BRITISH STANDARD

BS ISO 15686-8:2008

Buildings and constructed assets — Service-life planning

Part 8: Reference service life and service-life estimation

ICS 91.040.01

British Standards

National foreword

This British Standard is the UK implementation of ISO 15686-8:2008.

The UK participation in its preparation was entrusted to Technical Committee B/500, Basic data.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Part 8: Reference service life and service-life estimation

Bâtiments et biens immobiliers construits — Prévision de la durée de vie —

Partie 8: Durée de vie documentée et estimation de la durée de vie

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15686-8 was prepared by Technical Committee ISO/TC 59, *Building construction*, Subcommittee SC 14, *Design life*.

ISO 15686 consists of the following parts, under the general title *Buildings and constructed assets — Service-life planning*:

- *Part 1: General principles*
- *Part 2: Service life prediction procedures*
- *Part 3: Performance audits and reviews*
- *Part 5: Life-cycle costing*
- *Part 6: Procedures for considering environmental impacts*
- *Part 7: Performance evaluation for feedback of service-life data from practice*
- *Part 8: Reference service life and service-life estimation*

The following parts are in preparation:

- *Part 9: Guidance on assessment of service-life data*
- *Part 10: Levels of functional requirements and levels of serviceability — Principles, measurement and use*

Introduction

Typically, a person working with service-life planning of a design object is faced with the problem of estimating the service life of its components. Even if there are certain reference service life (RSL) data of a component available from various actual sources, such RSL data, as found, can rarely be used satisfactorily. This is because the in-use conditions specific to the design object usually are different from the reference in-use conditions, i.e. the in-use conditions under which the RSL data are valid.

Accordingly, in order to determine an appropriate estimated service life (ESL), it is necessary to modify the RSL by taking into account the differences between the object-specific in-use conditions and the reference in-use conditions. The factor method described in this part of ISO 15686 provides one systematic way of carrying out such a modification. It is necessary that any possible alternative method of determining the ESL from the RSL also be based on similar information on in-use conditions.

When applying the factor method, basically an ESL is estimated by multiplying an RSL value by a modifying number representing a combination of factor categories, each of which reflects a particular difference between the object-specific and reference in-use conditions. Several strategies at various levels of sophistication to determine this modifying number are described herein.

Beyond the knowledge of the RSL itself, it is necessary to have available detailed information of the reference in-use conditions as well as the object-specific in-use conditions in order to apply the factor method and allow an estimation of the modification. It is necessary that the reference in-use conditions be provided together with the RSL, while the object-specific in-use conditions are determined from the knowledge of the design object and the location of the site.

An RSL and the appurtenant reference in-use conditions, together with additional required or useful information concerning the RSL, form a set of RSL data. It is necessary that a set of RSL data be formatted into an RSL data record.

This part of ISO 15686 provides guidance on RSL issues and a means of determining the ESL through application of the factor method. The guidance for reference service life is structured into discussions regarding

— provision of RSL data utilizing existing general data (see 5.2);

— selection of RSL data or general data (see 5.3);

— formatting of general data into RSL data records (see 5.4).

Manufacturers of building and construction products are usually in possession of considerable knowledge concerning the service life and durability of their products. However, such information is only occasionally made public, typically in product declarations, other documents, company websites and/or databases. Use of this part of ISO 15686 is expected to motivate manufacturers to compile their knowledge and provide service-life data following the guidelines and requirements stated.

Buildings and constructed assets — Service-life planning —

Part 8:
Reference service life and service-life estimation

1 Scope

This part of ISO 15686 provides guidance on the provision, selection and formatting of reference service-life data and on the application of these data for the purposes of calculating estimated service life using the factor method.

