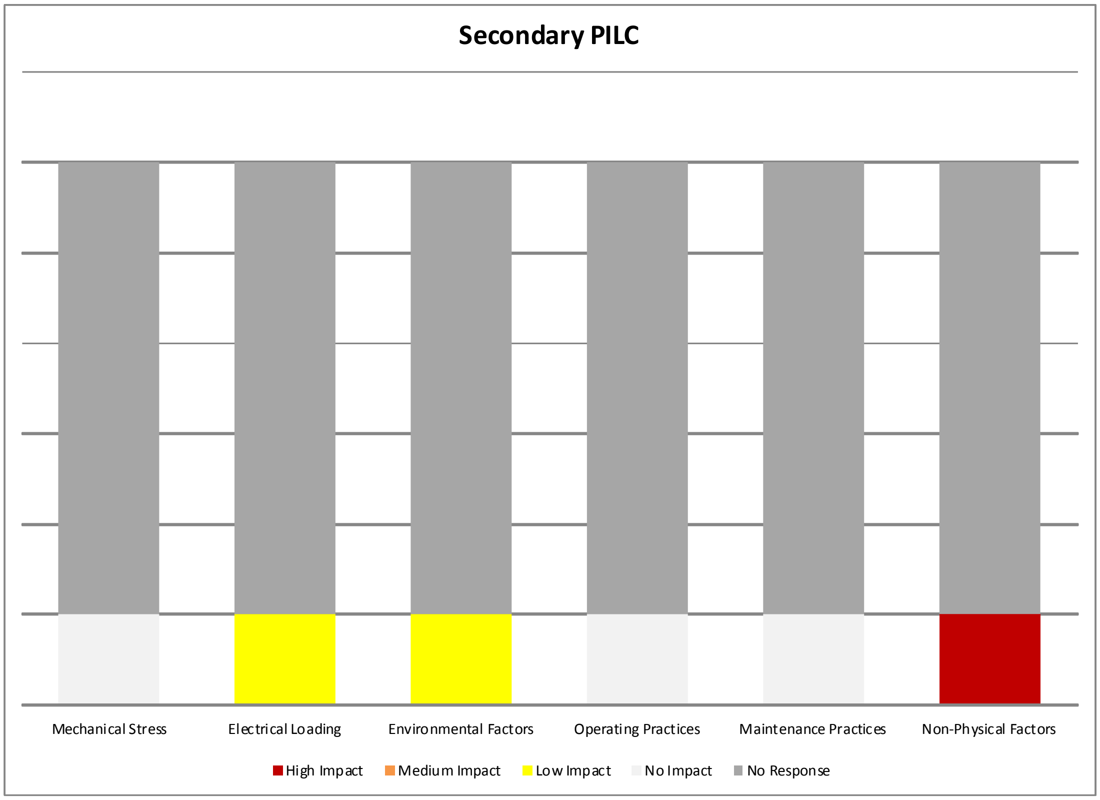


Figure 30-2 Impact of Utilization Factors on the Useful Life of Secondary Paper Insulated Lead Covered Cables

31. Secondary Cables – Direct Buried

31.1 Asset Description

Secondary underground cables are used to supply customer premises.

31.1.1 Componentization Assumptions

For the purposes of this report, the Secondary Cables – Direct Buried has not been componentized.

31.1.2 System Hierarchy

Secondary Cables – Direct Buried is considered to be a part of the Underground Systems asset grouping.

31.2 Degradation Mechanism

Degradation of secondary cables is commonly due to mechanical damage, overloading and chemical and environmental impacts on the insulation material.

31.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Secondary Cables – Direct Buried are displayed in Table 32-1.

Table 31-1 Useful Life Values for Secondary Cables – Direct Buried

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Secondary Cables - Direct Buried	25	35	40

31.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Secondary Cables – Direct Buried. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Secondary Cables – Direct Buried (Figure 31-1).

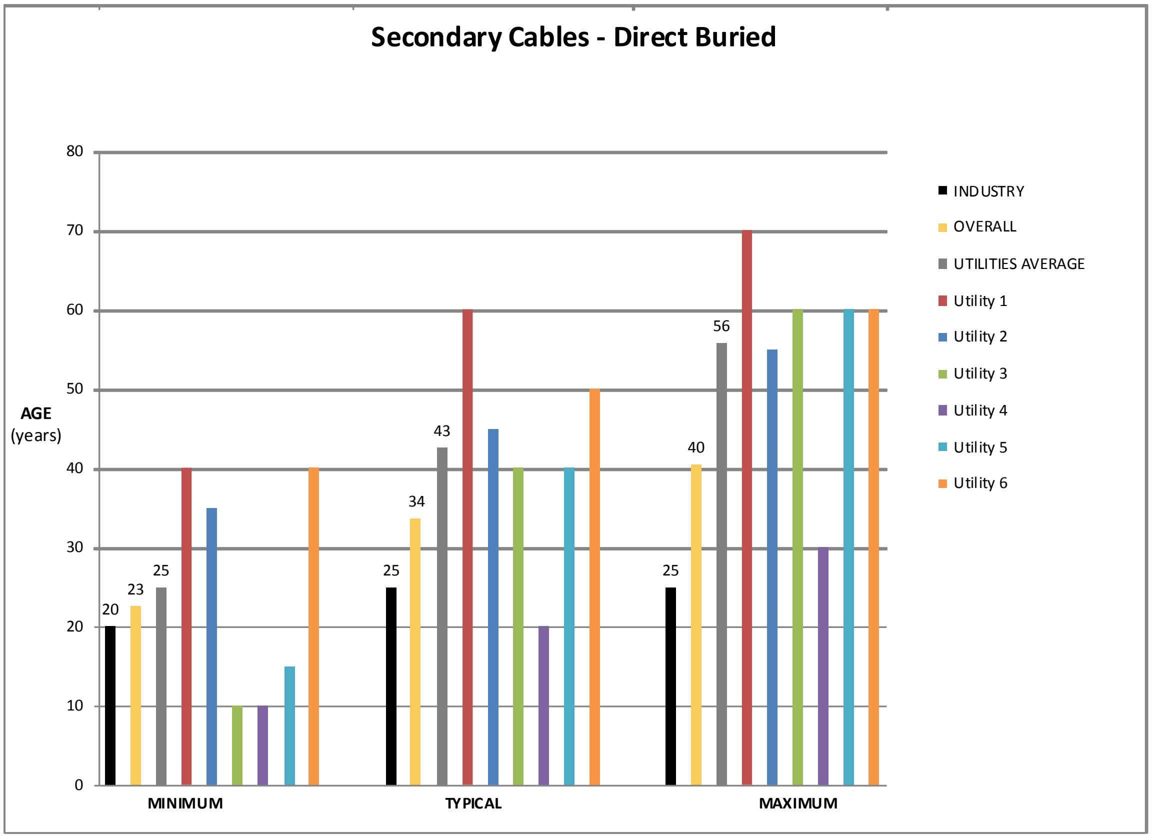


Figure 31-1 Useful Life Values for Secondary Cables – Direct Buried

31.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Secondary Cables – Direct Buried are displayed in Table 32-2.

Table 31-2 - Composite Score for Secondary Cables – Direct Buried

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	67%	50%	58%	23%	6%	0%
Overall Rating*	M	M	M	L	NI	NI

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

31.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Secondary Cables – Direct Buried. All six of the interviewed utilities provided their input regarding the UFs for Secondary Cables – Direct Buried (Figure 31-2).

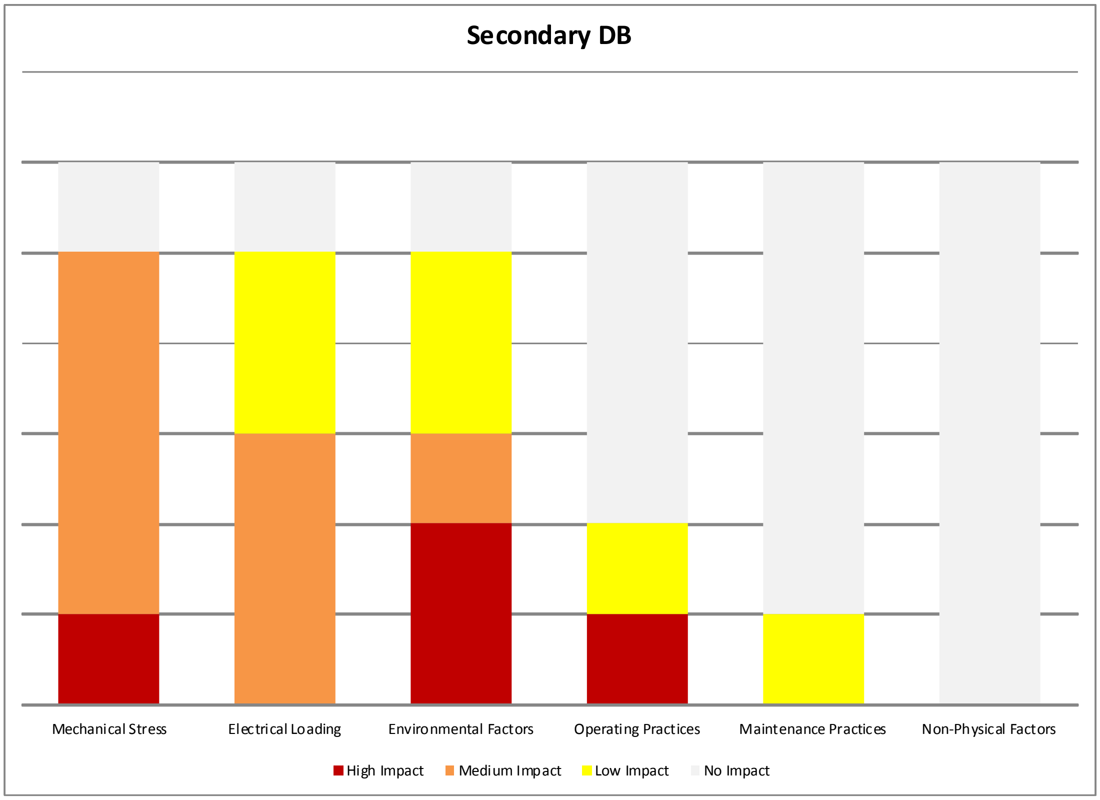


Figure 31-2 Impact of Utilization Factors on the Useful Life of Secondary Cables – Direct Buried

32. Secondary Cables – In Duct

32.1 Asset Description

Secondary underground cables are used to supply customer premises.

32.1.1 Componentization Assumptions

For the purposes of this report, the Secondary Cables – In Duct has not been componentized.

32.1.2 System Hierarchy

Secondary Cables – In Duct is considered to be a part of the Underground Systems asset grouping.

32.2 Degradation Mechanism

Degradation of secondary cables is commonly due to mechanical damage, overloading and chemical and environmental impacts on the insulation material. Placement of the cable in duct mitigates some of the mechanical and chemical damage mechanisms.

32.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Secondary Cables – In Duct are displayed in Table 33-1.

Table 32-1 Useful Life Values for Secondary Cables – In Duct

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Secondary Cables - In Duct	35	40	60

32.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Secondary Cables – In Duct. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Secondary Cables – In Duct (Figure 32-1).

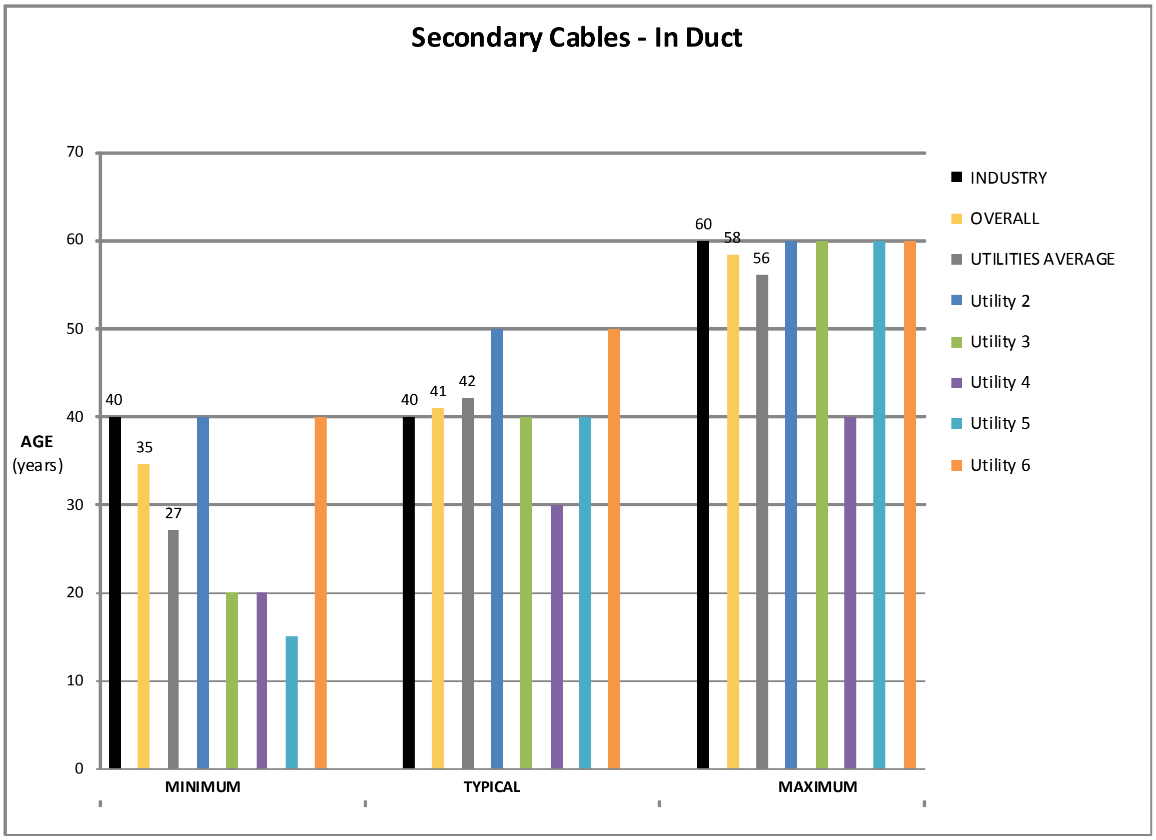


Figure 32-1 Useful Life Values for Secondary Cables – In Duct

32.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Secondary Cables – In Duct are displayed in Table 33-2.

Table 32-2 - Composite Score for Secondary Cables – In Duct

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	58%	45%	50%	28%	8%	0%
Overall Rating*	M	M	M	L	NI	NI
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

32.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Secondary Cables – In Duct. Five of the interviewed utilities provided their input regarding the UFs for Secondary Cables – In Duct (Figure 32-2).

