Facility and Equipment Reference and Estimated Service Life Research Report
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Executive Summary

This MEFMA research report presents a review of literature related to facility component service life expectancy information. The research did not cover data sources which may be embedded in or supplied as part of software applications.

The research reveals that there is a wealth of information available to facility management professionals, although the majority of that information originates from outside MEFMA’s catchment area. With little regional information available of reasonable quality, MEFMA members are presented with a starting point for component reference life assessment.

International standards are introduced that provide MEFMA members with excellent guidance on determining equipment reference service life and estimated service life values. The standards introduce the factor method as a means to adjust component reference life expectancies and provide guidance on the use of this method.

Several useful data sources have been identified and are introduced in this report. Taken together these data sources run to thousands of line items which should be of considerable value to MEFMA members tasked with assessing facility component life expectancies.

Published service life data has not been replicated in this report due to consideration of intellectual property rights. The report therefore introduces these data sources to MEFMA members as a directory and provides details of availability and current price. Where data can be downloaded from web sites, links have been provided to enable MEFMA members to begin to compile their own reference libraries.

The literature confirms that facility component life expectancy assessment is far from being a clinical assessment or exact science. Rather, it demands that facility managers use their operational experience and life cycle costing analysis and business skills together to derive meaningful data.

Improved accuracy in service life estimation will enable MEFMA members to prepare more accurate budgets. Individual component replacement frequencies may be used to support zero-based budgeting activities. The factor method is introduced as a tool to help facility managers derive estimated service life values from reference service life data.

The research confirms that facility managers are required to demonstrate sound judgement, financial, managerial accounting and life-cycle costing competency, business case development capability and presentation skills to operate effectively in matters of facility component life cycle-related decision making. A bibliography is included to assist facility managers in exploring these topics. MEFMA training courses also cover the above topics comprehensively.

The research reveals that component life expectancy values that have been used by engineers for decades are based on little more than the opinions of a number of survey respondents. This should encourage MEFMA members to develop a regional database based on real data.

A selection of regional air-cooled chiller life expectancy cases is presented to demonstrate the widely varying life expectancies of, and life cycle influences on, a single equipment type in various locations, with the equipment having been subjected to an assortment of differing operational environments. In some cases the example chillers have exceeded published reference service life estimates while in others the chillers have been decommissioned in a much shorter period. Reference weather data is provided for the different case locations to enable facility managers to make comparison between regional locations. The cases show that decisions made and actions taken throughout a component’s service life can affect its life expectancy. In 2 of the 5 cases presented the chillers have outlasted published reference service life expectancy, suggesting that the regional operational outdoor environment may not be the deciding factor in equipment service life reduction. The major influence may be more related to human action and interaction.
Introduction

Where does service life planning fit into Facilities Management (FM)?

Quite simply, service life planning is a design process that supports facility managers as they strive to ensure that the service life of a facility is equal to or greater than its design life.1

For a facility manager to achieve his/her goals therefore, service life planning should be introduced at the facility or system design stage. Typically this is, or may be, the Facilities Management consultancy stage.

There are many factors to consider when estimating a facility component service life, all of which the facility manager might be responsible for. These include making the right selection choice, ensuring adequate budget availability, commissioning, implementing a high-quality operation and maintenance regime etc.

But there is another aspect related to service life expectancies; forward funding requirements. Owners need to have enough money available to carry out major refurbishment or replacement of facility components. This money is often accumulated by way of a service charge mechanism and it is often facility managers or FM consultants who generate the service charge cost model for clients. Over-estimate the service life of a component and the owner may not have sufficient funds to replace it when the need arises earlier than planned. Under-estimate the service life and occupiers will be burdened with higher than necessary charges. Neither situation is desirable.

Our choice of components affects the environment while the environment also affects our components. Westberg et al.[2] highlight this interaction between component and the environment and advise us that the environmental impact of our selection decisions may be assessed through life-cycle assessment (LCA), while life-cycle costing (LCC) provides a vehicle for the assessment of economic factors. In order to conduct LCA or LCC we need to predict service lives of components. Westberg et al. also state that while the factor method provides a starting point for more structured development, it is difficult to apply with high accuracy.

Within regional FM circles there is often heated debate about the reference service life of a particular facility component. Some might say that a fan, for instance, has a reference service life of 15 years while others may say that the same fan has a reference service life of 25 years. Single figure life-expectancies are therefore subject to adjustment, with the factor method, presented in ISO 15686 and criticized by Westberg et al.[2] being a common choice of adjustment mechanism.

Ashworth[3] provides food for thought as he reminds us that “…the characteristics of such life expectancies are not so much a question of how long a building or a component may last but, of how long they will be retained”.

There is clearly much more for the facility manager to consider than a simple reference service life…
The development of reference material

While there are several sources of facility component and equipment reference service life data, ranging from manufacturer data to empirical data, there is no single data set that can be applied without adjustment to every facility. A shortage of life expectancy data relating to buildings and structures has been noted by Ashworth[1] and echoed by Tse[4] who noted that research undertaken by the Building Services Research and Information Association (BSRIA) highlighted “...a lack of data sets for building services components...”. Tse also tells us that BSRIA is looking to develop its own database.

