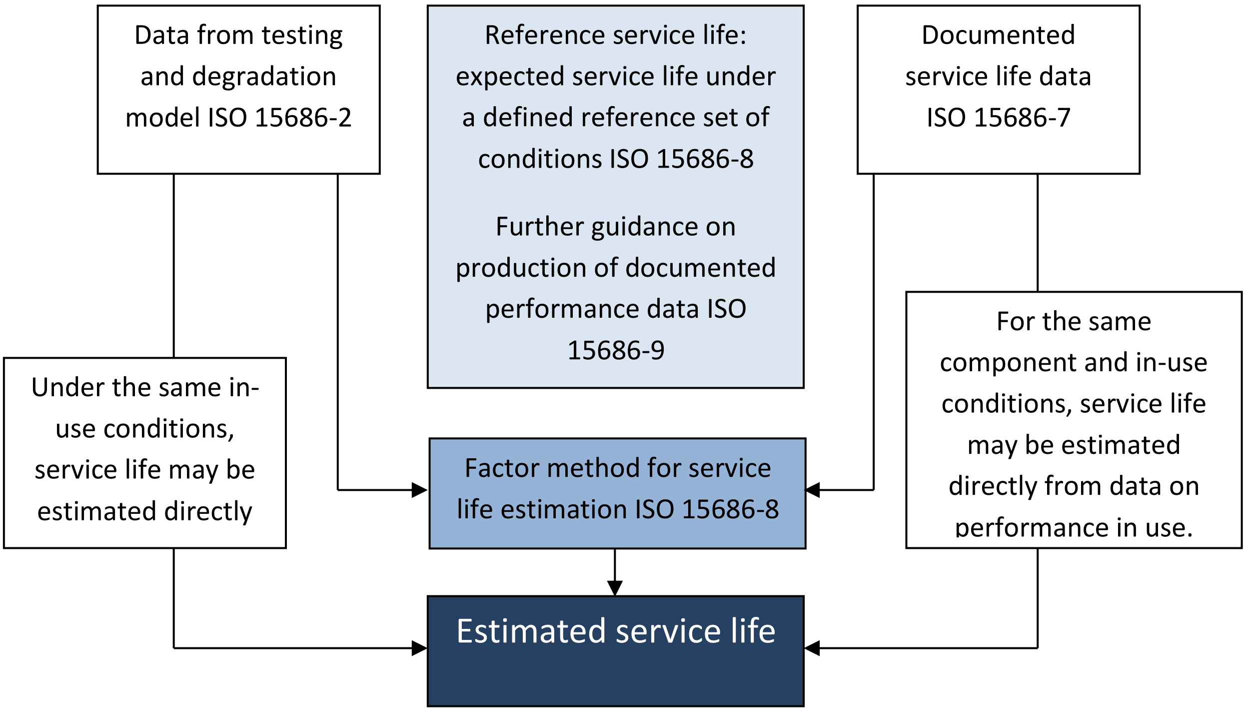
Service Life Planning Analysis of Accoya timber used in windows



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Executive Summary

This report uses the ISO 15686:8 methodology to evaluate the Estimated Service Life (ESL) of Accoya modified timber used in window frames.

Service Life Planning (SLP) is a decision process which addresses the development of the service life of a building, constructed work, or in this case, a component. Its purpose is to give a structured response to establishing normal service life from a reference or estimated service life framework. The objective of SLP is to provide reasonable assurance that the estimated service life of a building or construction on a particular site, with appropriate maintenance, is at least as long as the design of that building. The results show Accoya modified timber frames to have an expected service life of between 77 and 90 years, with the range representing exposure conditions from severe to mild.

This work draws on reports and peer reviewed evidence discussed in the literature review section, and listed in the reference section of this report.

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1.0 Introduction and Literature Review

This report analyses the Service Life Planning (SLP) of factory-finished acetylated Accoya timber window frames designed to Wood Window Alliance (WWA) criteria, under various construction and exposure conditions. It was commissioned by John Alexander, Director of Product Development, Accsys Technologies Plc and complements work completed for the Wood Window Alliance [Menzies 2013].

In this report, Accoya modified timber is defined as timber which has undergone acetylation to a uniform and high acetyl level (durability class 1) through the entire cross section. This technique creates a high performing wood which can be used in demanding outdoor applications, including windows, doors, decking, cladding, and bridges. Wood contains hydroxyl groups that interact with water according to changes in climatic conditions - the main reason wood swells and shrinks. Acetylation converts these hydroxyl groups to acetyl groups by reaction with acetic anhydride. Naturally grown timbers already contain a proportion of acetyl groups, but the acetylation process increases this proportion significantly and the resulting timber is more dimensionally stable, indigestible (rot resistant) and durable.