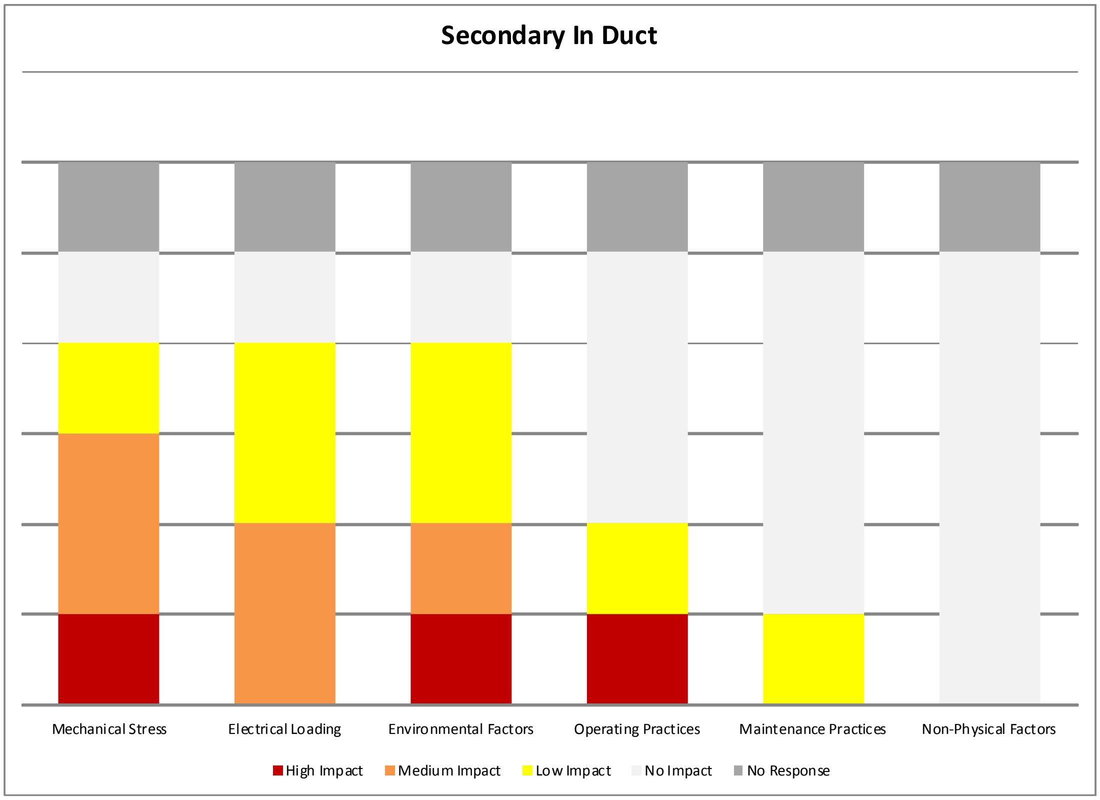


Figure 32-2 Impact of Utilization Factors on the Useful Life of Secondary Cables – In Duct

33. Network Transformers

33.1 Asset Description

Network transformers are special purpose distribution transformers, designed and constructed for successful operation in a parallel mode with a large number of transformers with similar characteristic. The primary winding of the transformers is connected in Delta configuration while the secondary is in grounded star configuration. The network transformers are provided with a primary disconnect, which has no current interrupting rating and is used merely as in isolating device after the transformer has been de-energized both from primary and secondary source. The secondary bushings are mounted on the side wall of the transformer in a throat, suitable for mounting of the network protector.

33.1.1 Componentization Assumptions

For the purposes of this report, the Network Transformers has been componentized so that the network protector is regarded as separated components. Therefore the Network Transformers has overall useful life values based and useful life values for the specific component, the network protector.

Network protectors are special purpose low voltage air circuit breakers, designed for successful parallel operation of network transformers. Network protectors are fully self contained units, equipped with protective relays and instrument transformers to allow automatic closing and opening of the protector. The relays conduct a line test before initiating close command and allow closing of the breaker only if the associated transformer has the correct voltage condition in relation to the grid to permit flow of power from the transformer to the grid. If the conditions are not right, protector closing is blocked. The protector is also equipped with a reverse current relay that trips if the power flow reverses from its normal direction, i.e. if the power flows from grid into the transformer.

33.1.2 System Hierarchy

Network Transformers is considered to be a part of the Underground Systems asset grouping.

33.2 Degradation Mechanism

Since in a majority of the applications transformers are installed in below grade vaults, the transformer is designed for partially submersible operation with additional protection against corrosion. While network transformers are available in dry-type (cast coil and epoxy impregnation) designs, a vast majority of the network transformers employ mineral oil for insulation and cooling. The network transformer has a similar degradation mechanism to other distribution transformers.

The life of the transformer's internal insulation is related to temperature rise and duration. Therefore, the transformer life is affected by electrical loading profiles and length of service life. Other factors such as mechanical damage, exposure to corrosive salts, and voltage current surges also have strong effects. Therefore, a combination of condition, age, and load based criteria is commonly used to determine the useful remaining life.

The breaker design in network protectors employs mechanical linkages, rollers, springs and cams for operation which require periodic maintenance. All network protectors are equipped with special load-side fuses, mounted either internally or external to the network protector housing. The fuses are intended to allow normal load current and overloads while providing backup protection in the event that the protector fails to open on reverse fault current (due to faults internal to the protector or near transformer low voltage terminals). Every time arcing occurs in open air within the network protector housing, whether due to operation of the air breaker or because of fuse blowing (except silver sand), a certain amount of metal vapour is liberated and dispersed over insulating parts. Fuses evidently liberate more vapour than breaker operation. Over time, this buildup reduces the dielectric strength of insulating barriers. Eventually this may result in a breakdown, unless care is taken to clean the network protector internally, particularly after fuse operations.

Various parameters that impact the health and condition and eventually lead to end of life of a network include condition of mechanical moving parts, condition of inter phase barriers, number of protector operations (counter reading), accumulation of dirt or debris in protector housing, corrosion of protector housing, condition of fuses, condition of arc chutes and time period elapsed since last major overhaul of the protector.

The health of network protector is established by taking into account the following:

- Number of operations since last overhaul
- Operating age of protector
- Condition of operating mechanism
- Condition of fuses
- Condition of arc chutes
- Condition of protector relays
- Condition of gaskets and seals for submersible units

33.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Network Transformers are displayed in Table 33-1.

Table 33-1 Useful Life Values for Network Transformers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Overall	20	35	50
Protector	20	35	40

33.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Network Transformers. One of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Network Transformers (Figure 33-1).

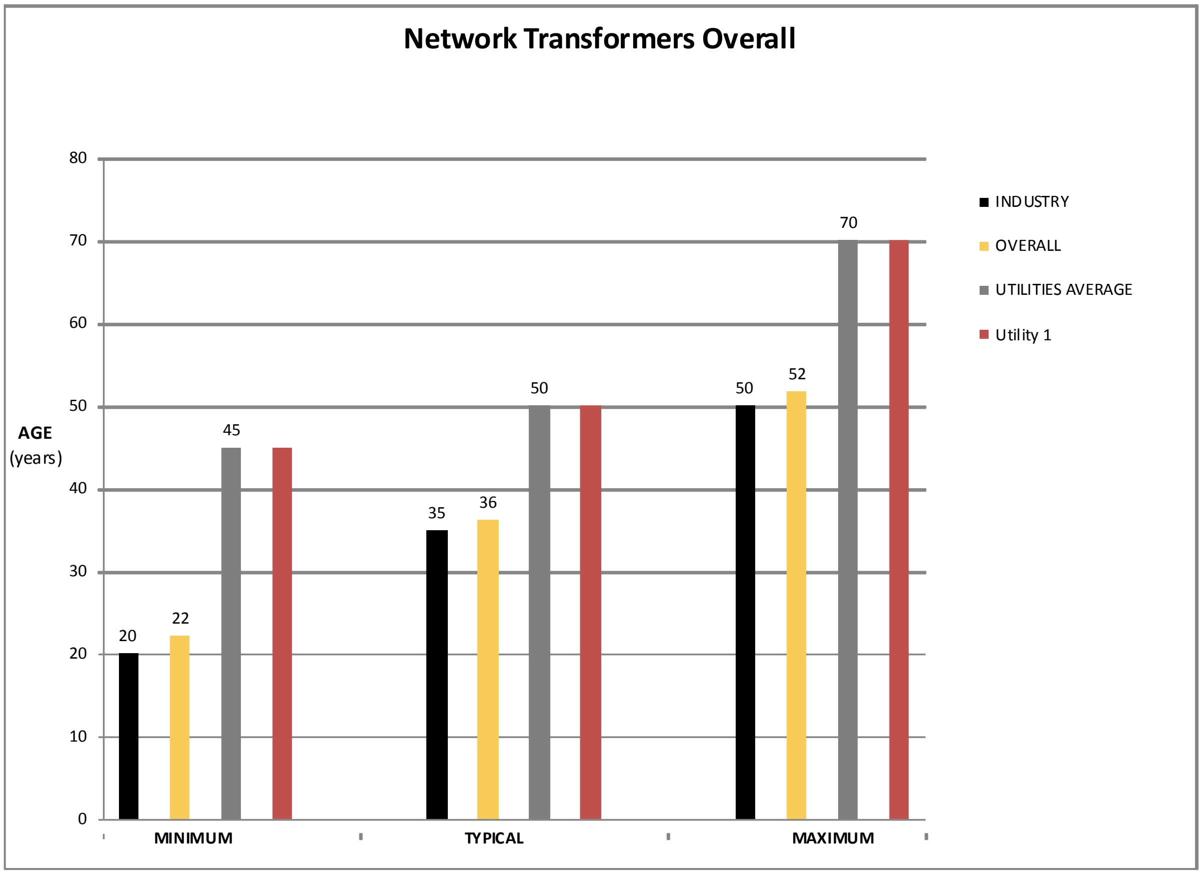


Figure 33-1 Useful Life Values for Network Transformers

33.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Network Transformers are displayed in Table 33-2.

Table 33-2 - Composite Score for Network Transformers

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	0%	38%	100%	0%	0%	0%
Overall Rating*	**NI**	**L**	**H**	**NI**	**NI**	**NI**
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

33.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Network Transformers. One of the interviewed utilities provided their input regarding the UFs for Network Transformers (Figure 33-2).

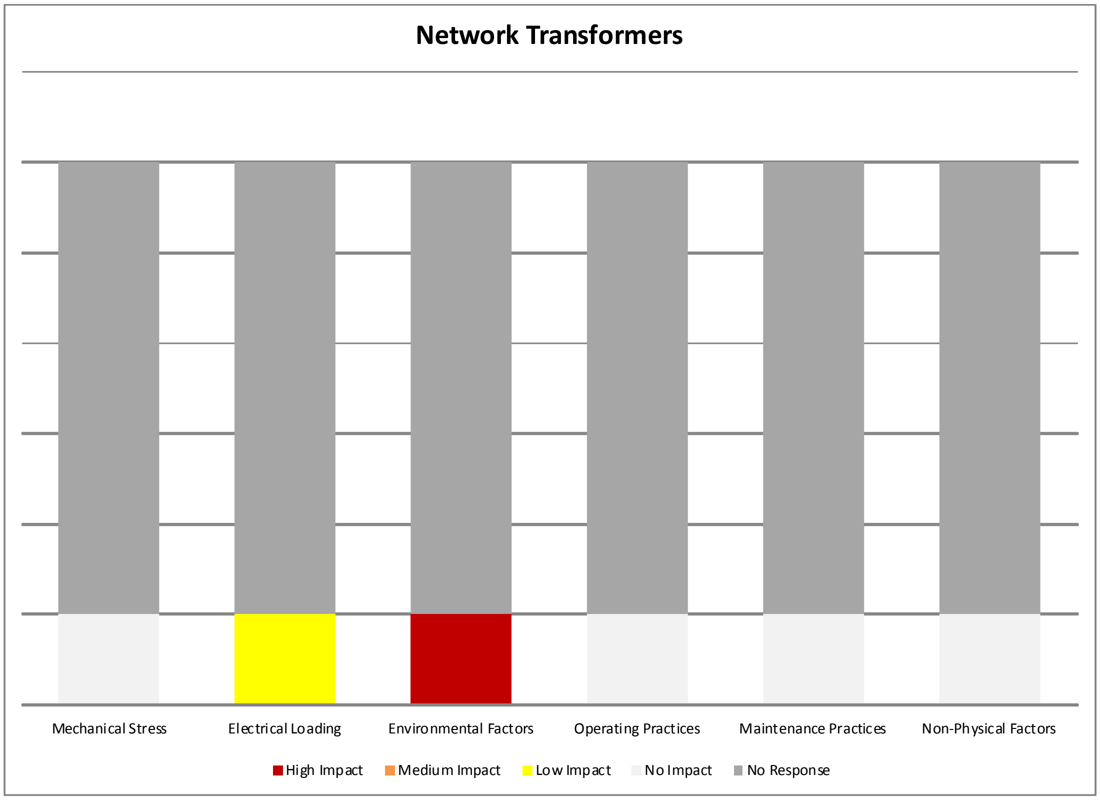


Figure 33-2 Impact of Utilization Factors on the Useful Life of Network Transformers

34. Pad-Mounted Transformers

34.1 Asset Description

Pad-Mounted transformers typically employ sealed tank construction and are liquid filled, with mineral insulating oil being the predominant liquid.

34.1.1 Componentization Assumptions

For the purposes of this report, the Pad-Mounted Transformers has not been componentized.

34.1.2 System Hierarchy

Pad-Mounted Transformers is considered to be a part of the Underground Systems asset grouping.

34.2 Degradation Mechanism

It has been demonstrated that the life of the transformer's internal insulation is related to temperature rise and duration. Therefore, the transformer life is affected by electrical loading profiles and length of service life. Other factors such as mechanical damage, exposure to corrosive salts, and voltage current surges also have strong effects. Therefore, a combination of condition, age, and load based criteria is commonly used to determine the useful remaining life.

In general, the following are considered when determining the health of the pad-mounted transformer:

- Tank corrosion, condition of paint
- Extent of oil leaks
- Condition of bushings
- Condition of padlocks, warning signs, etc.
- Transfer operating age and winding temperature profile

34.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Pad-Mounted Transformers are displayed in Table 34-1.

Table 34-1 Useful Life Values for Pad-Mounted Transformers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Pad-Mounted Transformers	25	40	45

34.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Pad-Mounted Transformers. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Pad-Mounted Transformers (Figure 34-1).