This part of ISO 15686 does not give guidance on how to estimate the modification part or the values of factors A to G, using given reference in-use conditions and the object-specific in-use conditions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6707-1, *Building and civil engineering — Vocabulary — Part 1: General terms*

ISO 15686-1:2000, *Buildings and constructed assets — Service life planning — Part 1: General principles*

ISO 15686-2:2001, *Buildings and constructed assets — Service life planning — Part 2: Service-life prediction procedures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6707-1, ISO 15686-1 and ISO 15686-2 and the following apply.

3.1
data record
set of **reference service-life data** (3.8) compiled into a prescribed format

3.2
factor category
category of **in-use conditions** (3.5) that are considered in the determination of an ESL from an RSL

EXAMPLE 1 Inherent performance level, design level, work execution level, indoor environment, outdoor environment, usage conditions and maintenance level

EXAMPLE 2 In-use conditions, such as temperature and moisture level, can be considered under the factor category, outdoor environment, in determining factor E.

NOTE Factor categories are used in the factor method to determine the factors A to G, and can be applicable in a similar way in any feasible alternative method.

3.3
general data
data of any format related to service life, as opposed to **reference service-life data** (3.8)

3.4
degradation
process whereby an action on an item causes a deterioration of one or more properties

NOTE Properties affected may be, for example, physical, mechanical or electrical.

3.5
in-use condition
any circumstance that can impact the performance of a building or a constructed asset, or a part thereof under normal use

NOTE In order to encompass all of the seven factors and their related **factor categories** (3.2), this definition is an extended version of the definition given in ISO 15686-2:2001, 3.3.5 (thus being in accordance with ISO 15686-1:2000, 3.1.2, where "in-use condition" is referred to as influencing any of the seven factors of the factor method).

3.6
in-use condition grading
act of applying collective judgment of all qualitative information of an **in-use condition** (3.5) within a **factor category** (3.2)

3.7
in-use condition grade
designation representing a qualitative description of an **in-use condition** (3.5)

NOTE 1 An in-use condition grade is the outcome of the **in-use condition grading** (3.6).

NOTE 2 In-use condition grades are designated qualitatively in terms of not available, very high/very mild, high/mild, normal, low/severe, very low/very severe and not applicable.

NOTE 3 In-use condition grades are designated numerically using numbers in the range from 0 to 5, with 3 representing a "normal" condition.

3.8
reference service-life data
RSL data
information that includes the reference service life and any qualitative or quantitative data describing the validity of the reference service life

EXAMPLE Typical data describing the validity of the RSL include the description of the component for which they apply, the **reference in-use condition(s)** (3.9) under which they apply, and their quality.

NOTE 1 The RSL data are reported in a **data record** (3.1).

NOTE 2 "Service life" and "reference service life" will be defined in the future ISO 15686-9.

3.9
reference in-use condition
in-use condition (3.5) under which the **RSL data** (3.8) are valid

NOTE The reference in-use conditions can be based upon information gathered through testing or from recorded performance and actual service-life data of a component.

3.10
usage condition
factor category (3.2) of **in-use conditions** (3.5) that considers the influence on performance due to the use of a building/constructed asset or any human activity adjacent to a building/constructed asset

NOTE In this part of ISO 15686, the **factor category** (3.2) relating to factor F is designated “usage conditions” rather than “in-use condition” as used elsewhere in order to distinguish the factor category from the concept “in-use condition”.

4 Abbreviated terms

DL design life

ESL estimated service life

RSL reference service life

UV ultra-violet

5 Reference service-life

5.1 Reference service-life data

It is generally necessary to determine an ESL for a design object by modifying some form of RSL applicable to such a design object. Since the RSL is normally generated under conditions different from the in-use conditions to which the design object is subjected, i.e. the object-specific in-use conditions, it is essential to provide as much information as possible on the conditions under which the RSL is generated. Therefore, jointly with the RSL, the reference in-use conditions should, as far as possible, be included when providing RSL data.

NOTE 1 The discussion on factor categories provides guidance on where and when information of in-use conditions should be provided.