Waier et al.[5] provide extensive information on cost planning for facilities maintenance and introduce readers to the concept of “effective age”. The authors show, by way of a simple table, how effective maintenance can result in an increase in remaining service life. This principle is reflected in the factor method described some 12 years later in ISO 15686-8.[6]

An often-cited information source for Heating, Ventilating and Air-Conditioning (HVAC) components is the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). ASHRAE publishes life expectancy figures that are based on data gathered in the 1970’s. Abramson et al.[7] introduce ASHRAE’s research project TRP-1237 which is designed to gather more accurate and up-to-date reference data. Abramson et al. caution that many users of the historical ASHRAE data, which is also published in ASHRAE’s 2011 Applications Handbook, are unaware that the data was gathered, with the exception of air-to-air heat pump data, in 1976 and that the data were gathered from only 68 survey responses. Survey respondents provided opinions regarding component service life rather than data being based on actual equipment installation and replacement dates.

While the ASHRAE data from the 1970’s continues to support facility managers and engineers, other sources of data have also been developed.

1992 saw the publication of the Housing Association Property Mutual (HAPM) Component Life Manual.[8] This book provided data for a range of over 500 building components, presented in seven component groups.

NIKB[9] also provides data on the service life of housing components including, appliances, interior doors, bathrooms, closets, floors, home security etc.

BPL[10] provided us with the Building Services Component Life Manual. BPL provides data on service life of components along with key durability issues. This work has been described as “...the definitive source of robust data on the durability and maintenance requirements of mechanical and electrical plants.” DelliSaola and Kirk[11] provide service life and maintenance data on over 800 line items, presented in a UNIFORMAT framework. The authors present data related to facility structure and components which they have collected through their extensive life cycle costing work. Information presented includes energy demand where applicable, component replacement life and percentage replaced. The authors also warn that inadequate maintenance can result in premature obsolescence.

An outline of the UNIFORMAT framework is provided at Appendix A. Construction elements are arranged in major group elements, group elements and individual elements.

NSRDEC[12] provides facility managers with service reference life on a range of food service equipment.

Mayer[13] provides an ISO 15686 based Durability Assessment for the UK’s National Audit Office on behalf of Building Life Plans. This work includes an assessment of component life of six different construction types of house and apartment.


A further study of the life expectancy of home components is provided by NAHB.[15] This publication includes data relating to appliances and cabinets in addition to building components.

The Chartered Institution of Building Services Engineers (CIBSE) provides indicative life expectancies for a range of building services equipment.[16]

RSMeans[17] provided a “complete reference for the Facility Manager” which includes maintenance, repair and replacement data for a wide range of facility components. Presented in accordance with the UNIFORMAT framework, this annually updated publication also covers civil as well as building services components.

Chew Yit Lin[18] focuses on the maintainability of buildings but also includes a useful material selection table listing expected service reference life span information relating to several facility elements. Chew provides data on steel, tiles, tile bedding, glass, sealants, gaskets, waterproofing, plastic pipes and paints. Chew also provides information on defect causes that may be of value to the facility manager who seeks to extend the life of building elements. He also provides guidance to those wishing to apply the factor method to adjust service reference lives for local conditions. Chew’s work is supported by an evolving online database of related information, accessible following purchase of the printed book.

In common with other authors, Stanford[19] also provides service life data presented in a UNIFORMAT framework.[19] The author provides service life information along with indicators that may be used to adjust service life values in line with the factor method.
International Standards

A suite of international standards exists to support MEFMA members.
ISO 15686 - Buildings and constructed assets - Service life planning comprises several parts:
- ISO 15686-1:2011 General principles
- ISO 15686-2:2012 Service life prediction procedures
- ISO 15686-3:2002 - Performance audits and reviews
- ISO 15686-5:2008 Life cycle costing
- ISO 15686-6:2004 Procedures for considering environmental impacts
- ISO 15686-7: 2006 Performance evaluation for feedback of service life data from practice
- ISO 15686-8: Reference service life and service life estimation
- ISO 15686-10:2010 When to assess functional performance

Part 4 of the suite of standards, ISO/NP TR 15686-4 Service Life Planning using IFC based Building Information Modelling, is under development as at September 2012 (ISO, 2012). Details of these standards are provided in the bibliography.

Of the ISO 15686 standards listed above, several have direct application to service reference life estimation:
ISO 15686-1 introduces general principles and includes a table of suggested component minimum design life based on building design life. This document also includes an introduction to service life forecasting. The standard notes that service reference life data are scarce and that accuracy of that data is questionable, a point also highlighted by Stanford as he refers to much data being anecdotal. The standard introduces the factor method of service life estimation which can be used by facility management professionals to estimate the service life of a building component.

The factor method takes the reference service life of a component as its starting point. The reference service life (RSL) of a component may be the expected service life under a set of operational circumstances as defined by the component manufacturer. A set of modifying factors is then applied to the RSL to derive the estimated service life (ESL) of the component.

The standard defines the modifying factors as:
A. Quality of components
B. Design level
C. Work execution level
D. Indoor environment
E. Outdoor environment
F. In-use conditions
G. Maintenance level

The ESL of a building component is calculated as the product of the RSL and all above factors.

The standard also includes worked examples of the use of the factorial method of component service life estimation.

ISO 15686-2 introduces service life prediction procedures to support the prediction of component reference service life (RSL) which may then be used as an input to the factor method described above.

ISO 15686-8 acknowledges that reference service life (RSL) data is often unsatisfactory due to component in-use conditions. The standard notes that those involved with service life estimation should ideally know the component reference in-use conditions that the RSL is based on. Suggestions are provided for possible sources of component RSL data and also on the interpretation of that data. The standard also provides useful information on the implementation of the factor method and includes examples of how factors may be applied, along with worked examples.

Distribution Curves

Tse informs us that the most widely used service life reference document in the UK is the CIBSE Guide M: Maintenance Engineering and Management. Tse notes that service life data provided by CIBSE is derived from several published sources.