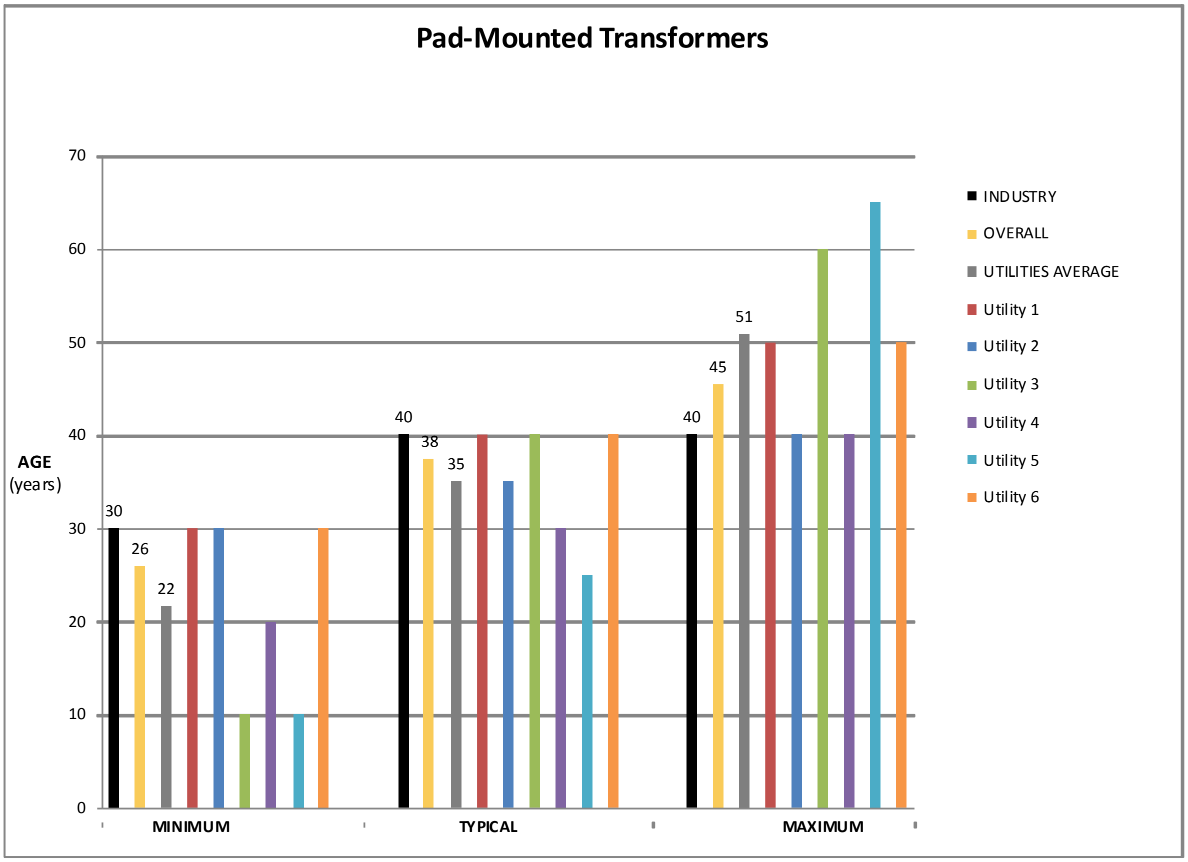


Figure 34-1 Useful Life Values for Pad-Mounted Transformers

34.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Pad-Mounted Transformers are displayed in Table 34-2.

Table 34-2 - Composite Score for Pad-Mounted Transformers

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	19%	56%	71%	0%	13%	19%
Overall Rating*	L	M	M	NI	L	L
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

34.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Pad-Mounted Transformers. All six of the interviewed utilities provided their input regarding the UFs for Pad-Mounted Transformers (Figure 34-2).

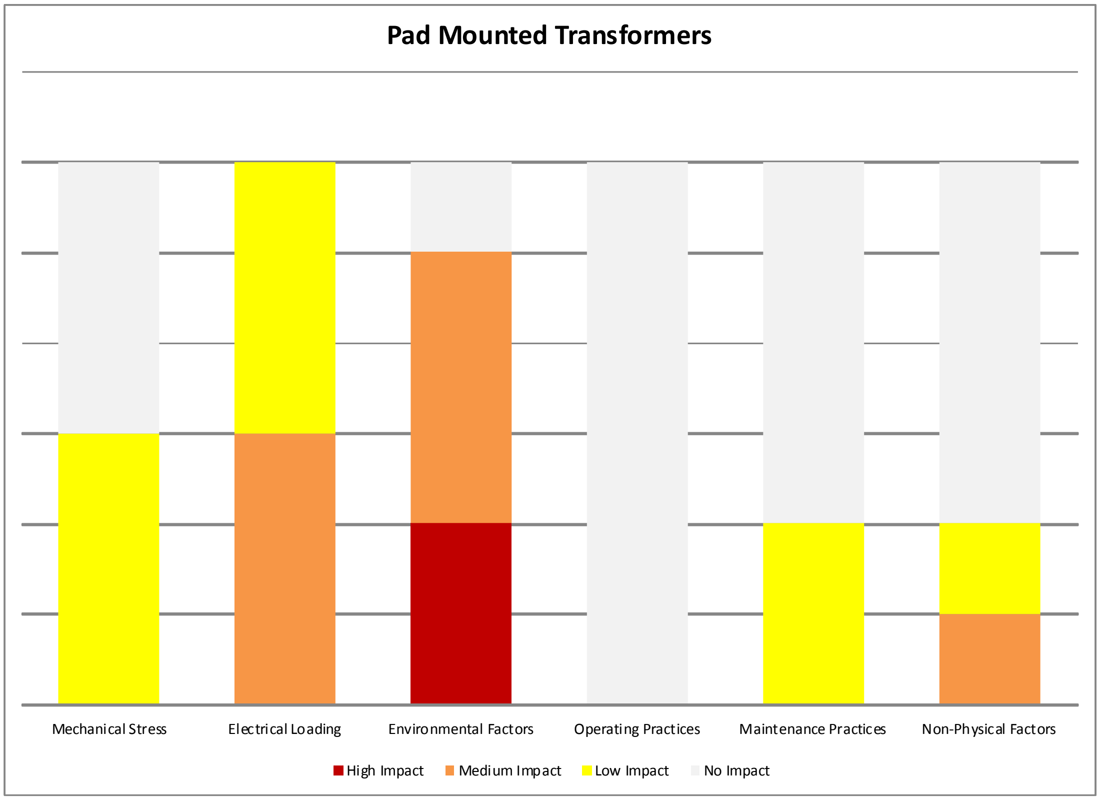


Figure 34-2 Impact of Utilization Factors on the Useful Life of Pad-Mounted Transformers

35. Submersible and Vault Transformers

35.1 Asset Description

Submersible transformers typically employ sealed tank construction with corrosion resistance hardware and are liquid filled with mineral insulating oil. Similar to submersible transformers, indoor vault transformers typically employ sealed tank construction and are liquid filled with mineral insulating oil.

35.1.1 Componentization Assumptions

For the purposes of this report, the Submersible and Vault Transformers has not been componentized.

35.1.2 System Hierarchy

Submersible and Vault Transformers is considered to be a part of the Underground Systems asset grouping.

35.2 Degradation Mechanism

The transformer has a similar degradation mechanism to other distribution transformers. The life of the transformer's internal insulation is related to temperature rise and duration, so transformer life is affected by electrical loading profiles and length of service life. Mechanical damage, exposure to corrosive salts, and voltage current surges has strong effects. In general, a combination of condition, age, and load based criteria is commonly used to determine the useful remaining life.

35.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Submersible and Vault Transformers are displayed in Table 35-1.

Table 35-1 Useful Life Values for Submersible and Vault Transformers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Submersible/Vault Transformers	25	35	45

35.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Submersible and Vault Transformers. Four of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Submersible and Vault Transformers (Figure 35-1).

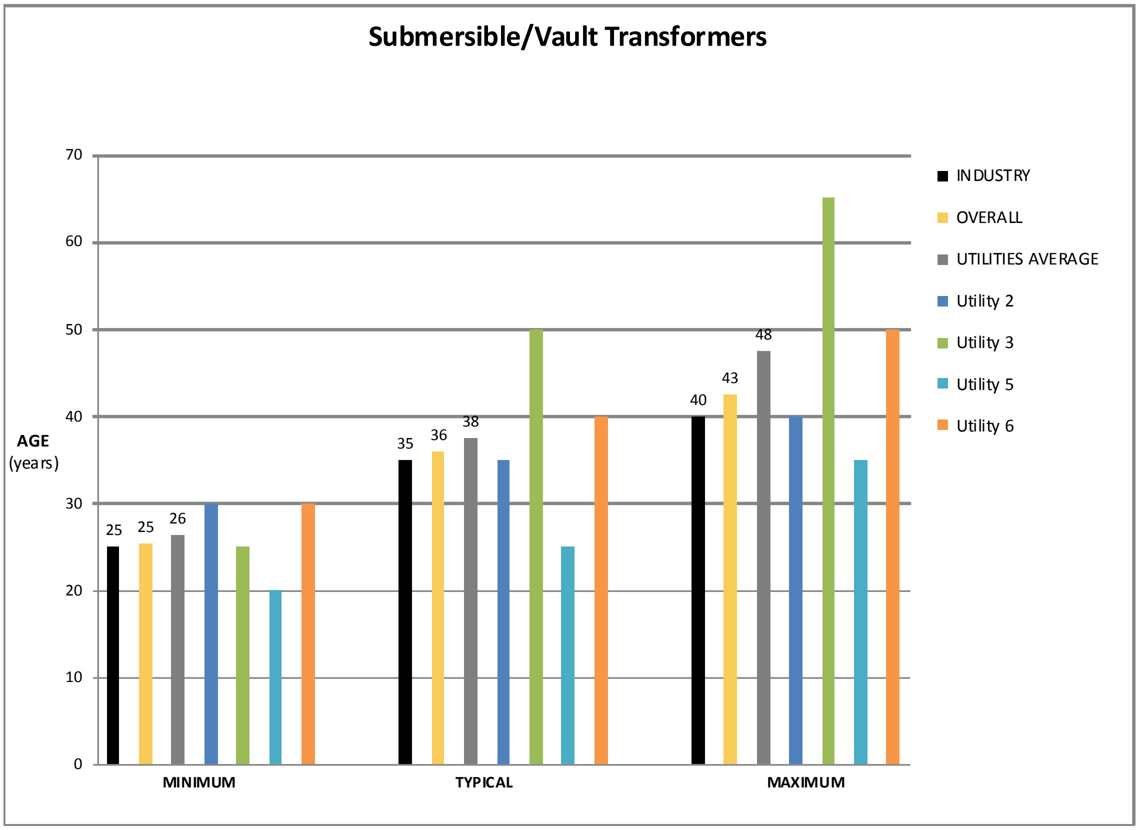


Figure 35-1 Useful Life Values for Submersible and Vault Transformers

35.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Submersible and Vault Transformers are displayed in Table 35-2.

Table 35-2 - Composite Score for Submersible and Vault Transformers

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	28%	72%	75%	9%	19%	28%
Overall Rating*	L	M	M	NI	L	L

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

35.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Submersible and Vault Transformers. Four of the interviewed utilities provided their input regarding the UFs for Submersible and Vault Transformers (Figure 35-2).

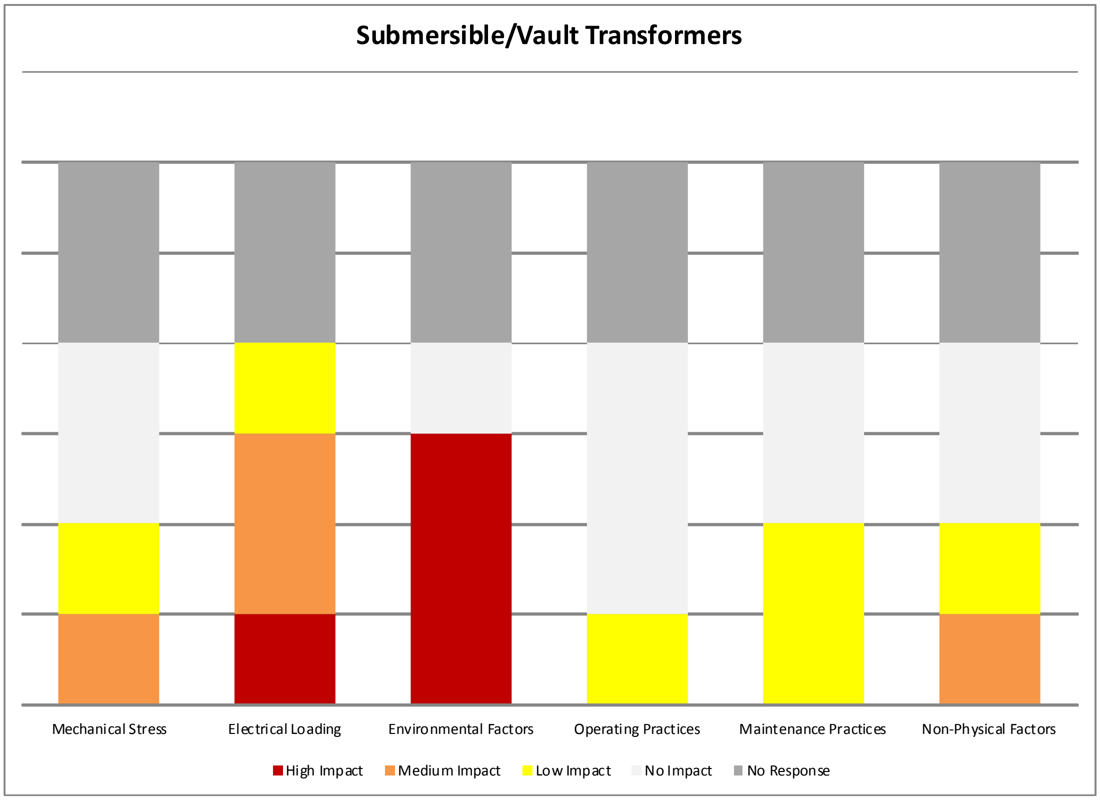


Figure 35-2 Impact of Utilization Factors on the Useful Life of Submersible and Vault Transformers

36. Underground Foundations

36.1 Asset Description

This asset class consists of a buried pre cast concrete vault on which pad-mounted transformers or switchgear are mounted. The foundation itself is buried; however the top portion is above ground.

36.1.1 Componentization Assumptions

For the purposes of this report, the Underground Foundations has not been componentized.

36.1.2 System Hierarchy

Underground Foundations is considered to be a part of the Underground Systems asset grouping.

36.2 Degradation Mechanism

These assets must withstand the heaviest structural loadings to which they might be subjected. For example, when located in streets, transformer and switchgear foundation must withstand heavy loads associated with traffic in the boulevard. When located in driving lanes, concrete vault must match street grading. Since vaults often experience flooding, they sometimes include drainage sumps and sump pumps. Nevertheless, environmental regulations in some jurisdictions may prohibit the pumping into sewer systems, without testing of the water for environmentally hazardous contaminants.