According to Hill [2007] wood which has been acetylated is far less susceptible to shrinking and swelling due to variations in atmospheric conditions. The understanding of this mechanism has received much research debate. Current thinking [Hill et al, 2005] maintains that the cell wall of acetylated wood is filled with chemically bonded acetyl groups which take up space within the cell wall of the wood. This means that the wood is already in a swollen condition and there is reduced additional swelling when the wood is in contact with water. This position is also supported by Thybring [2013], who maintains that the decay resistance of modified wood has been related to the reduction in maximum moisture capacity of the cell, and establishes a criterion of 25% moisture content below which decay does not occur.

Hill further quantifies this mechanism. The measure of uptake of acetylation in wood is measured by the Weight Percentage Gain (WPG). At around 20% WPG modified wood will shrink and swell by about ¼ of the amount exhibited with unmodified wood. Hill also maintains that the actual swelling and shrinkage is likely to be less than this as the laboratory conditions used to measure this value are seldom as severe under normal use. It is fair to say that it is unlikely that window frames will be subjected to constant soaking and high temperature drying on a cyclic basis. Larsson-Brelid and Westin [2010] agree with this finding, although applied to wood in ground contact and in marine water, quoting 22% WPG as a minimum requirement. Hill et al [2005] performed various decay studies on acetylated wood and concluded that it was not currently possible to derive a full protection WPG value. They concluded that decay protection was due to cell wall moisture content reduction, a blocking of cell-wall micropores, or a combination of both these phenomena. Rowell [2006] reports that acetylated wood which has been exposed to cyclic humidity conditions over a period of 20 years has shown little or no loss of acetyl. Tjeerdsma and Pfeiffer [2007] report the adsoption and desorption of Accoya compared to untreated Radiata Pine. Their results show that moisture adheres to and desorbs from Accoya by around 1/3 to 1/5 of untreated timber due to its increased dimensional stability. A recent report authored by Ferry Bongers for Accsys Technologies [Bongers, 2013] also reported on the uptake of water by different wood types. Accoya samples were shown to have a greater water uptake than untreated Radiata Pine. Whilst this report does not report on decay or rot associated with water uptake it does show that end grains which are not sealed will lead to the ingress of moisture, and that rounding of joints and sealing of end grains is still advantageous when designing window frames made from Accoya.

Other points of interest to note are that in outdoor weathering tests, discolouration of uncoated acetylated wood occurs in a similar fashion to unmodified wood, but where clear coatings have been applied the acetylation provides additional stability when these samples are exposed to UV light. With regard to strength testing, Jorissen et al [2005] found that acetylation made no appreciable difference to the mean strength properties of wood.

Further studies by the Australian Forest Research Company [Hague and Scown, 2012 and 2013], the Japan Food Research Laboratories [Kawamoto, 2012] and Mohebby and Militz [2010] have researched issues relating to destructive termite attacks, oral toxicity of acetylated wood, and microbial attach in field soil trials. As this report relates to windows used in buildings and includes consideration of design quality and materials, exposure, maintenance and treatment, these research sources have been reviewed for background but excluded from this direct scope of work at present.

SHR Timber Research investigated the performance of coatings on acetylated wood. The report [Bongers, 2005] concludes that a reduction of 70-80% of shrinkage and swelling can be achieved by acetylating wood. It also concludes that water uptake does not influence the adhesion of acetylated wood coatings, and that acetylated wood is not negatively affected by water uptake.

TRADA Technology was commissioned to investigate the impact on wood splitting of nailing Accoya and other timbers used in cladding systems [Kaczmar, 2011]. The report concluded that the superior performance of Accoya cladding could only be attributed to its superior stability characteristics which had the effect of reducing the degree of stress exerted on the fixings during alternating cycles of wet and dry weather.

Van der Lugt et al [2010] in a study which primarily considered the Life Cycle Assessment of acetylated wood application, also considered durability aspects and the use phase of products. Much of the discussion focuses on maintenance intervals and the suggestion that a longer maintenance interval is afforded for Accoya timber products due to its inherently more stable substrate.