As Tse confirms that CIBSE’s Guide M draws on other published sources, facility managers should consider the comments of Stanford which raise the issue of the anecdotal nature of some published data. Stanford does not substantiate his assertion.

Like many other data sources, CIBSE presents component life expectancy data as a single figure which cannot be used to derive life expectancy distribution curves. Tse confirms that distribution curves allow us to identify the dispersion of data about the mean. Distribution curves would therefore allow facility managers to estimate the most likely life expectancy of components instead of adopting a single figure.

The Building Services Research and Information Association (BSRIA) has contributed towards developing life expectancy distribution curves as part of the Construction Industry Life Cycle Costing Analysis European research project (CILLECTA).

ASHRAE introduces readers to a web-based database designed to capture data from ASHRAE members. The data captured can be used to derive mean and standard deviations, allowing facility managers to identify the expected life of facility components.

Tse states that the only other source of data that can be used to generate distribution curves is BCIS, Life Expectancy of Building Components: Surveyor’s Experiences of Buildings in Use - A Practical Guide.
Reference Service Life Values and Adjustment

The factor method introduced in ISO 15686-1 and ISO 15686-8 allows facility managers to adjust component reference service life values based on in-use conditions.

ISO 15686-8 provides worked examples of the implementation of the factor method and provides an example of in-use conditions of poor, normal and good. These in-use conditions will be used to modify values of relevant factors. A normal in-use condition may result in a factor of 1 whereas good would return a factor of 1.2, with a factor of 0.8 being applied to poor in-use conditions as shown in the table below:

<table>
<thead>
<tr>
<th>Category</th>
<th>In-use condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>A</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Thus if factors B to G were all normal, returning a modification value of 1, while factor A was found to return a result of poor, the ESL of a component having a reference service life of 20 years would be:

\[ \text{ESL} = 20 \times (\text{reference service life}) \times 0.8 \times 1 \times 1 \times 1 \times 1 \times 1 = 16 \text{ years} \]

By following Stanford’s guidance the air-cooled chiller may have an estimated service life of only 4.5 years.

It would be difficult for chiller manufacturers to sell chillers with a life expectancy of only 4.5 years into the MEFMA catchment area. It is possible therefore that Stanford meant that life expectancy is reduced to 70% of reference service life rather than by 70%, in which case the estimated service life of an air-cooled chiller would be as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Reference Service life (years)</th>
<th>Estimated (Adjusted) Service life (years) RSL – 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-cooled, electric drive chiller</td>
<td>15</td>
<td>10.5</td>
</tr>
<tr>
<td>16</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>11.9</td>
<td></td>
</tr>
</tbody>
</table>

Stanford’s publisher’s website does not indicate errata for the publication in question.

We could choose to coat the condenser coils with a protective coating to protect from the rapid oxidation that Stanford describes. Facility managers would then have to assess the life cycle implications of such an action. Coil coatings can be expensive and facility managers should be aware of the terms and conditions of coil coating applicator contracts. It is not uncommon for the coil coatings to require regular maintenance in order to maintain the coating warranty. Facility Managers should therefore budget for this maintenance and factor it into life cycle considerations.

Coil coatings will also be subject to physical damage, incurring reactive maintenance costs. Failure to implement remedial action in a timely manner may void the coil coating warranty.

Further, a coil coating warranty may only apply to the coil coating itself. In the event of coating failure, damage to the coil itself may not be covered under the coating warranty. In this situation the facility manager may be left paying for repairs to coat a deteriorating coil with no assurance that corrosion has been halted.

The facility manager also needs to be aware of the performance impact of coil coating applications. Even a minor reduction in heat transfer efficiency can have a significant long-term financial impact for the client.

One option overlooked by Stanford, possibly because he estimates a longer life for air-cooled condensers than for chillers, is the possibility of budgeting to replace a damaged condenser coil after 10.5 years rather than replacing the full chiller. The Facility Manager then has the option of avoiding the expense of coil coating, along with coating maintenance and repair costs, in exchange for the planned replacement of a coil which could ultimately prove to be the more satisfactory option for the client.
Westberg et al.[2] provide an example of the methodology that expectancies of the factor method to adjust simple reference service life accuracy of service life prediction rather than the application that it may be more beneficial to consider improving the accuracy of ESL figures.

Garris[21] states that HVAC equipment may be refurbished for less than 50% of the cost of new equipment, depending on the scope of work required. Garris also introduces a caution that more complex equipment, such as packaged chillers, may not be candidates for refurbishment.

The facility manager therefore needs to be fully capable of performing life cycle costing analyses. Part 5 of the ISO 15686 suite, Life Cycle Costing, provides guidance on this topic.[24]

Facility managers should be aware of the observation of Davies and Wyatt who caution that “The purpose of the factor approach is to provide a ‘rough and ready’ means of estimating, not predicting, service life.”[25] The authors suggest that it may be more beneficial to consider improving the accuracy of service life prediction rather than the application of the factor method to adjust simple reference service life expectancies.

Westberg et al.[2] provide an example of the methodology that Davies and Wyatt[25] caution against as they state that finding the estimated service life (ESL) of a component is “limited to the problem of finding the values of seven factors…” As the seven factors are applied to the reference service life (RSL) of a component, identifying a reasonably accurate RSL is, as Davies and Wyatt suggest, of clear value in increasing the accuracy of ESL figures.

ISO 15686-8[21] provides facility managers with information related to the gathering of reference service life data and suggests manufacturers, technical bodies and national building codes as potential data sources. The standard also notes that “the vast amount of existing data of scattered quality constitutes an important source of information…”

Regional Examples

The following cases are presented to MEFMA members to demonstrate the difficulties associated with generating accurate equipment service life estimates. For confidentiality reasons the ownership, exact location of the facilities and sources of information in the following cases cannot be revealed by MEFMA. MEFMA members are therefore cautioned to consider the cases as anecdotal. Service life information presented in these cases should not be used as a reference for decision making purposes.