Although age is loosely related to the condition of underground civil structures, it is not a linear relationship. Other factors such as mechanical loading, exposure to corrosive salts, etc. have stronger effects. Transformer and switchgear foundation degradation commonly includes corrosion of reinforcing steel, spalling of concrete, and rusting of covers or rings. Acidic salts (i.e. sulfates or chlorides) affect corrosion rates. Transformer and switchgear foundation also may experience a number of deficiencies or defects. In roadways, defects exist when covers are not level with street surfaces. Conditions that lead to flooding, clogged sumps, and non-functioning sump-pumps also represent major deficiencies in a transformer and switchgear foundation. Similarly, transformer and switchgear foundation with lights that do not function properly constitute defective systems.

36.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Underground Foundations are displayed in Table 36-1.

Table 36-1 Useful Life Values for Underground Foundations

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
UG Foundations	35	55	70

36.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Underground Foundations. Five of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and all six of the interviewed utilities gave TUL and MAX UL Values for Underground Foundations (Figure 36-1).

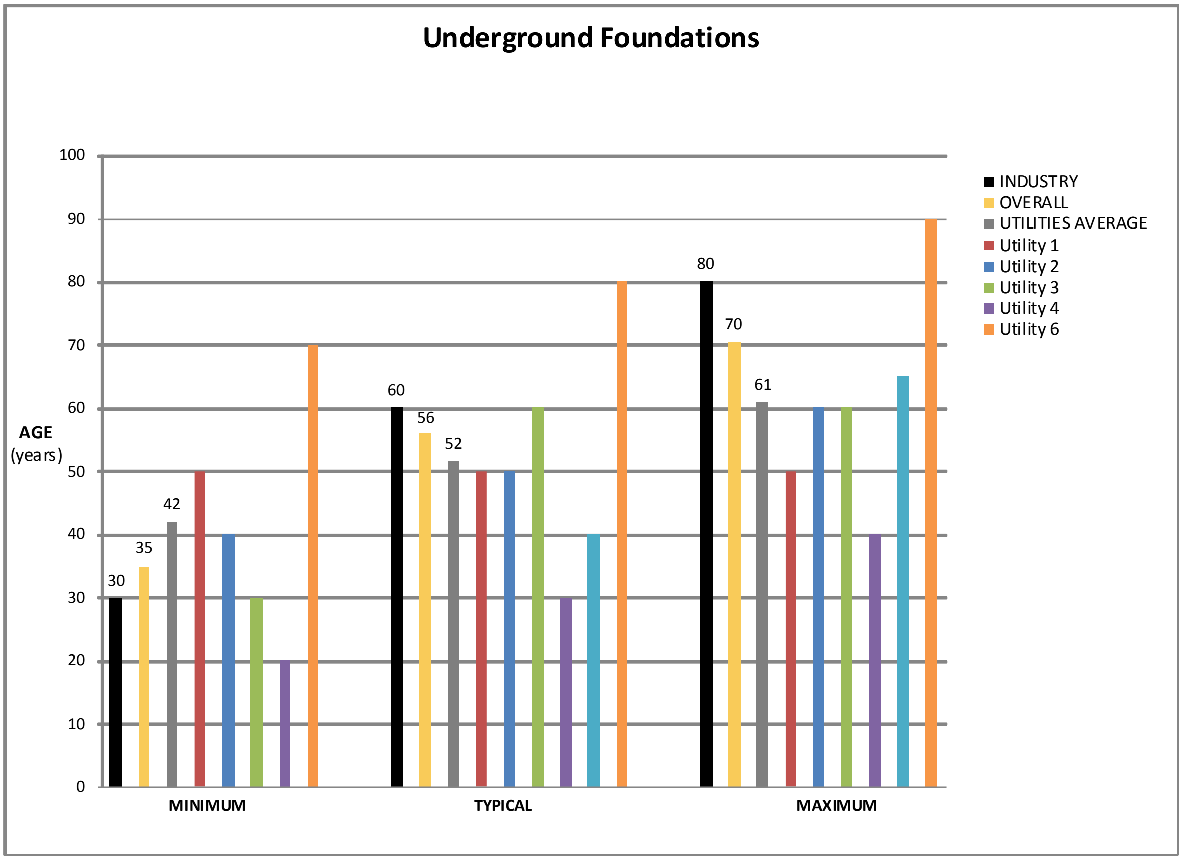


Figure 36-1 Useful Life Values for Underground Foundations

36.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Underground Foundations are displayed in Table 36-2.

Table 36-2 - Composite Score for Underground Foundations

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	48%	6%	54%	13%	13%	48%
Overall Rating*	**M**	**NI**	**M**	**L**	**L**	**M**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

36.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Underground Foundations. All six of the interviewed utilities provided their input regarding the UFs for Underground Foundations (Figure 36-2).

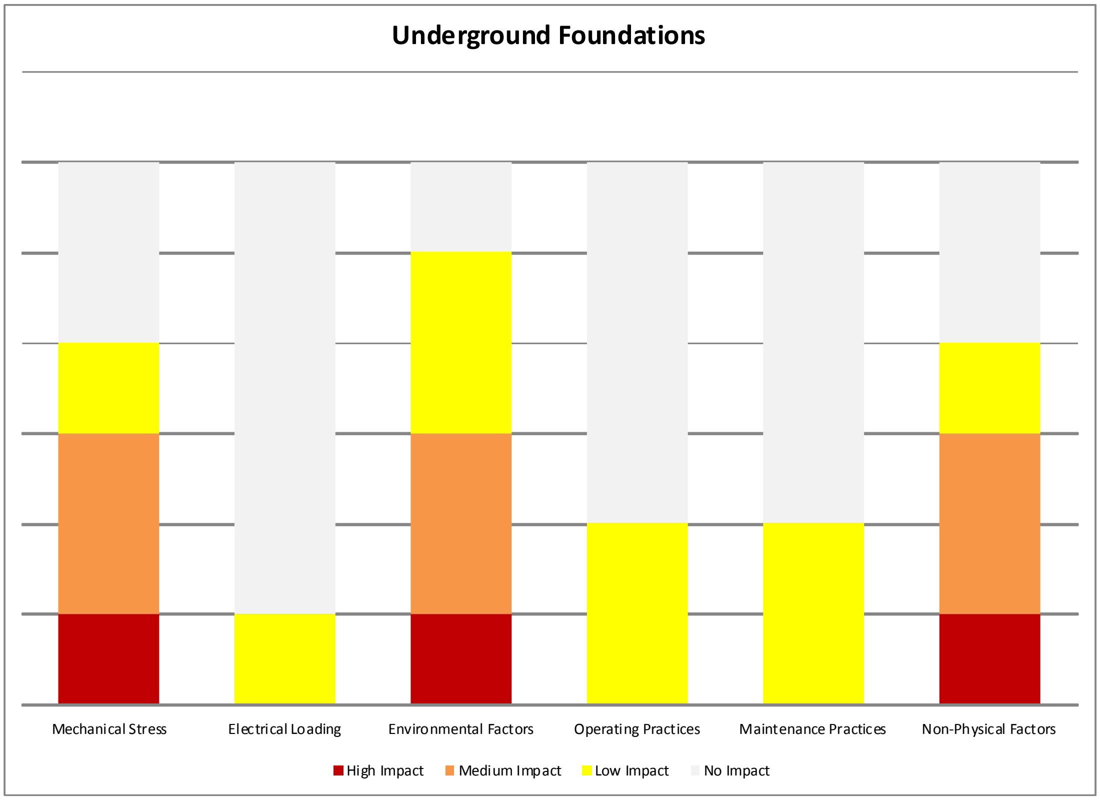


Figure 36-2 Impact of Utilization Factors on the Useful Life of Underground Foundations

37. Underground Vaults

37.1 Asset Description

Equipment vaults permit installation of transformers, switchgear or other equipment. They are often constructed out of reinforced or un-reinforced concrete. Vaults used for transformer installation are often equipped with ventilation grates to provide natural or forced cooling.

37.1.1 Componentization Assumptions

For the purposes of this report, the Underground Vaults has been componentized so that the roof is regarded as separated components. Therefore the Underground Vaults has overall useful life values based and useful life values for the specific component, the roof.

37.1.2 System Hierarchy

Underground Vaults is considered to be a part of the Underground Systems asset grouping.

37.2 Degradation Mechanism

Vaults should be capable of bearing the loads that are applied on them. As such, mechanical strength is a basic end of life parameter for a vault. Although age is loosely related to the condition of underground civil structures, it is not a linear relationship. Other factors such as mechanical loading, exposure to corrosive salts, etc. have a stronger effect. Degradation commonly includes corrosion of reinforcing steel, spalling of concrete, and rusting of covers or rings. Acidic salts (i.e. sulfates or chlorides) affect corrosion rates. In roadways, defects exist when covers are not level with street surfaces. Conditions that lead to flooding, clogged or non-functioning sump pumps also represent major deficiencies.

37.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Underground Vaults are displayed in Table 37-1.

Table 37-1 Useful Life Values for Underground Vaults

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Overall	40	60	80
Roof	20	30	45

37.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Underground Vaults. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Underground Vaults (Figure 37-1).

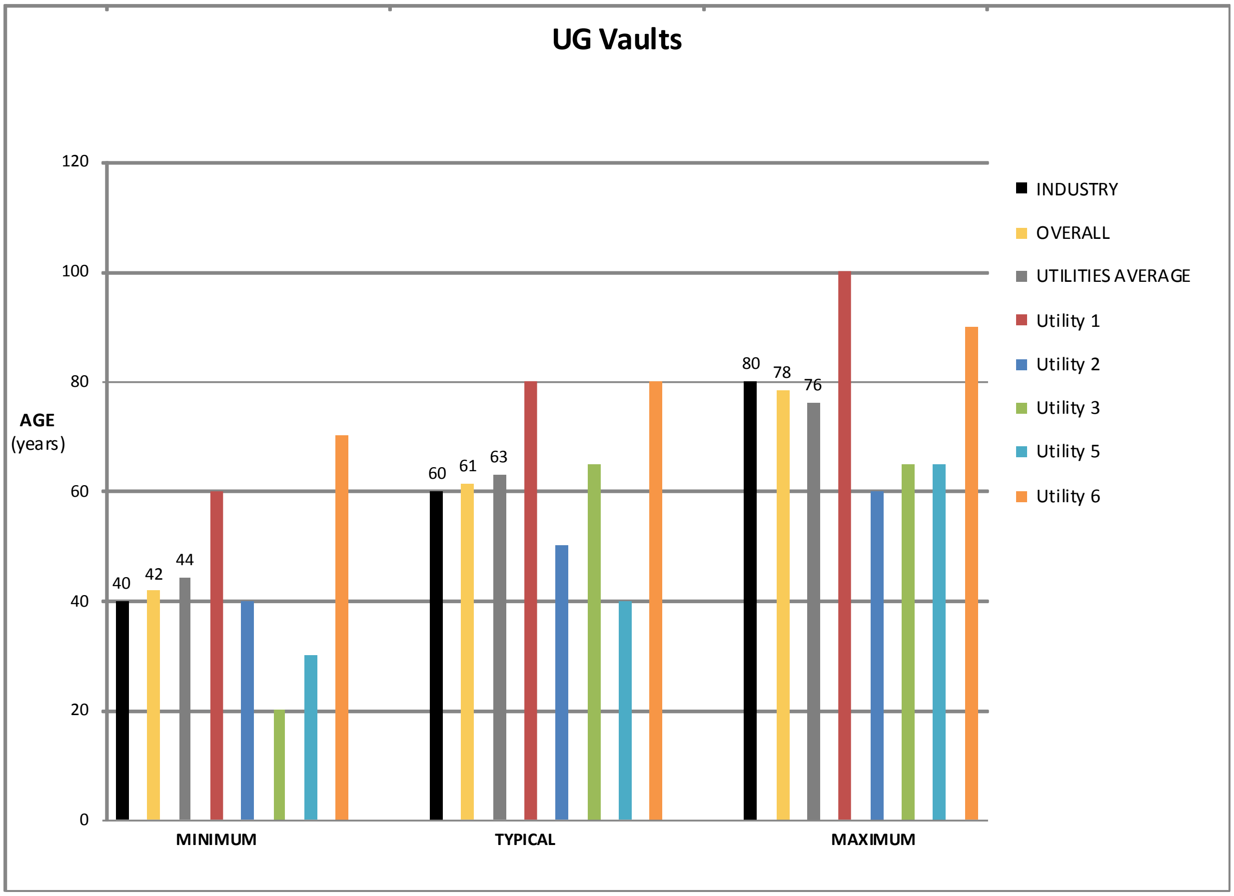


Figure 37-1 Useful Life Values for Underground Vaults

37.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Underground Vaults are displayed in Table 37-2.

Table 37-2 - Composite Score for Underground Vaults

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	58%	0%	63%	15%	23%	43%
Overall Rating*	**M**	**NI**	**M**	**L**	**L**	**L**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

37.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Underground Vaults. Five of the interviewed utilities provided their input regarding the UFs for Underground Vaults (Figure 37-2).

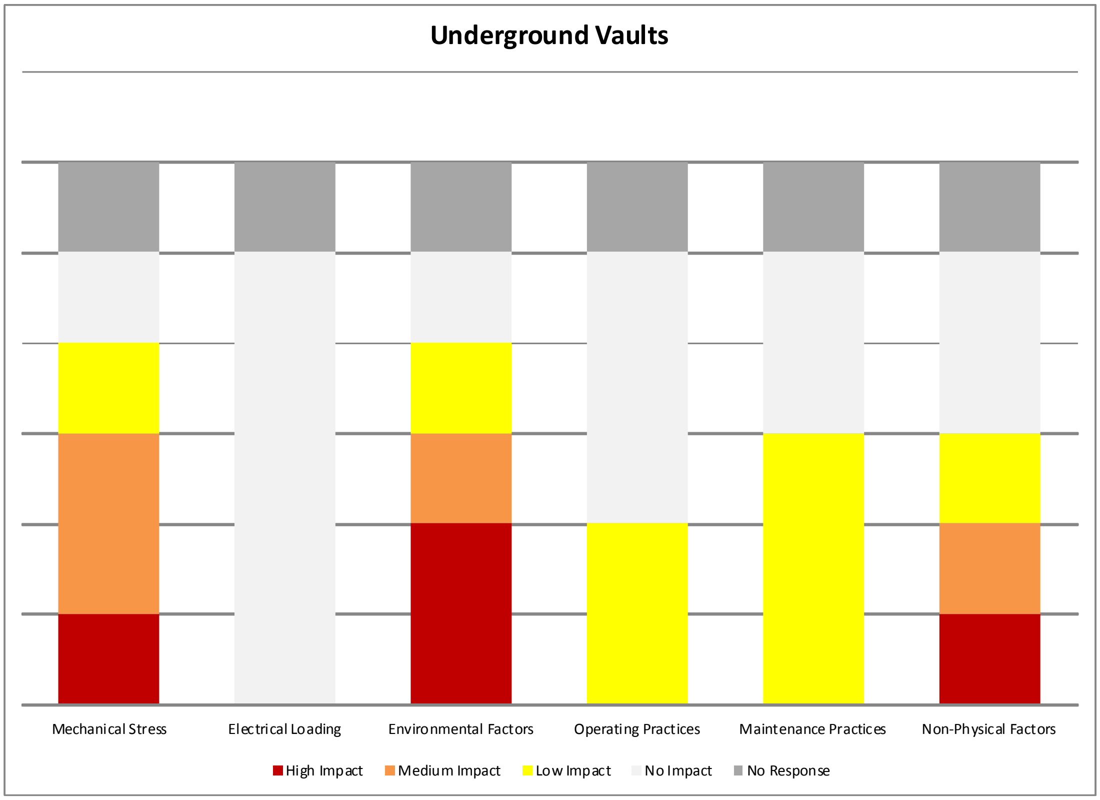


Figure 37-2 Impact of Utilization Factors on the Useful Life of Underground Vaults

38. Underground Vault Switches

38.1 Asset Description

Underground Vault Switches can be wall mounted air insulated switches or switchgear enclosed in stainless steel containers with the ability to be wall or ceiling mounted.