2.0 Service Life Planning

Establishing an estimated service life, herein referred to as ESL, is an essential precursor for analyses which may follow. Further analyses may include Life Cycle Cost (LCC) analysis or Life Cycle Assessment. *ISO 15686* is the international standard dealing with service life planning; it is a decision process which addresses the development of the service life of a building, constructed work, or in this case, a component. Its purpose is to give a structured response to establishing normal service life from a reference or estimated service life framework. The objective of SLP is to provide reasonable assurance that the estimated service life of a building or construction on a particular site, with appropriate maintenance, is at least as long as the design of that building.

ISO 15686-1 describes the general principles of service life planning, of which there are a number of approaches that can be used to estimate service life. Figure 2.1 shows the possible approaches to service life estimation.

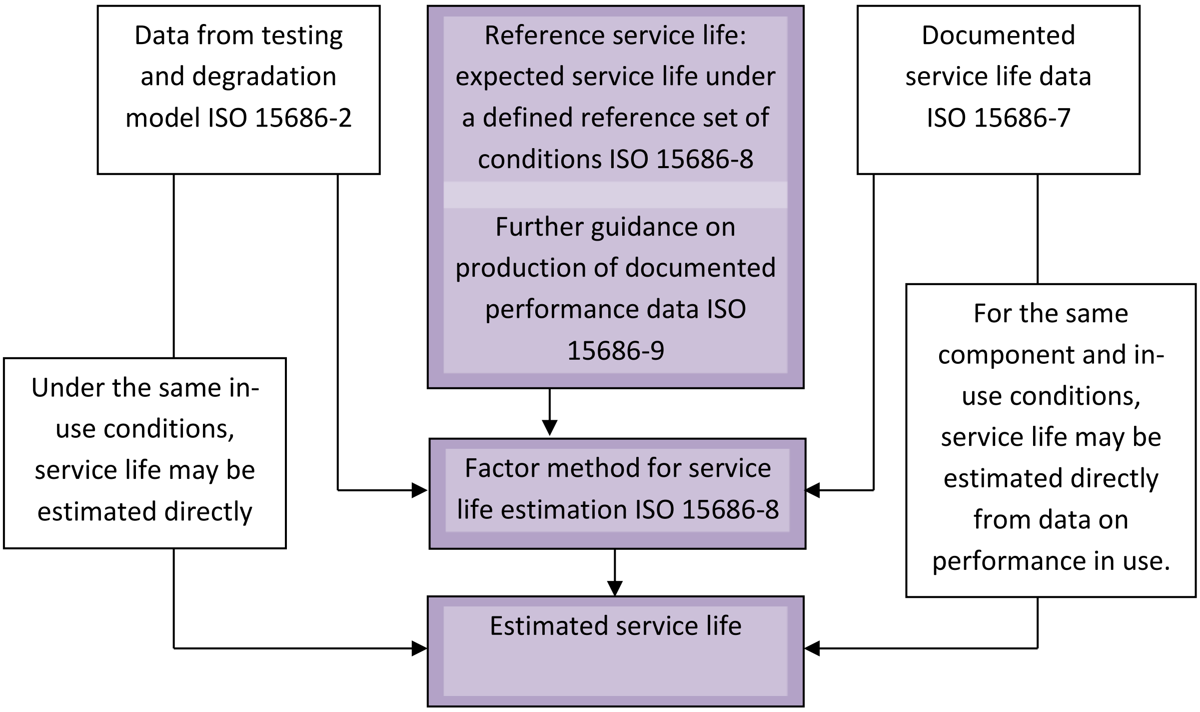

Figure 2.1: Approaches to service life estimation, adapted from ISO 15686-8, page 8.

The factor method for service life estimation, ISO 15686-8 is used in this report, and is based on earlier work completed at Heriot Watt University [Menzies, 2013], and originating from research started at Imperial College London. Seven factor categories are used to estimate service life impact, as shown in Table 2. 1. The factor method is used to obtain an ESL of a component or a designed object by modifying a Reference Service Level (RSL) and considering the differences between the object-specific and the reference in-use conditions under which the RSL is valid[1]. The RSL used here is derived from communication with the Building Research Establishment, which points to a minimum service life of 60 years. It states that,

> "a window prepared from Accoya, will show significantly improved coatings performance properties. If the window is designed and built to the principles of best practice, factory finished using quality coatings such as Sikkens or Teknos, installed by competent contractors and linked to a recognised best practice maintenance and care package it will provide a window of outstanding durability and dimensional stability that would meet a 60 year service life requirement."

This position is confirmed by communication from Trada Technology, based on a review of independent test data that relates to the service life of Accoya when used as window joinery in Europe [Trada 2013]. This review states that,

[1] ISO 15686:8 page 11

> "Based on the evidence presented in a series independent test reports that we have reviewed, TTL can confirm that Accoya is Very Durable (i.e. Durability Class 1) this is the highest Durability class that can be assigned to a timber. Durability Class 1 exceeds Durability Class 2 which can achieve a 60 year service life according to BS8417 when coated."