Reference service life data for air-cooled chillers suggests a service life ranging from 15 years, based on Stanford[19], to 20 years, based on CIBSE and Dell’Isola and Kirk.[11, 16] Stanford confers a longer service reference life on an air-cooled condenser, 20 years, than he does on an air-cooled chiller, while it is often the condenser that deteriorates quickly. This coil deterioration can, of course, have an impact on the overall chiller life cycle.

Weather information provided is for reference only and should not be used as input to design or service life decision-making processes.

Case 1: United Arab Emirates

The owner of a Dubai retail establishment installed several air-cooled, centrifugal chillers in the late 1990’s. It is believed that the condensers were treated with a protective coating on site but this cannot be confirmed.

The facility owners replaced 5 of the air-cooled chillers in 2009. The replacement chillers were also air-cooled. This gives an actual life-cycle of approximately 12.5 years. According to Stanford[19], who provides the most conservative reference service life for an air-cooled chiller, these chillers should have lasted upwards of 15 years due to their protective coating, suggesting that the local operating environment is extremely harsh on air-cooled chillers. Operation and maintenance regimes and the operational environment are factors in service life expectancy. The chillers in question have been operated and maintained by a reputable facility management company with occasional support from the chiller manufacturer for major works. Maintenance of the coil coating cannot be confirmed.

A further 8 air-cooled chillers at the same facility have had condenser coils replaced within the last 5 years, indicating a condenser service life expectancy of between 7 and 12 years, far short of the 20 year reference service life published in several data sources.

Given the above replacement actions it may be assumed that the remaining air-cooled chillers at this same facility are also approaching the end of their economic life span.

This case demonstrates that in the absence of regionally generated data, published reference service life data has to be adjusted for local conditions, possibly using the factor method with due consideration for all factors listed in ISO 15686-1.[11]

The facility owners have clearly considered life cycle implications and budgetary constraints in their decisions to invest in condenser replacement rather than chiller replacement in some instances, while opting for full chiller replacement in others.
This case demonstrates that facility managers need to be able to conduct a thorough analysis of all aspects of service life related matters and prepare and present sound business cases to ensure adequate budget allocation.

Dubai weather information (source: Meteonorm V6.1)

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean temp (ºC)</th>
<th>Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>21.3</td>
<td>64</td>
</tr>
<tr>
<td>Feb</td>
<td>22.3</td>
<td>64</td>
</tr>
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<td>Mar</td>
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<tr>
<td>May</td>
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<td>Jun</td>
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<tr>
<td>Jul</td>
<td>30.6</td>
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</tr>
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<td>Nov</td>
<td>33.5</td>
<td>57</td>
</tr>
<tr>
<td>Dec</td>
<td>30.7</td>
<td>57</td>
</tr>
</tbody>
</table>

Case 2: Qatar

A 4-star hotel has three air-cooled screw chillers. The chiller nameplates indicate factory testing in mid-2007. Allowing for shipment and installation, the chillers are assumed to have entered service at the end of 2007, giving approximately 5 years of service to date. Condenser coils are uncoated.

A brief visual inspection was carried out. Two chillers show no obvious signs of deterioration while the third has sustained considerable physical damage to condenser fins. This fin damage restricts airflow through the condenser coil and reduces the operational efficiency of the chiller. Condenser deterioration may also begin at these damage sites. This may impact the service life of the chiller.

Stanford[19] suggests that the reference service life of these chillers would be between 4.5 and 5.1 years, allowing for the initial reference service life of 15 years, reduced by 70% due to lack of coating. None of the chillers appears to be nearing the end of service life.

In the event that Stanford did mean that the reference service life should be reduced to 70% of the initial value, rather than by 70%, facility managers could assume that these chillers are approximately half way through their service lives.

Case 3: Qatar

The owner of a residential facility installed a new air-cooled, reciprocating chiller which was manufactured in 1980. An installation date of 1981 is assumed but cannot be verified. Condenser fins are aluminium and not coated.

Chiller replacement has been scheduled for 2013, giving an actual service life of approximately 22 years, as condenser fins have deteriorated considerably and crumble when touched. Operational efficiency is now unacceptable.

This example demonstrates that the actual service life of an air-cooled chiller, with uncoated condenser fins and operating in what many facility management professionals consider to be a harsh environment, can be extended beyond published reference life expectancy.

Doha weather information (source: Meteonorm V6.1)

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean temp (ºC)</th>
<th>Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
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<td>68</td>
</tr>
<tr>
<td>Feb</td>
<td>23.7</td>
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<td>Mar</td>
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<td>Apr</td>
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<td>30.9</td>
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<tr>
<td>Nov</td>
<td>26.1</td>
<td>62</td>
</tr>
<tr>
<td>Dec</td>
<td>25.1</td>
<td>69</td>
</tr>
</tbody>
</table>

Case 4: Yemen

A government entity in Aden installed several new air-cooled screw chillers in the late 1990’s. CIBSE[16] suggests an indicative service life of 25 years for screw chillers although the authors do not make clear whether this relates to air or water cooled screw chillers. Condenser coils were uncoated.