38.1.1 Componentization Assumptions

For the purposes of this report, the Underground Vault Switches has not been componentized.

38.1.2 Design Configuration

For the purposes of this report, the switch interrupting mediums include oil, gas (SF6) and air.

38.1.3 System Hierarchy

Underground Vault Switches is considered to be a part of the Underground Systems asset grouping.

38.2 Degradation Mechanism

Aging and end of life is established by mechanical failures, such as corrosion of operating mechanism from rusting of enclosure or moisture and dirt ingress. Switchgear failure is associated more with outside influences rather than age. For example, switchgear failure is more likely to be caused by rodents, dirt or contamination, vehicle accidents, rusting of the case, and broken insulators caused by misalignment during switching.

38.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Underground Vault Switches are displayed in Table 38-1.

Table 38-1 Useful Life Values for Underground Vault Switches

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
UG Vault Switches	20	35	50

38.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Underground Vault Switches. Three of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and four of the utilities interviewed gave TUL and MAX UL for Underground Vault Switches (Figure 38-1).

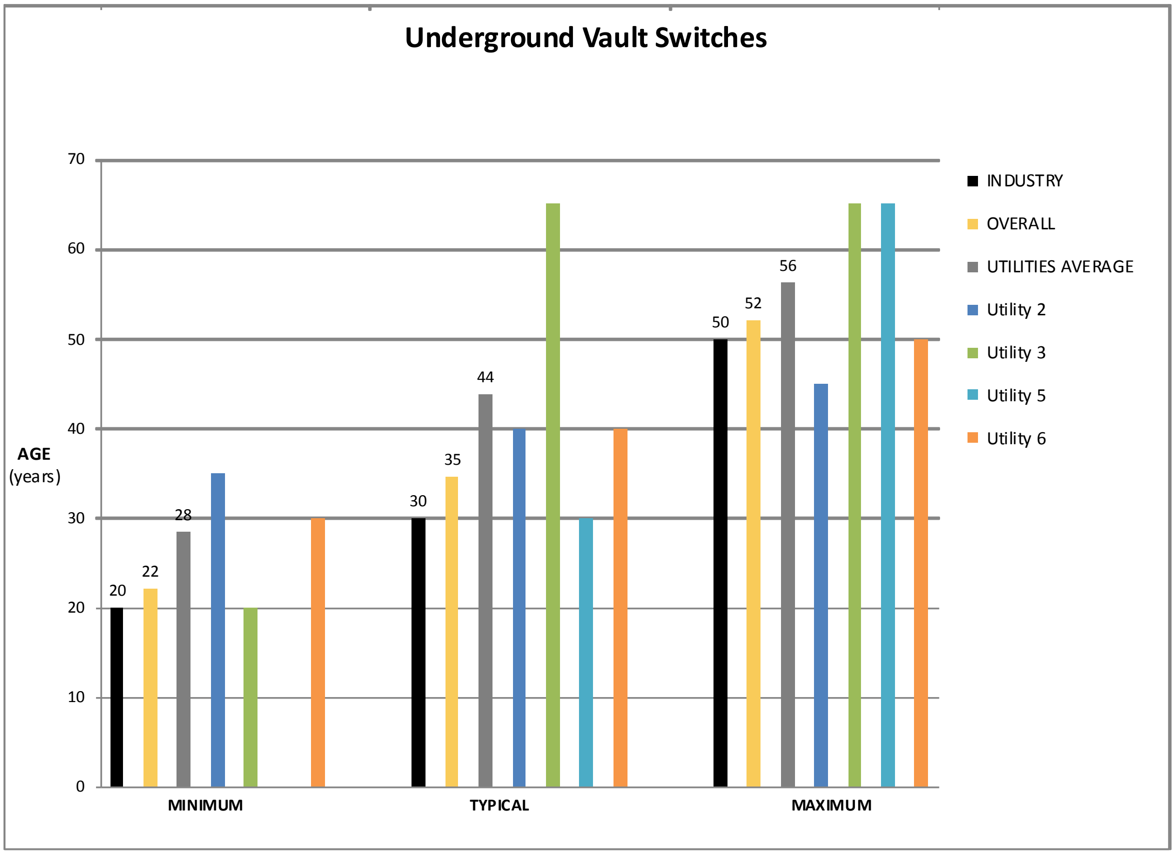


Figure 38-1 Useful Life Values for Underground Vault Switches

38.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Underground Vault Switches are displayed in Table 38-2.

Table 38-2 - Composite Score for Underground Vault Switches

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	19%	38%	38%	38%	19%	9%
Overall Rating*	L	L	L	L	L	NI
* H = High Impact	M = Medium Impact	L = Low Impact	NI = No Impact			

38.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Underground Vault Switches. Four of the interviewed utilities provided their input regarding the UFs for Underground Vault Switches (Figure 38-2).

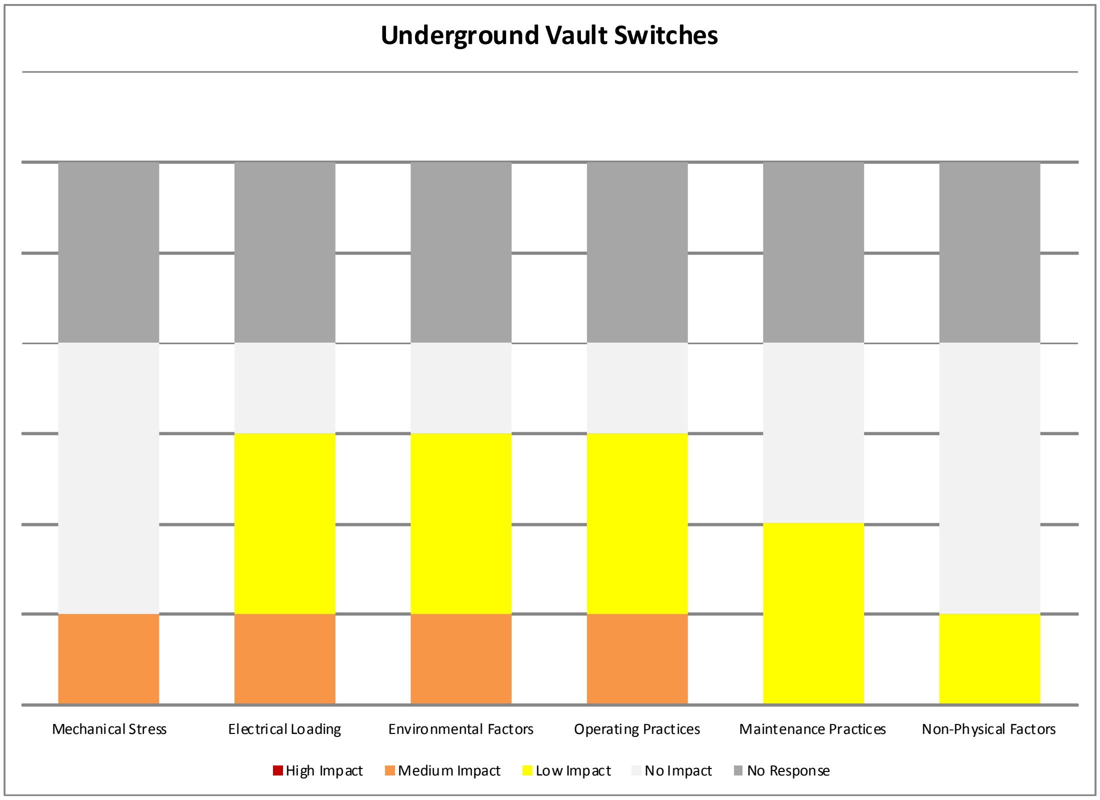


Figure 38-2 Impact of Utilization Factors on the Useful Life of Underground Vault Switches

39. Pad-Mounted Switchgear

39.1 Asset Description

Pad-mounted switchgear is used for protection and switching in the underground distribution system. The switching assemblies can be classified into air insulated, SF6 load break switches and vacuum fault interrupters. A majority of the pad mounted switchgear currently employs air-insulated gang operated load-break switches.

39.1.1 Componentization Assumptions

For the purposes of this report, the Pad-Mounted Switchgear has been componentized.

39.1.2 Design Configuration

For the purposes of this report, the interrupting medium types included are oil, air, gas (SF6), solid dielectric and vacuum.

39.1.3 System Hierarchy

Pad-Mounted Switchgear is considered to be a part of the Underground Systems asset grouping.

39.2 Degradation Mechanism

The pad-mounted switchgear may be used infrequently for switching and often used only to drop loads below its rating. Therefore, switchgear aging and eventual end of life is often established by mechanical failures, e.g. rusting of the enclosures or ingress of moisture and dirt into the switchgear causing corrosion of operating mechanism and degradation of insulated barriers.

The first generation of pad mounted switchgear was first introduced in early 1970's and many of these units are still in good operating condition. The life expectancy of pad-mounted switchgear is impacted by a number of factors that include frequency of switching operations, load dropped, presence or absence of corrosive environmental and absence of existence of dampness at the installation site.

In the absence of specifically identified problems, the common industry practice for distribution switchgear is running it to end of life, just short of failure. To extend the life of these assets and to minimize in-service failures, a number of intervention strategies are employed on a regular basis: e.g. inspection with thermographic analysis and cleaning with CO_2 for air insulated pad-mounted switchgear. If problems or defects are identified during inspection, often the affected component can be replaced or repaired without a total replacement of the switchgear.

Failures of switchgear are most often not directly related to the age of the equipment, but are associated instead with outside influences. For example, pad-mounted switchgear is most likely to fail due to rodents, dirt/contamination, vehicle accidents, rusting of the case, and broken insulators caused by misalignment during switching. All of these causes are largely preventable with good design and maintenance practices. Failures caused by fuse malfunctions can result in a catastrophic switchgear failure.

Aging and end of life is established by mechanical failures, such as corrosion of operating mechanism from rusting of enclosure or moisture and dirt ingress. Switchgear failure is associated more with outside influences rather than age. For example, switchgear failure is more likely to be caused by rodents, dirt or contamination, vehicle accidents, rusting of the case, and broken insulators caused by misalignment during switching.

39.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Pad-Mounted Switchgear are displayed in Table 39-1.

Table 39-1 Useful Life Values for Pad-Mounted Switchgear

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Pad-Mounted Switchgear	20	30	45

39.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Pad-Mounted Switchgear. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Pad-Mounted Switchgear (Figure 39-1).

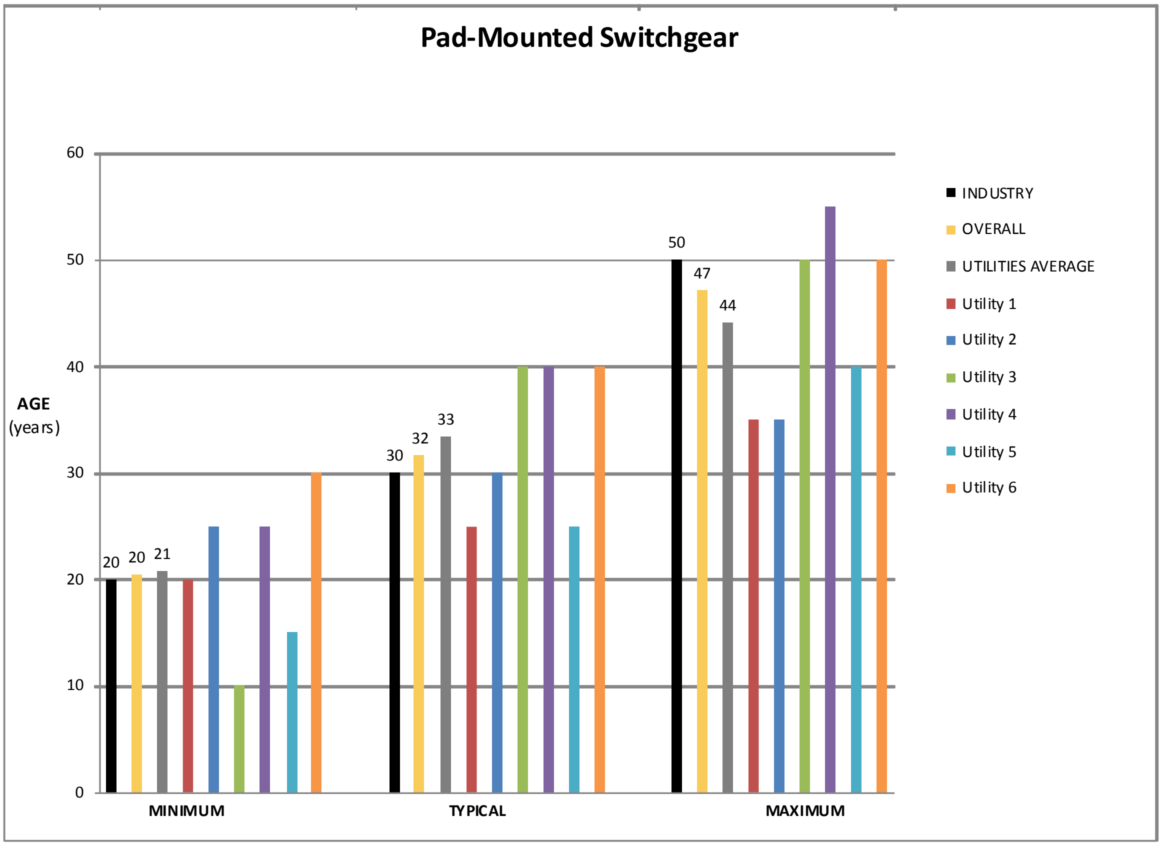


Figure 39-1 Useful Life Values for Pad-Mounted Switchgear

39.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Pad-Mounted Switchgear are displayed in Table 39-2.