RSL data are formatted into an RSL data record that contains the RSL value and the appurtenant reference in-use conditions as well as additional information on critical properties, performance requirements and data quality.

NOTE 2 RSL data does not include the actual values of the factors A to G but the information needed to estimate these factors.

Currently, there is a limited number of systematic studies on service-life prediction and there is an urgent need for data. For the provision of RSL data, the capturing of existing general data of any kind is acceptable.

For the generation of new data, the methodology as described in ISO 15686-2 should be used.

5.2 Provision of reference service-life data

5.2.1 General

It is intended that 5.2 assist providers of RSL data in

a) finding sources of existing general data;

b) assessing such data in terms of RSL data.

The discussion on provision of RSL data is intended for the various providers of data, such as

— manufacturers of building and construction products;

— test laboratories;

— national assessment bodies and technical approval organizations;

— database holders;

— other data providers.

The discussion on formatting general data as RSL data provides guidance to the providers of data on how to structure and format general data into RSL data. The process of providing RSL data is outlined in Figure 1.

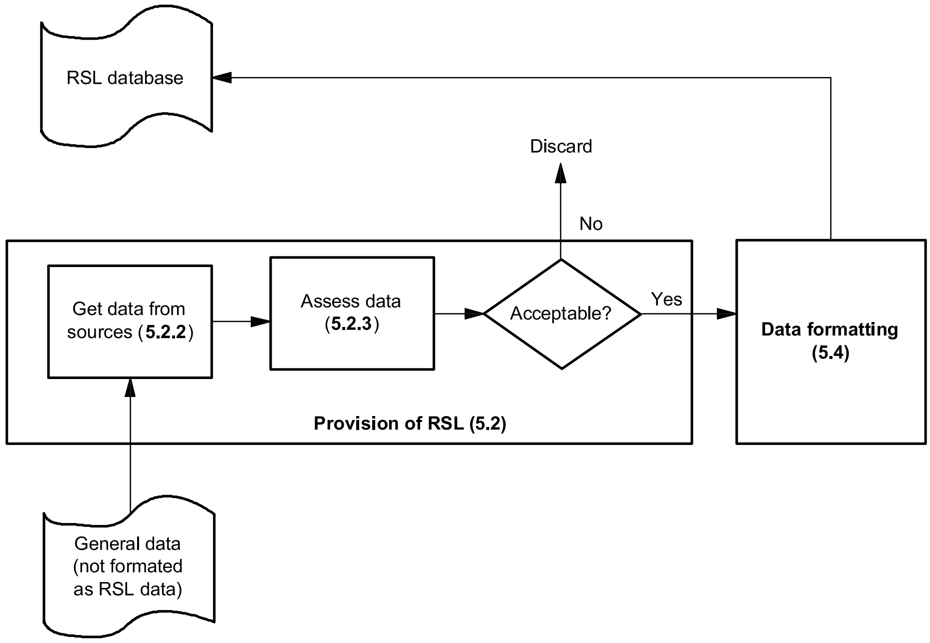


Figure 1 — The process of providing RSL data

5.2.2 Data sources

Manufacturers of building and construction products can have in-house information concerning the service life and durability of their products. Occasionally, manufacturers' data are made public in a product's declarations, other documents, company websites and/or databases.

Several other possible sources of data should be employed. National building codes can list typical service lives of components, and boards of agreement and technical approval bodies in governing states can provide assessments of service lives in their certificates or reports of national product evaluation services. Other sources of information are databases, published tables based on empirical time-to-failure assessments and judgements of experienced professionals. More scattered empirical knowledge from previous experience and observations of similar constructions or materials in similar in-use conditions should also be used.

NOTE The vast amount of existing data of scattered quality constitutes an important source of information, especially if data generated based on ISO 15686-2 are not available.