Client administrators requested intervention from the chiller manufacturer after only 18 months of chiller operation due to claimed poor chiller performance and repeated breakdowns. A visual inspection revealed serious condenser fin deterioration. Chiller performance was confirmed to be poor by the manufacturer’s representative. A review of commissioning data revealed that the chillers had not been correctly commissioned by the installing contractor. Facility operation and maintenance (O&M) staff had been given no training when the chillers were handed over to them and they had no experience of screw chillers. A review of operational log sheets revealed that the chillers had been consistently operating outside their design parameters while no maintenance had been carried out at all. Chiller plant control was found to be faulty resulting in uncontrolled chiller shutdowns.

This case reveals the importance of correct installation and full commissioning in addition to O&M staff training. The chillers were operating outside their design conditions in a coastal environment. Rapid condenser fin degradation added to the operational problems and was unchecked by the maintenance team.
ASHRAE, Dell’Isola and Kirk, CIBSE and Stanford all give air-cooled condensers a 20 year reference service life. The condensers in the case were compromised in less than 18 months.

Aden weather information (source: Meteonorm V6.1)

<table>
<thead>
<tr>
<th>Jan</th>
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<th>Mar</th>
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</tbody>
</table>

Muscat (Seeb) weather information (source: Meteonorm V6.1)

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
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Managing Component Service Life

This section introduces information available to facility managers that may be of use in managing facility component service life. The section supplements the information available in data sources listed in the directory section of this report.

Operational Environment

Westberg et al. discuss the use of environmental data in estimating component service life and also provide an example of degradation agents that affect the service life of building components.

Spare Parts

Port warns that the selection of spare parts can have an impact on the life expectancy of components, noting that the use of counterfeit parts can cause, along with other issues, equipment malfunction and equipment life reduction.

Facility managers are therefore cautioned that achieving the estimated service life of components is dependent upon the use of the correct spares for the particular component.

Parking Structures

Shiu and Stanish provide a life-cycle cost considerate example of the extension of service life of a parking structure.

The authors note the following key points to maintaining a parking structure over its full service life:

- The importance of timely repair
- Deterioration root cause analysis
- Designing repairs with an adequate service life
- Implementing a comprehensive maintenance program

The above points may be beneficial to facility managers throughout their portfolios.
Building Envelope

Shohet et al. [28] set out to develop a methodology to establish databases of building component deterioration patterns using the following steps:
- Identification of failure patterns
- Determination of component performance
- Determination of life expectancy deterioration path
- Evaluation of predicted service life

Included in this work is an example of deterioration agents of cementitious stucco along with possible failure modes that may be of interest to facility managers. The authors deploy a variation of the factor method in deriving component predicted service life values.

Shohet and Paciuk [29] predict the life expectancy of four different cladding materials under normal in-use conditions:
- Cementitious mortar
- Synthetic rendering
- Ceramic mosaic
- Stone cladding

Of the materials considered, stone cladding was found to the most durable with cementitious mortar least durable.

Shohet and Paciuk provide life expectancy limiting coefficients for cladding components under differing failure mechanisms that may be of use to facility managers. [30]

Silva et al. propose the application of the factor method for stone cladding directly adhered to the substrate. [31] To overcome some of the limitations of the factor method the authors also propose the use of multiple linear regression to identify relevant sub-factors.

Silva et al. present a method for service life prediction of stone cladding directly adhered to the substrate. [32] The Portugal-based authors also provide a table of estimated service life data according to cladding characteristics. The authors have considered:
- Type of stone
- Type of finish
- Orientation
- Exposure to damp
- Colour of stone
- Distance from sea
- Exposure to wind / rain

Silva et al. use studies of 140 different stone-clad facades to develop models to describe the degradation of facades and describe the use of neural networks to predict the service life of stone cladding that is directly adhered to the substrate. [33]

Usman and Resdiansyah also use neural networks to predict component service life of materials in Malaysia. [34] The authors identify three methods commonly used to determine components service life: the factor method, probabilistic method and engineering method and note the ease of use of the factor method. They do however note that the factor method can cause confusion due to overlapping of individual factors, observing that component quality can also be an influence on the design factor.

The authors hypothesize that the service life of a component can be predicted from internal and external factors. Internal factors include building design and usage while external factors include environmental aspects. As part of their work, the authors collected data on environmental conditions of 6 different zones:
- Urban
- Industrial
- Island
- Rural
- Coastal
- Highland

Gaspar and De Brito use the factor method to derive the estimated service life of cement-rendered facades and provide useful suggestions for values of modifying factors that may assist facility managers with service life prediction. [35]

With a focus on adhesive ceramic tiling systems in Lisbon, Portugal, Bordalo et al. have developed a model for prediction of service life. [36] The authors use the model to identify factors affecting service life and have established a hierarchy of defects. They also inform us that while 42% of degradation is due to environmental factors the remaining 58% is due to design and installation errors.

Rudbeck tells us that methods of improving the service life prediction of building envelope components would be improved by incorporating consideration of life-cycle cost assessment. [37] Rudbeck provides a method of linking service life prediction with economic assessment and uses the factor method as a component of the method.

Facility managers may also need to predict the service life of electrochromic windows. A methodology to do this is outlined by Czanderna et al. [38] The authors note that their service life prediction methodology can also be applied to industrial situations.

Paint finishes to old buildings present another service life issue to facility managers. Garrido et al. [39] identify 5 degradation factors that may affect the service life of paint coatings:
- Thickness of coating film
- Choice of resin or oil based coating
- Choice of textured or smooth coating
- Substrate preparation
- Facade orientation

Simmler and Brunner provide insight into the ageing mechanisms, properties and service life issues of vacuum insulation panels (VIPs). [40]

Reinforced Concrete

While several of the data sources listed in this report provide service life data for reinforced concrete components, Lin et al. develop a model for the prediction of service life of reinforced concrete exposed to chloride environments and demonstrate the model by predicting the service life of a reinforced concrete slab exposed to a chloride environment. [41]
Residential Water Meters

In his work linking economic analysis to service life prediction, Allender demonstrates the integration of concepts relating to the economic optimum service life of residential water meters in Maryland, USA, noting that the methodology could be adapted to other agencies. Allender cites the time-related decay of meter accuracy as the driver for his work and demonstrates the annual losses associated with keeping ageing water meters with diminishing accuracy in service. The author provides a step-by-step explanation of his method. This life-cycle cost approach to decision making should be familiar to facility management professionals.