Best practice is assumed here to be represented by Wood Window Alliance certified window designs, which will include a factory finish, installation by competent contractors, and maintained to a high standard. Maintenance is discussed separately, later in this report. This statement gives assurance that a well-designed, installed and maintained Accoya acetylated timber window will meet a 60 year design life requirement. This statement does not, however, place a limit or maximum life expectancy on such windows. A precedent of 60 years is set out as a reference for the comparison of building materials and components in the BRE Green Guide [BRE, 2009].

Table 2.1 Factors and factor categories of the factor method ISO 15686-8, page 16.

Factor	Factor category
A	Inherent performance level
B	Design level
C	Work execution level
D	Indoor environment
E	Outdoor environment
F	Usage conditions
G	Maintenance level

A factor > 1.00 denotes longer service life estimation, while a factor < 1.00 denotes shorter service life estimation. The factors applied can be seen in Table 2.4 and the working spreadsheet which accompanies this report. No single factor applied is greater than 1.10. This is deemed conservative, but in line with ISO 15686 guidance, whereby ESL should be within 2 standard deviations of a documented or tested normal service life distribution[2]. ISO 15686:8 also states that it is preferable for all factors to be within the interval of 0.8 to 1.2, although Note 7 states that larger deviations from unity are possible if just a few factors deviate from unity and can be assumed to be independent of each other[3].

The use of acetylated timber in window frame construction does not eliminate the need for good design and craftsmanship when constructing windows. The acetylation treatment does lead to a longer life and more stable material, but is still subject to decay and deterioration in certain locations and exposures. Therefore, many initiatives which are used to improve the design quality of all timber frame windows are also applicable to Accoya acetylated timber window frames and also contribute to quality, long-lasting products. This report argues that manufacturing criteria play a strong role in extending service life, despite the higher quality of substrate that can be expected when using Accoya acetylated timber. These criteria include:

[2] ISO 15686:8 page 15
[3] ISO 15686:8 page 13

- Window design elements such as rounded edges, water shedding angles on cills and beads, and joint and end grain sealing
- The application of flexible, micro-porous protective paint

Design improvements and associated standards are listed in Table 2.2

Table 2.2 Service Life Factors for timber frame windows

Category	Influencing Factor	Associated Standard
Stable substrate	Timber acetylation	BS EN 942
Beads	Rounded edges Capillary gaps Fully coated Drained rebates	BS EN 644
Joints and Cills	Filled construction joints Exposed end grain sealed Joints fully coated with D3/D4 adhesive	WWA Design Standards
Glazing	Drained and vented upstand Coated rebates and upstands Robust glazing beads	BS 8000
Coatings	Preservative treated Quality tested Full factory finish: 120µ dft minimum All surfaces coated	BS EN 599 BS 8417 BS EN 927
Installation/Maintenance	Controlled transport and site storage Qualified installers Manufacturer maintenance instructions	WWA Installation Standards
Environment	Waste recovery Water based coatings: VOC < 50g/l No heavy metal additives	ISO 14001
Shelter	Implementation of specific partial or full shelter measures can be envisaged at conservative factors of 1.05 and 1.10. Evidence for specific circumstances may also indicate that higher factors than these are required.	

This report also considers the influence of maintenance levels on the design life and durability of Accoya acetylated window frames. Various maintenance cycles are analysed. The influence of location is considered for three scenarios; ***mild***, representing sheltered or part-sheltered positions at non-coastal, low altitude locations; ***moderate***, representing sheltered positions in harsh or extreme locations, or part-sheltered positions in harsh locations; and ***severe***, reflecting part-sheltered or exposed positions in more exposed rural locations which may experience wind-driven rain or salt conditions.