Table 39-2 - Composite Score for Pad-Mounted Switchgear

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	44%	44%	92%	25%	31%	38%
Overall Rating*	**L**	**L**	**H**	**L**	**L**	**L**

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

39.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Pad-Mounted Switchgear. All six of the interviewed utilities provided their input regarding the UFs for Pad-Mounted Switchgear (Figure 39-2).

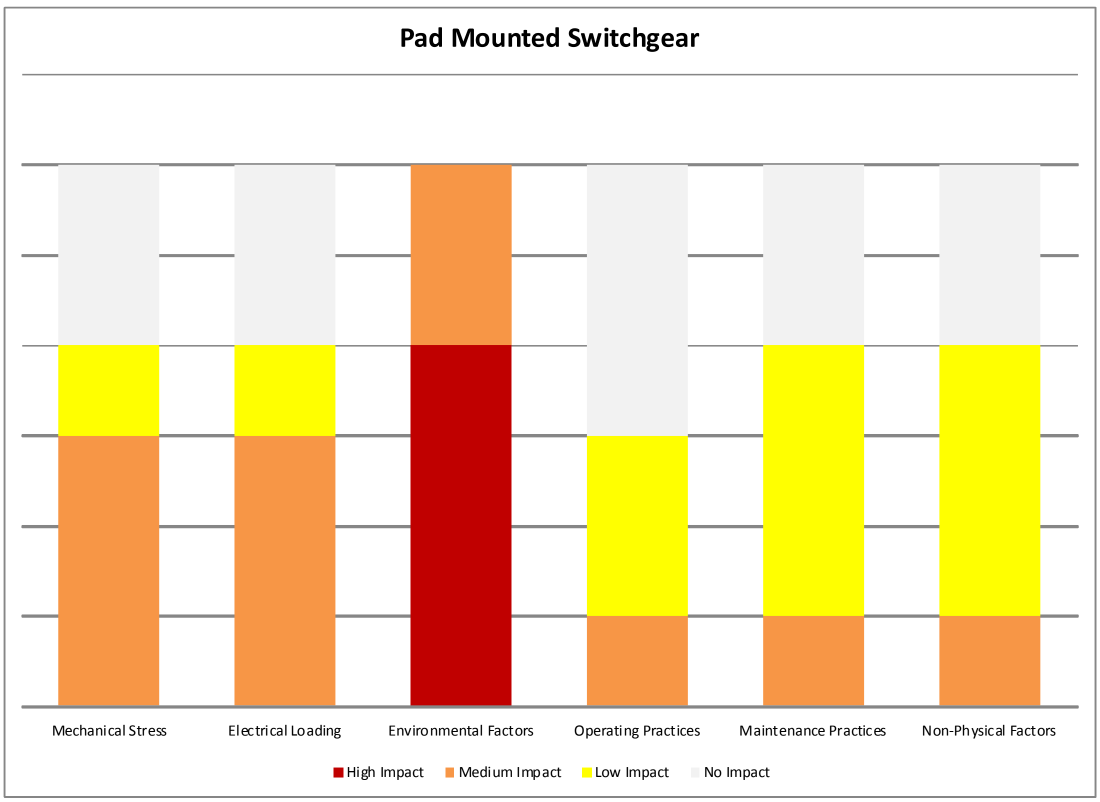


Figure 39-2 Impact of Utilization Factors on the Useful Life of Pad-Mounted Switchgear

40. Ducts

40.1 Asset Description

In areas such as road crossings, ducts provide a conduit for underground cables to travel. Ducts are sized as required and are usually two to six inches in diameter.

40.1.1 Componentization Assumptions

For the purposes of this report, the Ducts asset category has not been componentized.

40.1.2 Design Configuration

For the purposes of this report, the duct types included are clay, polyvinyl chloride (PVC), fiber reinforced epoxy (FRE), and high density polyethylene (HDPE).

40.1.3 System Hierarchy

Ducts are considered to be a part of the Underground Systems asset grouping.

40.2 Degradation Mechanism

The ducts connecting one utility chamber to another cannot easily be assessed for condition without excavating areas suspected of suffering failures. However, water ingress to a utility chamber that is otherwise in sound condition is a good indicator of a failure of a portion of the ductwork. Since there are no specific tests that can be conducted to determine duct integrity at reasonable cost, the duct system is typically treated on an ad hoc basis and repaired or replaced as is determined at the time of cable replacement or failure.

40.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Ducts are displayed in Table 40-1.

Table 40-1 Useful Life Values for Ducts

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Ducts	30	50	85

40.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Ducts. Four of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and five of the utilities interviewed gave TUL and MAX UL Values for Ducts (Figure 40-1).

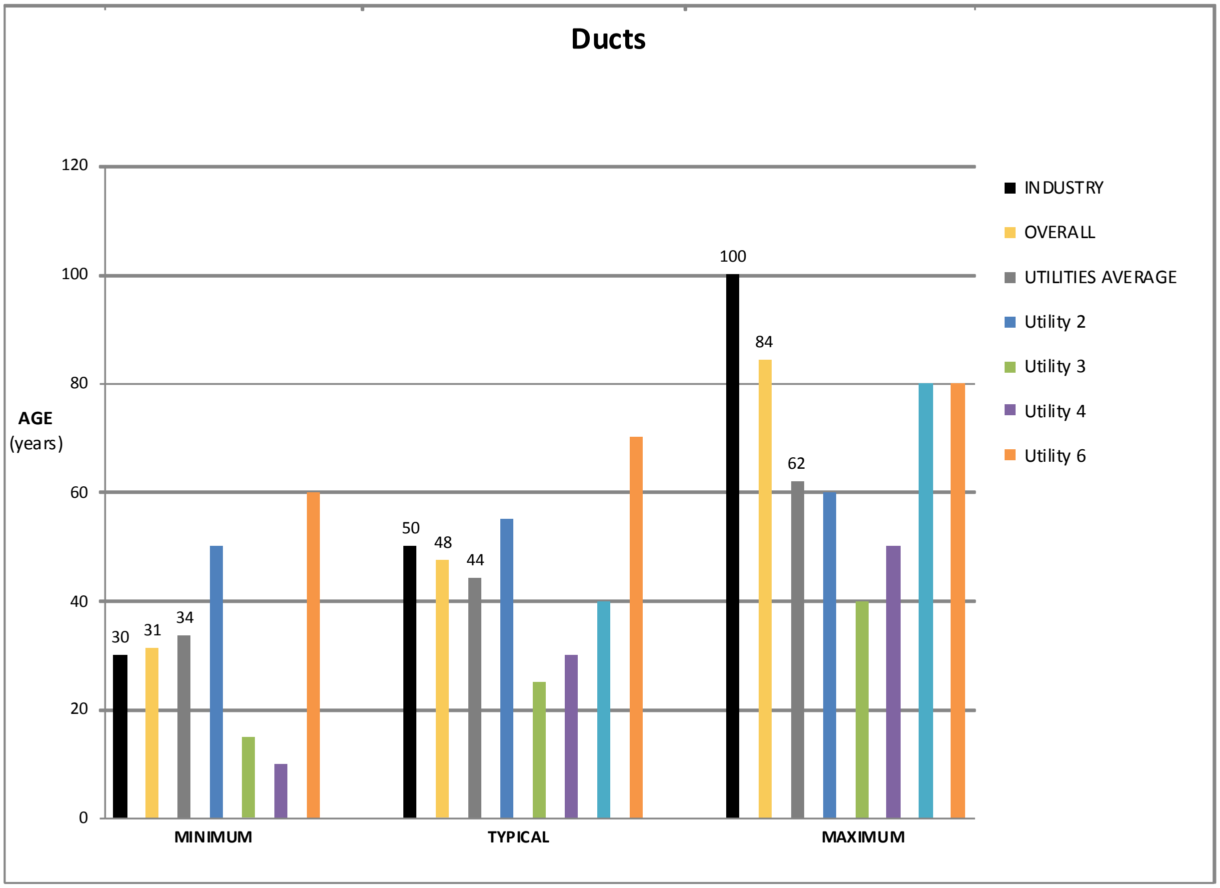


Figure 40-1 Useful Life Values for Ducts

40.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Ducts are displayed in Table 40-2.

Table 40-2 - Composite Score for Ducts

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	85%	0%	65%	8%	8%	15%
Overall Rating*	H	NI	M	NI	NI	L
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

40.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Ducts. Five of the interviewed utilities provided their input regarding the UFs for Ducts (Figure 40-2).

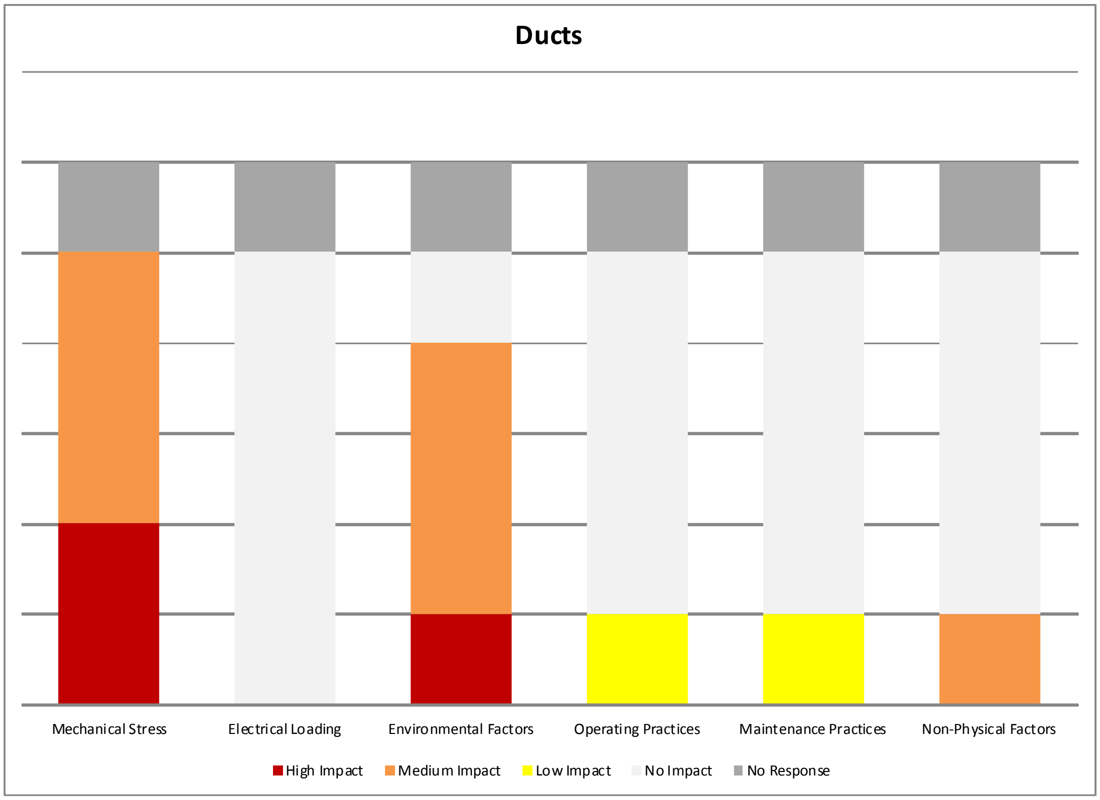


Figure 40-2 Impact of Utilization Factors on the Useful Life of Ducts

41. Concrete Encased Duct Banks

41.1 Asset Description

In areas such as road crossings, ducts provide a conduit for underground cables to travel. They are comprised of a number of ducts, in trench, and typically encased in concrete.

41.1.1 Componentization Assumptions

For the purposes of this report, the Concrete Encased Duct Banks asset category has not been componentized.

41.1.2 System Hierarchy

Concrete Encased Duct Banks are considered to be a part of the Underground Systems asset grouping.

41.2 Degradation Mechanism

The ducts connecting one utility chamber to another cannot easily be assessed for condition without excavating areas suspected of suffering failures. However, water ingress to a utility chamber that is otherwise in sound condition is a good indicator of a failure of a portion of the ductwork. Since there are no specific tests that can be conducted to determine duct integrity at reasonable cost, the duct system is typically treated on an ad hoc basis and repaired or replaced as is determined at the time of cable replacement or failure.

41.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Concrete Encased Duct Banks are displayed in Table 41-1

Table 41-1 Useful Life Values for Concrete Encased Duct Banks

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Concrete Encased Duct Banks	35	55	80

41.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Concrete Encased Duct Banks. Five of the interviewed utilities gave Minimum Useful Life (MIN UL) Values and all six of the utilities interviewed gave TUL and MAX UL Values for Concrete Encased Duct Banks (Figure 41-1).

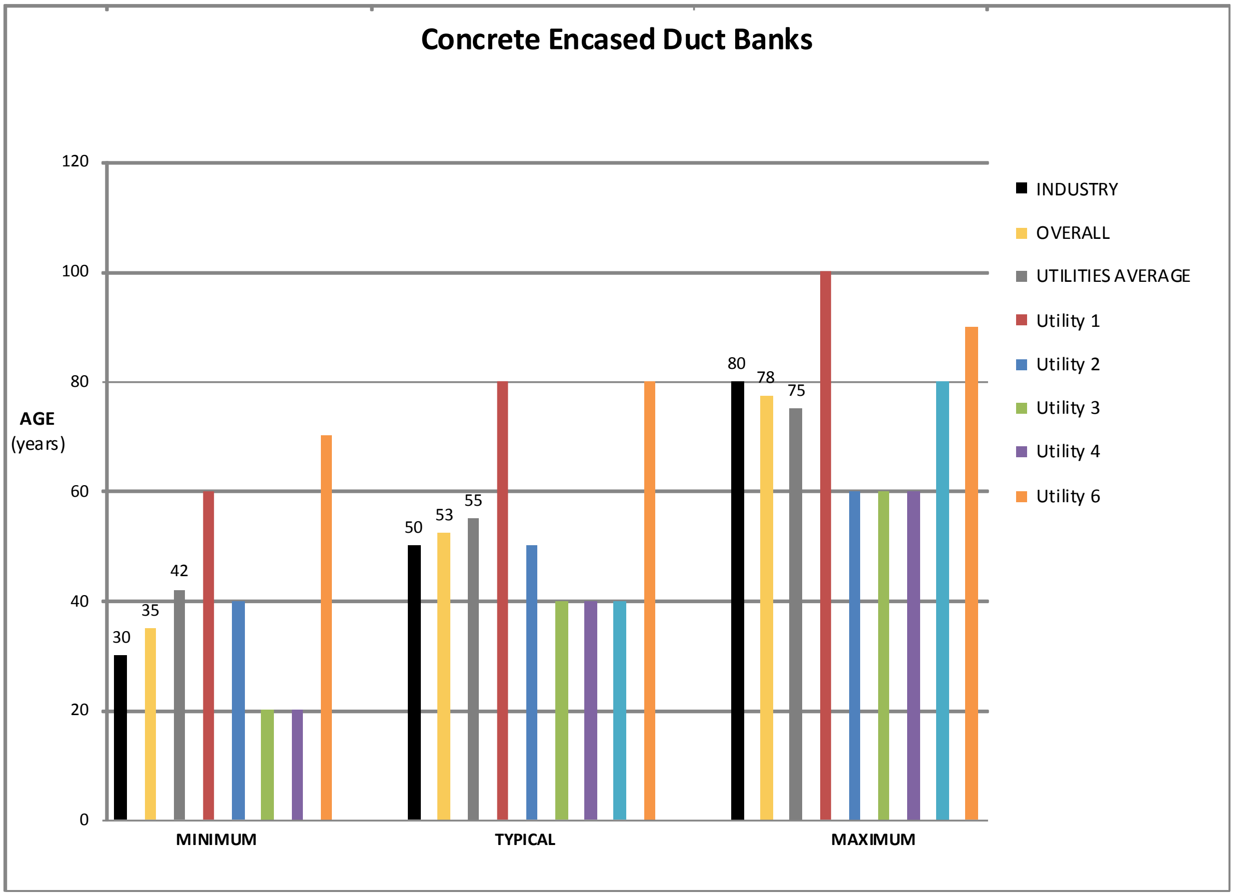


Figure 41-1 Useful Life Values for Concrete Encased Duct Banks

41.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Concrete Encased Duct Banks are displayed in Table 41-2.