5.2.3 Data evaluation

RSL data should contain at least a general description of the material or component and data on service life, in an indicated outdoor (or indoor) environment, and should preferably encompass all relevant information concerning the generation of the service-life data. The following types of data are of particular importance:

— in-use conditions structured according to all corresponding factor categories;

— critical properties;

— performance requirements.

This set of data should form part of an RSL data record.

NOTE For instructions and details on how to structure and format general data into an RSL data record, see 5.4.

5.3 Selection of data

5.3.1 General

It is intended that 5.3 assist users of RSL data in

a) finding service-life data;

b) assessing the appropriateness of using these data as RSL data.

The discussion on selection of data is intended for the various users of data, such as

— clients;

— owners and developers;

— professional advisors;

— constructors, suppliers;

— assessors and underwriters;

— managers of existing constructed assets;

— other users of such data.

The discussion on formatting general data as RSL data provides guidance to the users of data on how to interpret selected RSL data. The process of selecting RSL data is outlined in Figure 2.

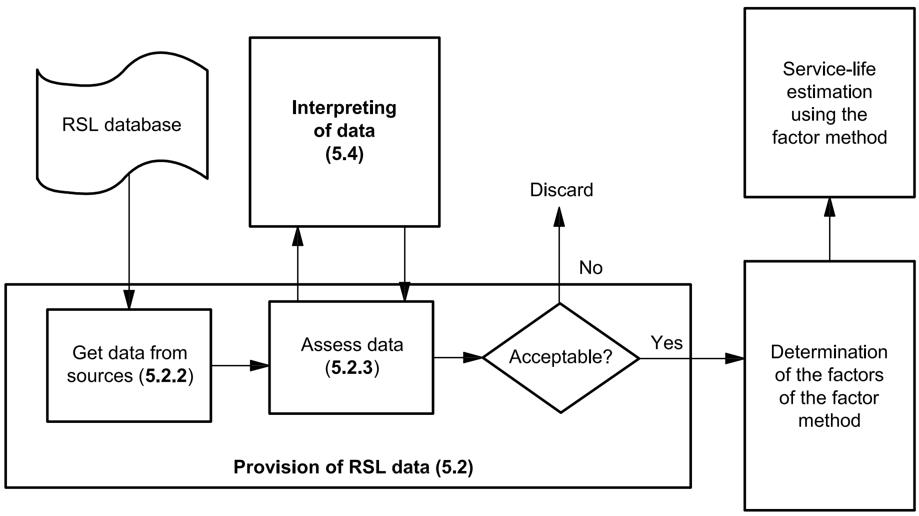


Figure 2 — Process of selecting RSL data

As an alternative to selecting RSL data, users of data may select general data, in which case the data are then structured and formatted as RSL data. Discussions on formatting general data as RSL data provide guidance to users of data on how to carry this out. The process of selection of general data is outlined in Figure 3.