Figure 2.2 relates these scenarios, and their associated maintenance frequencies, to the durability matrix described in BS EN 927-1: Paints and Varnishes - Coating Materials and Coating Systems for Exterior Wood - Part 1: Classification and Selection

WINDOW EXPOSURE

CONSTRUCTION	***Moderate: typically non-coastal areas at low altitude***	***Harsh: exposed inland locations and areas within 0.5 miles of the coast***	***Extreme: areas of high altitude and exposed coastal sites***
Sheltered e.g. beneath porch or large roof overhang	8 years for timber 12 for Accoya 30 for Alu-clad timber	7 years for timber 9 for Accoya 30 for Alu-clad timber	7 years for timber 9 for Accoya 30 for Alu-clad timber
Partly sheltered, e.g. window built back in reveal.	8 years for timber 12 for Accoya 30 for Accoya	6 years for timber 9 for Accoya 30 for Accoya	5 years for timber 7 for Accoya 20 for Alu-clad timber
Not Sheltered, e.g. face of building	7 years for timber 10 for Accoya 30 for Alu-clad timber	5 years for timber 7 for Accoya 20 for Alu-clad timber	4 years for timber 6 for Accoya 20 for Alu-clad timber

Key:

(light shading)	**Mild**
(medium shading)	**Moderate**
(dark shading)	**Severe**

Figure 2.2 Maintenance frequency for factory finished joinery [BS EN 927-1]

Using ISO 15686-8 methodology, and based upon a service life estimate from the Building Research Establishment of 60 years, factors greater than 1.00 can be applied to account for the above design improvements. Factors can be made cumulatively, but care must be taken to exclude double counting.

A working spread sheet accompanies this report, but a summary of the factors used in calculation are given in Table 2.3.

Table 2.3 ISO 15686-8 Factors applied

Factor Category (see Table 2.1)	**Description**	**Justification**	**Factor Applied**
A	Endgrain sealing Construction joint sealing Modified bottom beads BS EN 644	A review of literature in section 1.0 reveals the likely impact of water absorption/ adsorption and moisture uptake is around 25% of non-acetylated timber. A previous report by Menzies [2013] and based on work by Murphy [20**] reports a factor of 1.3 for preservative treated timber.	1.0078
B	Cill extension < 70mm Min 7° angle on horizontal surfaces rounded arrisses: min 3mm round installed in recess	A review of literature in section 1.0 reveals the likely impact of water absorption/ adsorption and moisture uptake is around 25% of non-acetylated timber. A previous report by Menzies [2013] and based on work by Murphy [20**] reports a factor of 1.5 for preservative treated timber.	1.013
C	Factory glazed BS 8000 Factory coated: min 120µ dft BS EN 927 Quality Standard: ISO 9001 or equivalent	This factor remains unchanged. It is independent of frame material choice.	1.033
E	Sheltered	These factors remain unchanged	1.05
	Exposed		0.95
	Severe		0.90
G	Annual wipe-down/wash	These factors remain unchanged	1.05
	Redecorate 10 to 12 years		1.10

Applying the factors given in Table 2.3, using the descriptions of construction and exposure in Figure 2.2, and applying a Reference Service Life of 60 years, the cumulative effect on Estimated Service Life (ESL) is calculated as follows:

ESL (years) = RSL (years) * ∑A factors * ∑B factors * ∑C factors * ∑E factors * ∑G factors

The resulting ESL for mild, moderate and severe scenarios is shown in Table 2.4.

Table 2.4: Summary of Service Life Planning ISO 15686-8 analysis (cumulative for factors A, B, C, E, G described in Table 2.1)

Window type	Typical Maintenance Period	Mild	Moderate	Severe
Accoya	Standard 10-12 years	**90**	**82**	**77**
Timber*	Standard 5-7 years	**65**	**59**	**56**
Aluminium-clad* Timber	Standard 20-30 years	**83**	**75**	**71**
PVC-U*	Annual wash down only	**35**	**30**	**25**

* From Menzies [2012]

3.0 Conclusions

This report considers the Service Life Planning (SLP) of Accoya timber window frames. Applying a factor analysis, as set out in ISO 15686:8, predicts an Estimated Service Life (ESL) for Accoya timber windows of between 77 and 90 years, with the range representing exposure conditions from severe to mild. This ESL far exceeds that of PVC-U windows which have an ESL maximum of 35 years in mild exposures, whilst placin Accoya timber window frames in a similar performance category to aluminium-clad timber (perhaps exceeding the ESL by 6-7 years for each exposure category). The maintenance actions for these two window frame materials are however radically different. Accoya timber frames require a rub down and repaint on a 10-12 year basis, while aluminium-clad timber frames are assumed to have a new aluminium profile every 20-30 years. The Life Cycle Global Warming Potential comparison of these can be found in Menzies [2013]. This report shows that Accoya Timber frames, maintained within the recommendations set out here, have an ESL which is 21 to 25 years longer than preservative treated timber. The Reference Service Life (RSL) adopted for this analysis was derived from communication with the Building Research Establishment (BRE) and TRADA to be 60 years.

The factors applied represent the latest developments and innovations to window design, materials specification, window maintenance, location and installation.

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