Table 41-2 - Composite Score for Concrete Encased Duct Banks

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	73%	6%	60%	0%	0%	19%
Overall Rating*	M	NI	M	NI	NI	L

* H = High Impact   M = Medium Impact   L = Low Impact   NI = No Impact

41.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Concrete Encased Duct Banks. All six of the interviewed utilities provided their input regarding the UFs for Concrete Encased Duct Banks (Figure 41-2).

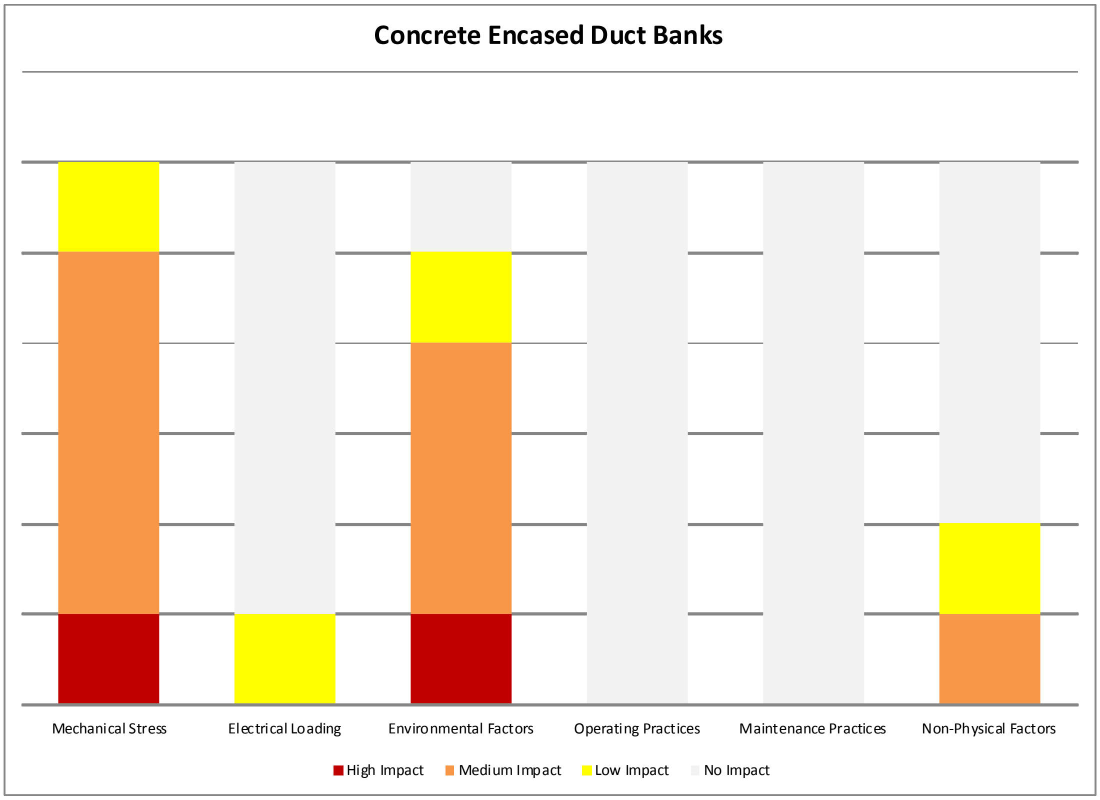


Figure 41-2 Impact of Utilization Factors on the Useful Life of Concrete Encased Duct Banks

42. Cable Chambers

42.1 Asset Description

Cable Chambers facilitate cable pulling into underground ducts and provide access to splices and facilities that require periodic inspections or maintenance. They come in different styles, shapes and sizes according to the location and application. Pre-cast cable chambers are normally installed only outside the traveled portion of the road although some end up under the road surface after road widening. Cast-in-place cable chambers are used under the traveled portion of the road because of their strength and also because they are less expensive to rebuild if they should fail. Customer cable chambers are on customer property and are usually in a more benign environment. Although they supply a specific customer, system cables loop through these chambers so other customers could also be affected by any problems.

42.1.1 Componentization Assumptions

For the purposes of this report, the Cable Chambers has not been componentized..

42.1.2 System Hierarchy

Cable Chambers is considered to be a part of the Underground Systems asset grouping.

42.2 Degradation Mechanism

When located in streets, cable chambers must withstand heavy loads associated with traffic in the street. When located in driving lanes, cable chamber chimney and collar rings must match street grading. Since utility chambers and vaults often experience flooding, they sometimes include drainage sumps and sump pumps. Nevertheless, environmental regulations in some jurisdictions may prohibit the pumping of utility chambers into sewer systems, without testing of the water for environmentally hazardous contaminants.

Although age is loosely related to the condition of underground civil structures, it is not a linear relationship. Other factors such as mechanical loading, exposure to corrosive salts, etc. have stronger effects. Cable chamber degradation commonly includes corrosion of reinforcing steel, spalling of concrete, and rusting of covers or rings. Acidic salts (i.e. sulfates or chlorides) affect corrosion rates. Cable chamber systems also may experience a number of deficiencies or defects. In roadways, defects exist when covers are not level with street surfaces. Conditions that lead to flooding, clogged sumps, and non-functioning sump-pumps also represent major deficiencies in a cable chamber system. Similarly, cable chamber systems with lights that do not function properly constitute defective systems. Deteriorating ductwork associated with cable chambers also requires evaluation in assessing the overall condition of a cable chamber system.

42.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Cable Chambers are displayed in Table 42-1.

Table 42-1 Useful Life Values for Cable Chambers

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Cable Chambers	50	60	80

42.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Cable Chambers. Five of the interviewed utilities gave Minimum (Min UL) Values and all six of the utilities interviewed gave TUL and MAX UL for Cable Chambers (Figure 42-1).

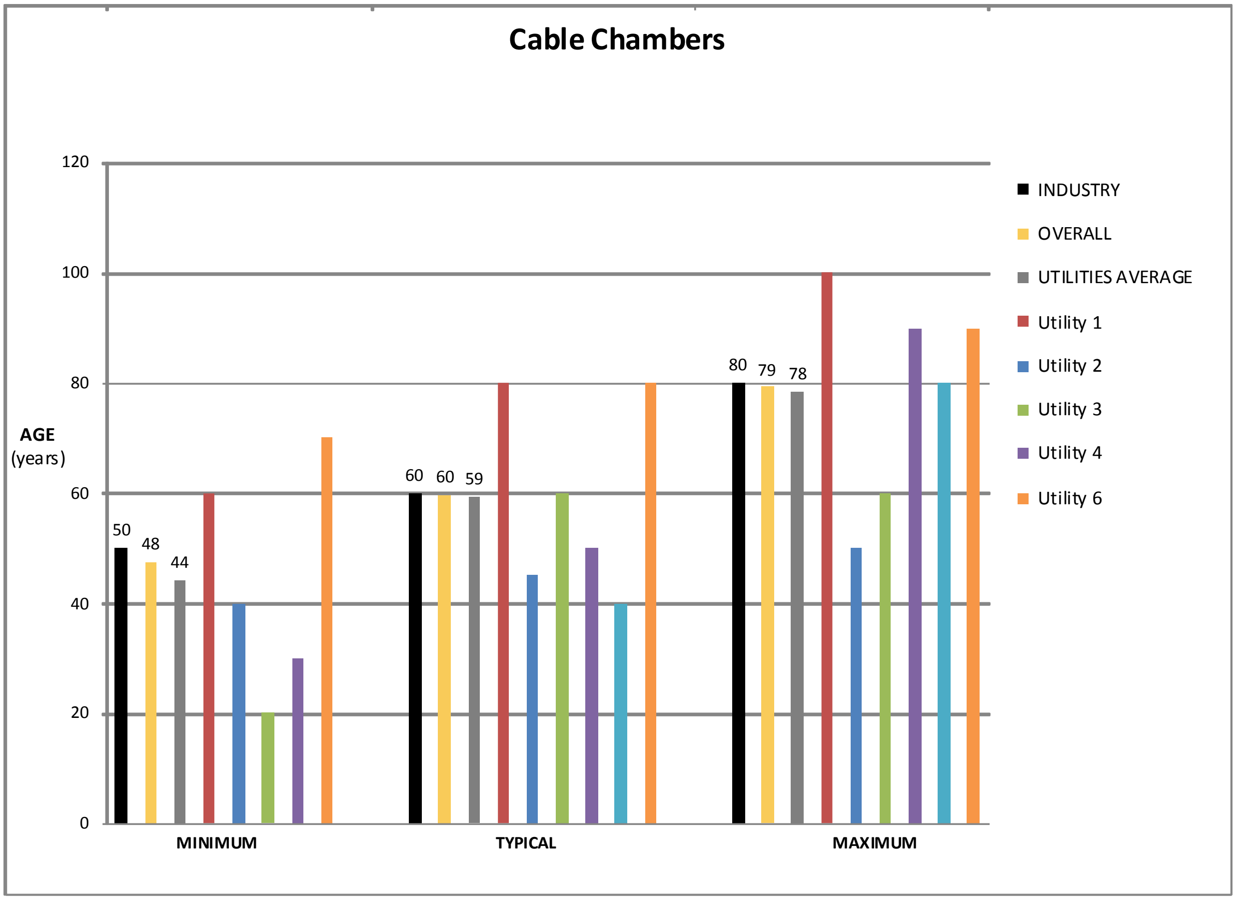


Figure 42-1 Useful Life Values for Cable Chambers

42.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Cable Chambers are displayed in Table 42-2.

Table 42-2 - Composite Score for Cable Chambers

	Utilization Factors					
	Mechanical Stress	**Electrical Loading**	**Environmental Factors**	**Operating Practices**	**Maintenance Practices**	**Non-Physical Factors**
Composite Score	58%	0%	92%	0%	19%	6%
Overall Rating*	**M**	**NI**	**H**	**NI**	**L**	**NI**
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

42.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Cable Chambers. All six of the interviewed utilities provided their input regarding the UFs for Cable Chambers (Figure 42-2).

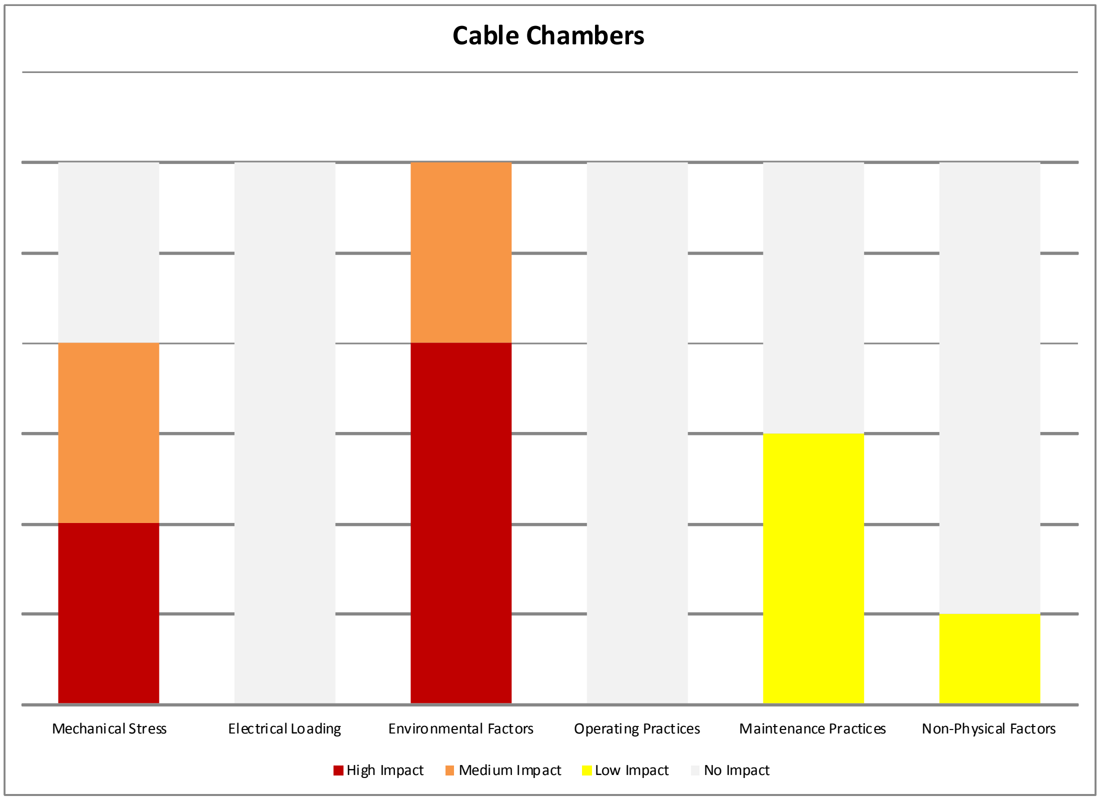


Figure 42-2 Impact of Utilization Factors on the Useful Life of Cable Chambers

43. Remote Supervisory Control and Data Acquisition

43.1 Asset Description

Supervisory Control and Data Acquisition (SCADA) refers to the centralized monitoring and control system of a facility. SCADA remote terminal units (RTUs) allow the master SCADA system to communication, often wirelessly, with field equipment. In general, RTUs collect digital and analog data from equipment, exchange information to the master system, and perform control functions on field devices. They are typically comprised of the following: power supply, CPU, I/O Modules, housing and chassis, communications interface, and software.