Power Factor Correction

Elektrotek delivers power factor correction equipment with capacitors having a service life expectancy of 150,000 hours, equivalent to approximately 17 years of continuous operation. This figure may be of use to facility managers who lack other related reference service life data.

Maintenance

Stanford tells us that when the performance of a component falls below some minimum level and the cost of continuing to maintain a failing component threatens to exceed the cost of replacement, the component has reached the end of its design service life. ISO 15686-1 informs us that designers should consider local conditions to ensure that service life will be no less than design life. It would appear therefore that Stanford has confused design service life with actual service life resulting from operational conditions, as design service life may not be achieved if operation and maintenance requirements are not adequately met.

Chew Yit Lin provides facility managers with a wealth of information related to the maintainability of facilities and provides a defect library that should be of use to facility managers as they strive to achieve design service life expectancies of facility components.

Taking a health care facility example, Lavy and Shohet hypothesise that facility maintenance resources are a function of building service life, occupancy and environmental conditions. The authors conclude that maintenance costs of a hospital can vary between -9% and +18.6% when related to standard values, depending on occupancy levels and environmental conditions. The authors confirm that their conclusions can be adapted to other facility types such as residential, commercial, educational and public buildings. As part of their work, Lavy and Shohet developed a facility coefficient based on the following hypotheses:

- Ambient environment affects the exterior envelope of the facility and consequently the maintenance of its components
- Occupancy of the facility affects the service conditions and consequently the deterioration patterns of the interior finishing and the electro-mechanical systems
- Age of the building is a significant factor in the planning and allocation of resources for maintenance
- The particular design of the building affects the resources it needs

As ISO 15686-1 has identified level of maintenance as a modifying factor for service life prediction, and Lavy and Shohet confirm that occupancy levels and ambient environment affect maintenance cost, facility managers need good budgeting skills to ensure adequate funding of maintenance regimes for facilities under management.

Directory Of Service Reference Life Data Sources

This section lists data sources relevant to facility component service life estimation.

Entries are listed by publisher and include details of the data source, price, if any, and availability. A short description of each entry is also provided. Where information is available for download, links are provided. Links were tested as part of this research but MEFMA cannot guarantee that the links will always be active and cannot be responsible if MEFMA members find the links to be broken or documents no longer available.

MEFMA members are therefore encouraged to make use of any freely available information in a timely manner.

ASHRAE - 1976 - 2005

Data source:
1. ASHRAE (2011) HVAC Applications, Atlanta, ASHRAE
2. ASHRAE Service Life and Maintenance Cost Database

Price:
- Item 1: ASHRAE Handbooks are issued annually, free to members. Available to purchase at US$ 199 from http://www.techstreet.com/ashrae/cgi-binbrowse?publisher_id=33&subgroup_id=37400

Description

Heating, ventilating and air-conditioning (HVAC) equipment service life data provided by the American Society of Heating, Refrigerating and Air Conditioning Engineers has been a useful reference source for many years.

Original data were based on a 1976 survey that comprised only 68 responses while those responses were based on respondents’ opinions rather than empirical service life data. Although lacking in quality, the ASHRAE data source has been used as a reference by ASHRAE members across the world since publication.
Recognizing the need for more realistic HVAC equipment service life data, ASHRAE initiated a web-based project in 2003, seeded with data from 163 commercial buildings, with the intent of allowing the ASHRAE community to add to the database.

The ASHRAE web-based project remains an active data gathering tool and is available for members and non-members to use. The data are presented in spreadsheet format. The database is free to download.

**HAPM - 1999**

**Data Source:** Component Life Manual  
**Price:** Update 14 (2003) GBP 99.99 (approx AED 600)  
**Availability:**  

**Description**  
“HAPM” is the Housing Association Property Mutual Ltd. HAPM’s Component Life Manual provides information on reference, or median, service life of building components and, according to Stanford, provides “the best current reference” for related information.[19] Stanford also tells us that the data presented relate to materials commonly used in housing and light commercial construction in the United Kingdom and are not as comprehensive as that found in the United States. Stanford confirms his faith in HAPM by using it as a reference source for his own published data.

**BPG - 1999**

**Data Source:** BPG Building Fabric Component Life Manual  
**Price:** GBP 375 (approx AED 2250)  
**Availability:**  
http://www.taylorandfrancis.com/books/details/9780419255109/  
[Last accessed 24 September 2012]

**Description**  
From the publisher’s website (see “availability” for address): “This manual provides a comprehensive source of building component life-span and maintenance data for commercial and industrial building components, following the same format as the ground-breaking HAPM Component Life Manual for domestic buildings. Each building component is allocated its own data sheet on which a number of generic descriptions are provided together with assessed life-spans and maintenance requirements.”

**NIBS - 2000**

**Data Source:** Residential Rehabilitation Inspection Guide  
**Price:** Free to download  
**Availability:**  
http://www.huduser.org/portal/publications/destech/inspection.html  
[Last accessed 24 September 2012]

*Note that this website appears to block IP addresses originating from the UAE.

**BPL - 2001**

**Data Source:** Building Services Component Life Manual: Building Life Plans  
**Price:** US$ 270 (Approx AED 1017) as at 24 September 2012  
**Availability:**  
[Last accessed 24 September 2012]

**Description**  
From the publisher: “This unique manual provides much-needed guidance on the whole-life performance of building services components - which often account for 60% of a building’s running costs. Service lives of components are explained - from control valves to hydraulic lifts, and are ranked according to recognized quality benchmarks, with adjustment factors for differing environments, use patterns and operating regimes. Summaries of typical inspection and maintenance requirements are given, along with specification guidance and references to further detailed sources of information.”
Dell’Isola & Kirk - 2003

Data Source: Life Cycle Costing For Facilities
Price: US$ 99.95 (Approx AED 377) as at 24 September 2012
Availability: http://www.amazon.com/s/ref=nb_sb_noss_1?url=searchalias%3Dstripbooks&field-keywords=life+cycle+costing+for+f +facilities
[Last accessed 24 September 2012]

Description
The authors provide a wealth of life cycle information, comprising well over 800 line items, collected through their work on life cycle cost analyses. The data are presented using the UNIFORMAT framework and the authors also provide an indication of the percentage of components to be replaced, along with frequencies. Energy demand information is included where applicable. The authors present information relating to building structure, engineering services and site work.

NSRDEC - 2004

Data Source: Food Service Equipment Life Expectancy
Price: Free to download
[Last accessed 24 September 2012]

Description
This resource provides information relating to equipment installed in general messes. Life expectancy data is provided for a range of food service equipment.

Mayer - 2005

Data Source: BLP Durability Assessment for National Audit Office
Price: Free to download
[Last accessed 24 September 2012]

Description
Mayer presents a durability assessment of components along with assumptions and an explanation of the underlying data. Components of the following building types are considered:
- Brick and block house
- Brick and block flat
- Thin joint house
- Timber frame house
- Timber frame flat
- Advanced timber frame house
- Hybrid frame house
- Volumetric house

While this document relates to UK housing, the author includes information on design and detail assumptions, workmanship and installation and maintenance activity which facility managers may find helpful when using the factor method to estimate component service life expectancies.

BCIS / RICS - 2006

Data Source: Life Expectancy of Building Components: Surveyors’ Experiences of Buildings in Use : A Practical Guide
Price: GBP 169 (Approx AED 1014) as at 24 September 2012
[Last accessed 24 September 2012]

Description
From the publisher: “Life Expectancy of Building Components presents the findings from a survey of the life expectancy of common building components based on the experience of building surveyors. It also highlights the factors that affect the deterioration or failure of the components. A checklist of the factors to be considered when assessing life expectancy will provide invaluable assistance for anyone involved in condition surveys and building design. A checklist identifying causes of early deterioration is also included to provide further advice.”

NAHB - 2007

Data Source: Study of Life Expectancy of Home Components
Price: Free to download
[Last accessed 24 September 2012]

Description
This publication presents the results of a telephone survey of manufacturers, trade associations and researchers. Survey respondents cautioned that the life expectancy of housing components is dependent upon the quality of maintenance. The study lists life expectancies of a wide range of components in the following categories:
- Appliances
- Cabinetry and storage
- Concrete and masonry
- Counter tops
- Decks
- Doors
- Electrical and lighting
- Engineered lumber
- Faucets and fixtures
- Flooring
- Footings and foundations
- Framing and other structural systems
- Garages
- Home technology
- HVAC
- Insulation and infiltration
- Job site equipment
- Molding and mill work
- Paint, caulks and adhesives
- Panels
- Roofing
- Siding and accessories
- Site and landscaping
- Walls, ceilings and finishes
- Windows and skylights
CIBSE-M - 2008

**Data Source:** CIBSE Guide M - Maintenance engineering and management  
**Price:** GBP 98 (Approx AED 594) for hard copy or GBP 89.83 (Approx 539) for soft copy as at 24 September 2012  
**Availability:** https://www.cibseknowledgeportal.co.uk/component/dynamicdatabase/?layout=publication&revision_id=116&st=guide+m  
[Last accessed 24 September 2012]

**Description**
Referring to building component life expectancies, Tse[4] describes this publication as "the most widely used reference document for this topic available in the UK". Like ASHRAE, CIBSE has a large international membership that uses its resources as reference material. This publication provides indicative life expectancy values for a range of building services components. Categories covered include:

- Heating source
- Cooling source
- Water and fuel installations
- Calorifiers / heat exchangers
- Pumps
- Pressurisation systems
- Water boosters
- Pipe work systems and components
- Insulation (pipe work)
- Valves
- Terminal units (wet systems)
- Air handling and ventilation
- Miscellaneous mechanical equipment and plant
- Electrical installations
- Lighting
- Drainage and sanitation
- Metering and measurement
- Protection systems (fire and security)
- Miscellaneous electrical equipment and plant
- Vertical and horizontal transportation
- Lifting equipment
- Other (e.g. Photovoltaic panels, solar panels, pool filtration)

Chew – 2010

**Data Source:** Maintainability of Facilities For Building Professionals  
**Price:** AED 351  
**Availability:** http://www.amazon.com/Maintainability-Facilities-For-Building-Professionals/dp/9814291757/ref=sr_1_1?ie=UTF8&qid=1348482324&sr=8-1&keywords=9789814291750  
[Last accessed 24 September 2012]

**Description**
Chew provides life expectancy data, with adjustment factors where applicable, for the following building components:

- Hot rolled steel
- Reinforced dense concrete
- Clay brick
- Homogeneous tiles
- Ceramic tiles
- Concrete tiles
- Tile bedding
- Glass (curtain walling)
- Sealants (solvent based)
- Gasket
- Basement waterproofing
- Plastic pipes

Although Chew provides some component life expectancy data the focus of the book is, as the title suggests, the maintainability of facilities. Chew also therefore provides facility managers with a considerable amount of information relating to defects and possible causes. The work is well illustrated with photographs and the author also provides purchasers of the book with access to an evolving online database of facility related information.