43.1.1 Componentization Assumptions

For the purposes of this report, the Remote Supervisory Control and Data Acquisition asset category has not been componentized.

43.1.2 System Hierarchy

Remote Supervisory Control and Data Acquisition is considered to be a part of the Monitoring and Control Systems asset grouping.

43.2 Degradation Mechanism

There are many factors that contribute to the end-of-life of RTUs. Utilities may choose to upgrade or replace older units that are no longer supported by vendors or where spare parts are no longer available. Because RTUs are essentially computer devices, they are prone to obsolescence. For example, older units may lack the ability to interface with Intelligent Electronic Devices (IEDs), be unable to support newer or modern communications media and/or protocols, or not allow for the quantity, resolution and accuracy of modern data acquisition. Legacy units may have limited ability of multiple master communication ports and protocols, or have an inability to segregate data into multiple RTU addresses based on priority.

43.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Remote Supervisory Control and Data Acquisition are displayed in Table 43-1.

Table 43-1 Useful Life Values for Remote Supervisory Control and Data Acquisition

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
Remote SCADA	15	20	30

43.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Remote Supervisory Control and Data Acquisition. Five of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Remote Supervisory Control and Data Acquisition (Figure 43-1).

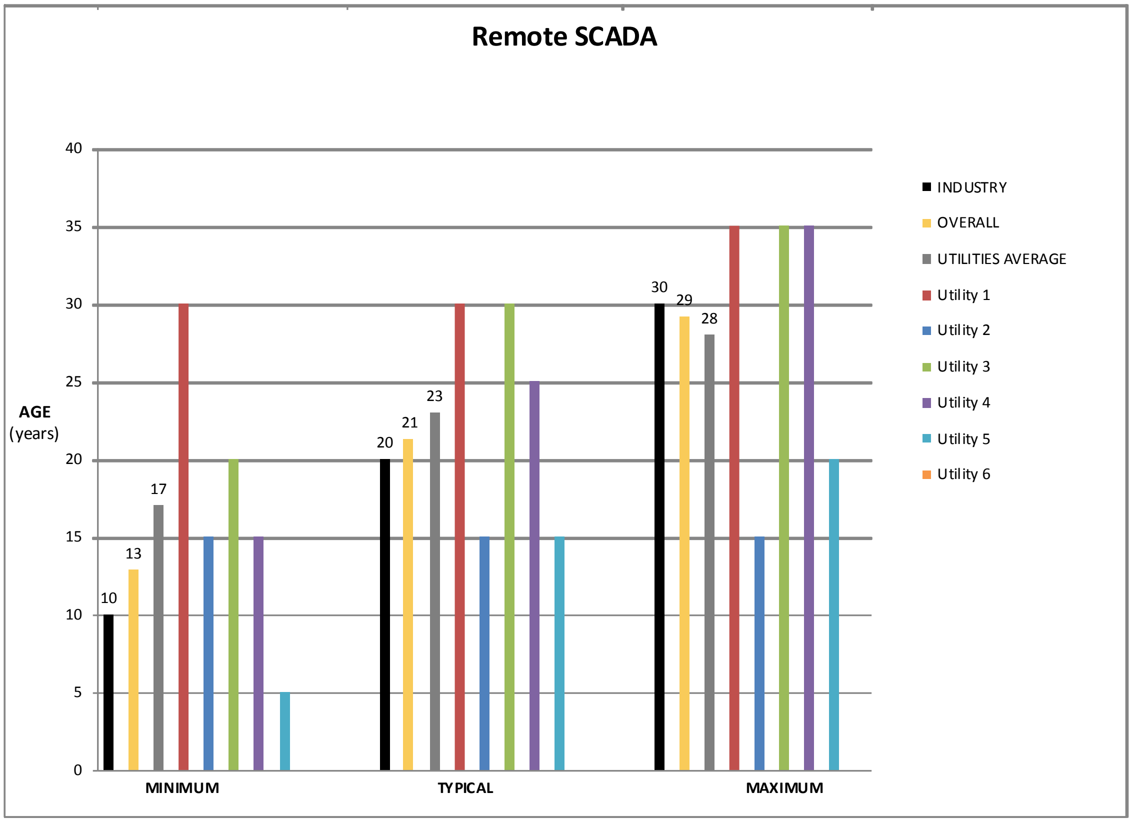


Figure 43-1 Useful Life Values for Remote Supervisory Control and Data Acquisition

43.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Remote Supervisory Control and Data Acquisition are displayed in Table 43-2.

Table 43-2 - Composite Score for Remote Supervisory Control and Data Acquisition

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	0%	0%	19%	0%	44%	95%
Overall Rating*	NI	NI	L	NI	L	H
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

43.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Remote Supervisory Control and Data Acquisition. Five of the interviewed utilities provided their input regarding the UFs for Remote Supervisory Control and Data Acquisition (Figure 43-2).

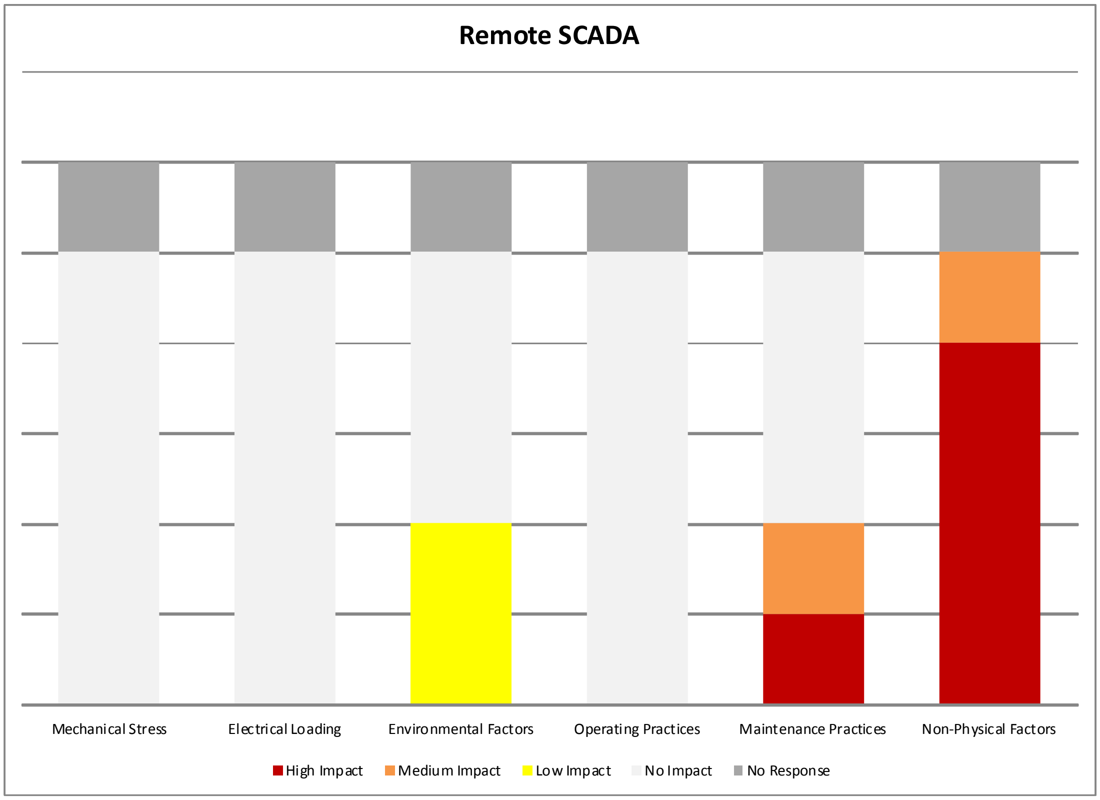


Figure 43-2 Impact of Utilization Factors on the Useful Life of Remote Supervisory Control and Data Acquisition

I APPENDIX – PERCENT OF ASSETS IN THE USEFUL LIFE RANGE

This Appendix describes the statistical analysis that was performed to estimate the percentage of assets that fall within the useful life range (MIN UL – MAX UL). Note that the values of MIN UL and MAX UL were determined using industry research and utility interviews. The statistical analysis estimates the percentage of an a asset population that will fall in the useful life range. The following is discussed:

- Review of definitions
- Assumptions used in useful life analysis
- Useful life range coverage
- Sample calculation of useful life range

Definitions used in Useful Life Analysis for Utility Asset Groups

End-of-life - An asset reaches its end-of-life when it is considered unable to perform its functions as designed physically.

Useful Life Range (MIN UL – MAX UL) - The asset life range that covers the end-of-life year data for the majority of the population in a specific asset group.

Typical useful life (TUL) - The value that corresponds to the peak of failure probability density function (useful life distribution function in this project) for a specific asset category, assuming the failure distribution is of unimodal type (i.e. with only one global maximum).

In mathematics, this value is called the mode. It is the value of end-of-life year datum that is most likely to be sampled at a single sampling, or the value that appears most frequently at a group sampling.

Mean useful life (μ) - Probability weighted average value. It is the arithmetic average value of the end-of-life year data for a group of sampled assets, provided that the sample size is sufficiently large and representative.

Minimum useful life (MIN UL) - The lower set value of useful life range. It refers to the age when a small percentage of assets reaches the physical end-of-life. In this project, it is defined as

$$\text{MIN UL} = \mu - k\sigma \qquad \text{(Equation 1)}$$

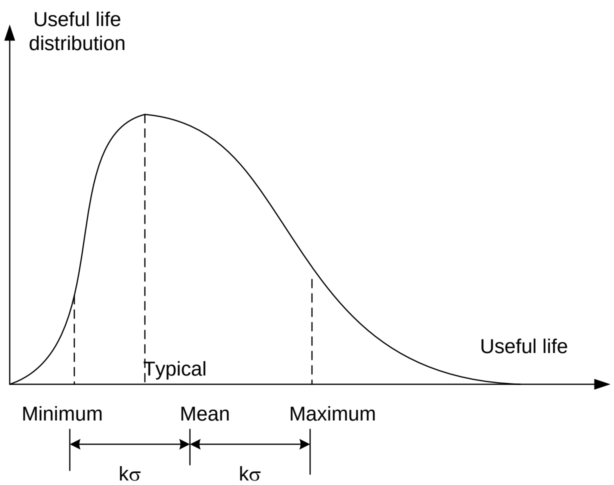
Where $k = \sqrt{3}$ (defined in later section)
σ standard deviation of useful life distribution

Maximum useful life (MAX UL)

The upper set value of useful life range. It refers to the age when most of assets reach the physical end-of-life. In this project, it is defined as

$$\text{MAX UL} = \mu + k\sigma \qquad \text{(Equation 2)}$$

Where $k = \sqrt{3}$ (defined in later section)
σ standard deviation of useful life distribution



<u>Assumptions in Useful Life Analysis for Utility Asset Groups</u>

To facilitate the analysis on useful life range coverage for utility asset groups, the following assumptions are made based on the information obtained during utility interviews as well as the character of various types of asset groups.

A. In a utility, there are always some asset groups that have their useful life distribution curve severely skewed to the either end of useful life range.

B. For all asset categories, the useful lives distribution is such that the mean (μ) is within k x standard deviation (σ) from MIN UL and MAX UL, regardless of where TUL is relative to the mean (μ).

C. For any specific asset group, the typical useful life is always captured within the useful life range.

D. For some asset groups, the typical values coincide with either minimum or maximum useful life values.

Assumption A is based on the fact that, due to different degradation mechanisms and operation modes, some of the asset groups have some predominant factors than exclusively determine the probability of failure of the asset group, thus making the asset end-of-life not follow normal distribution or other symmetrical distributions.

Assumption B is expanded from the special case where the asset end-of-life follows normal distribution. Under such condition, a utility needs to assign the same k coefficient to ensure that there is always a fixed percentage of asset population that is covered by the useful life range, regardless of how much the standard deviation is. If it is agreed that the same k coefficient is also adopted for the non symmetrical distribution, assumption B can be validated.

Assumptions C and D are validated by the results of interviews with various utilities.

In mathematics, it can be proven that the difference between the mean and the mode of a unimodal distribution is less than or equal to the square root of three times the standard deviation ($\sqrt{3}\sigma$).

With assumptions A, B and C, it can be concluded that the k coefficients should be greater than or equal to $\sqrt{3}$, applicable to all the asset groups.

With all the above assumptions validated, it is reasonable to conclude that the useful life range provided by utilities is within the interval between $\mu - \sqrt{3}\sigma$ and $\mu + \sqrt{3}\sigma$.

Useful Life Range Coverage

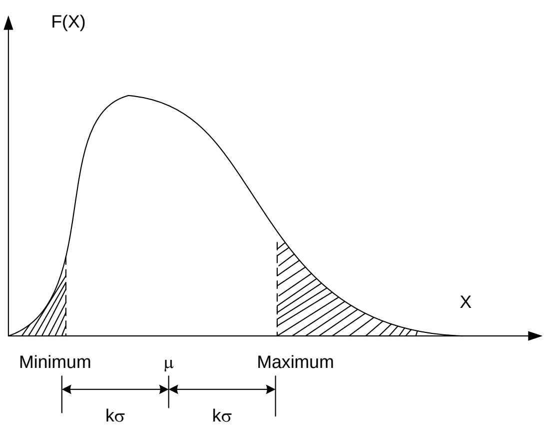
For any uni-modal useful life distribution, the coverage of a specific useful life range can be calculated using Chebyshev's inequality.

Chebyshev's Inequality

Let *X* be a random variable with mean value μ and finite variance σ^2. Then for any real number $k > 1$,

$$\Pr(|X-\mu| \geq k\sigma) \leq \frac{1}{k^2}$$

where the above inequality refers to the probability of the shadowed area in the following diagram.



Therefore the coverage of a useful life range is $1-1/k^2$.
For the useful life range specified in the previous section, it can be estimated that the range covers at least $1-\frac{1}{(\sqrt{3})^2} = 66.7\%$ of the whole population.

In case the useful life distribution is close to normal distribution for some asset groups, the percentage of data covered by the useful life range is determined by:

$$\Pr(|X-\mu| \leq k\sigma) = \mathrm{erf}\left(\frac{k}{\sqrt{2}}\right)$$

Where erf is the error function defined as

$$erf(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}\,dt$$

At $k = \sqrt{3}$, it can be calculated that the useful life range covers $\mathrm{erf}\left(\frac{\sqrt{3}}{\sqrt{2}}\right) = 91.7\%$ of the whole population.
In general, the percentage of the whole population covered by the useful life range defined in this study is between 66.7% and 91.7%.

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