Means - 2010

**Data Source:** Facilities Maintenance and Repair Cost Data  
**Price:** Approximately US$ 400 (Approx AED 1508)  
**Availability:** http://rsmeans.reedconstructiondata.com/60302.aspx  
[Last accessed 24 September 201]

**Description**
The 2010 version of this publication provides a wide range of facility maintenance and repair cost data including replacement frequencies. Data is presented using the UNIFORMAT framework, similar to that of Dell’Isola and Kirk.[11] The work is updated annually.

The authors note that the frequency listing facilitates the preparation of zero-based budgets.

When referring to the availability of data from professional organizations and commercial entities, and he names “Whitehead, Means etc.” as examples, Stanford cautions that almost all data is anecdotal in origin and “not based on any real scientific study”. Stanford does not provide any substantiating evidence for his claim.

RSMeans state that "The staff at RSMeans continuously monitors developments in the construction industry in order to ensure reliable, thorough and up-to-date cost information".

Stanford - 2010

**Data Source:** Effective Building Maintenance – Protection of capital assets  
**Price:** Approximately US$ 99.95 (Approx AED 377)  
**Availability:** http://www.amazon.com/Effective-Building-Maintenance-Protection-Capital/dp/1439845530/ref=sr_1_1?ie=UTF8&qid=1348824308&sr=8-1&keywords=stanford+effective+building+maintenance  
[Last accessed 28 September 2012]
Description
As the title suggests, Stanford’s focus is on building maintenance. Stanford also includes a table of component service life values, presented in the UNIFORMAT framework. Stanford challenges the reliability of other published data by stating that much of it is anecdotal, rather than based on scientific study. Stanford also covers a wide range of maintainability issues in his book.

Conclusions
This report has identified several data sources of use to facility management professionals. Available data provides a foundation upon which MEFMA members may build to develop a comprehensive regional data source.

MEFMA members should contribute to a database of regional facility component life expectancy data. Properly designed, such a data source would support the development of locally relevant equipment and component life cycle distribution curves which should improve the accuracy of, amongst other things, forward funding assessments.

The development of such a database of local data would serve to improve facility component service life prediction accuracy, as suggested by Davies and Wyatt. The development of a regionally relevant database will be a long term project.

The Yemen case study highlights the potential impact of failing to commission assets correctly. Asset service life is reduced and operational expense is increased.

Much of the literature, while targeted at specific facility components or facility types, provides valuable information that can be adapted to other facility components or types, as suggested by Lavy and Shohet in their research.

The literature makes it clear that facility managers cannot avoid the linkage between finance and budgeting, adequate levels of maintenance and service design life. Inadequate budgeting can lead to less than optimum maintenance, which can have an adverse effect on facility component service life. The factor method provides a fairly simple means for facility managers to estimate component service life based on an initial reference service life and the application of any or all of 7 modifying factors:
A. Quality of components
B. Design level
C. Work execution level
D. Indoor environment
E. Outdoor environment
F. In-use conditions
G. Maintenance level

By integrating life-cycle costing with service life estimation, as proposed by Allender and Rudbeck, facility managers will be able to assess the optimum economic life of components rather than relying on reference service life data.

Budgeting accuracy should be enhanced by the use of zero-based budgeting, supported, as noted by RSMeans, by equipment replacement frequency data.

Facility managers should, however, exercise caution when selecting a component reference service life from any data source. The literature confirms that data such as that provided in the 1970’s by ASHRAE is not based on scientific research or verifiable empirical data. A point reinforced by Stanford.

Much of the published data relates to construction in the United Kingdom and United States of America. While it may be argued that these locations may not accurately reflect environmental conditions within MEFMA’s catchment area, the information does provide a useful initial reference for facility managers. The air-cooled chiller examples presented in this report show that equipment service life can, under the right circumstances, approximate and even exceed the values given in the literature, even if the data originates in a different geographical region.

The example cases demonstrate the difficulty that facility managers face in accurately estimating facility component service life. Using the factor method to determine estimated service life (ESL) of a component should not be considered a one-time task. Component ESL values should be periodically reassessed to confirm or refine predictions throughout the facility life cycle.

Limitations of the Research
The research did not include an investigation of data sources which may be embedded in or supplied with, or as part of, software applications.

Although example cases are introduced in the report, the research was not designed to include field research within MEFMA’s catchment area.

Further Research
MEFMA members are encouraged to conduct field research within their own geographical areas. This research should capture facility component service life data and also reasons for removal e.g. end of economic life, beyond economical repair, obsolescence, reduced energy performance, risk management etc. This life expectancy data could then be used to seed a MEFMA service life database with local data.

A spreadsheet template is provided with this report to facilitate the recording of facility component and equipment service life data.
References


Bibliography


### Appendix A

The UNIFORMAT Framework

#### ASTM Uniformat II Classification for Building Elements

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<th>Level 1 Major Group Elements</th>
<th>Level 2 Group Elements</th>
<th>Level 3 Individual Elements</th>
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<td>E1090 Other Equipment</td>
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<td>E20 Furnishings</td>
<td>E2010 Fixed Furnishings</td>
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<td><strong>F. SPECIAL CONSTRUCTION &amp; DEMOLITION</strong></td>
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