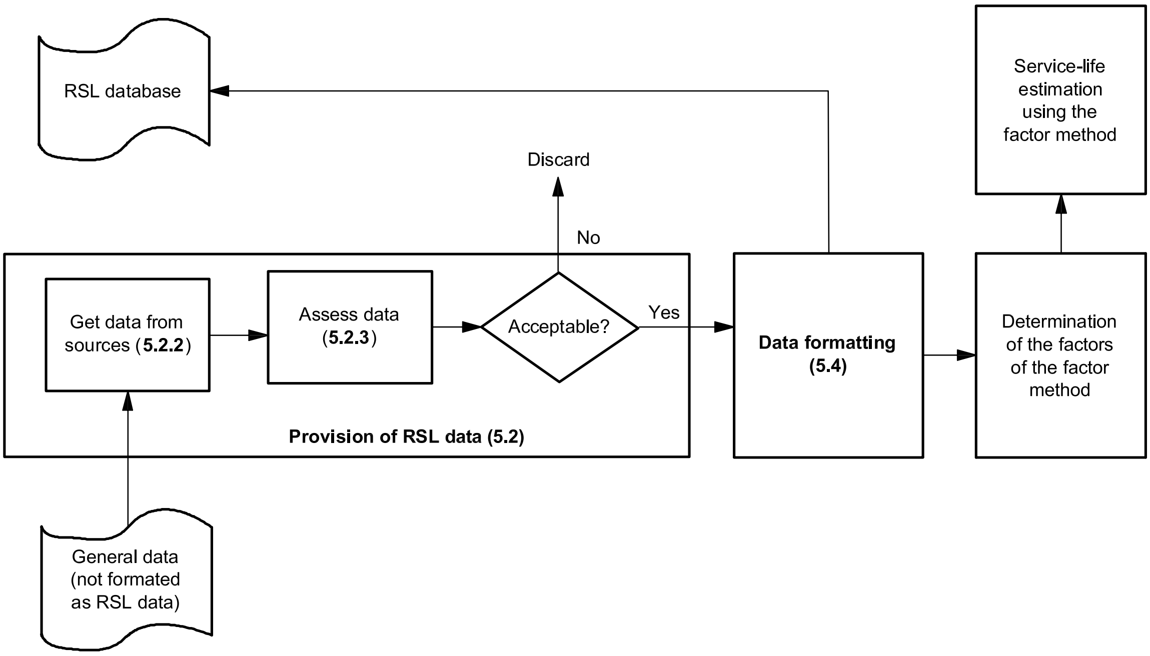


Figure 3 — Process of selecting general data

The normal route of selecting data is expected to become selection of RSL data, in which case the process of Figure 2 is appropriate. However, it is necessary initially for many users of data to resort to general data as the only available source of information, in which case the process of Figure 3 is required.

5.3.2 Data sources

Databases providing RSL data records have the advantage that the data are given in a format ready for that purpose.

NOTE 1 For instructions on how to interpret RSL data records, see 5.4.

NOTE 2 The availability of databases providing RSL data records will be limited in the initial phase following publication of this part of ISO 15686. It is expected that such databases will become more extensively established as general use of this part of ISO 15686 becomes more widespread.

This does not imply that RSL data records should always be selected even if available. When general data on service life, other than RSL data records, are of higher quality or more appropriate for the object-specific in-use conditions, these should be used.

NOTE 3 Possible sources of general data on service life are indicated in 5.2.2.

5.3.3 Data evaluation

5.3.3.1 General

If the data found are not given as RSL data records, data should first be assessed in accordance with 5.2.3.

It should be ensured that data are appropriate to use for the object of the service-life planning process. Caution should be taken where the critical properties deemed to degrade in the object-specific in-use conditions are not all encompassed by data. This can result in a critical property being excluded, which can then possibly become the terminal critical property. For a building element, data on the weakest part is sufficient when this can be identified, e.g. from experience.

5.3.3.2 Rejection of data

Data should be rejected when

- the degradation agents that are deemed to be significant for the expected degradation process(es) are not all encompassed,
- any one of the degradation agents excluded is known or believed to be a part of the object-specific in-use conditions,
- the performance requirement(s) assumed differ(s) significantly from that specified for the object and the RSL cannot be modified accurately enough in accordance with these difference(s).

5.3.3.3 Similarity of in-use conditions

Data based on reference in-use conditions similar to the object-specific in-use conditions should always be sought. Such data

- keep the modifying factors as close to unity as possible, thus minimizing the probability of error in the ESL due to uncertainty in the way mechanisms of degradation are taken into account by the modifications;
- minimize the probability that a critical property not encompassed by data becomes the terminal critical property.

To judge which reference in-use conditions are most similar to, or deviate the least from, the object-specific in-use conditions, consideration should be given only to the in-use conditions or degradation agents known to, or believed to, have the greatest impact on the service life.

5.3.3.4 Consideration of data quality

For the final choice of data, the data quality should be considered. A higher-quality grade of data can justify the use of such data, even though it might have been generated at more deviating in-use conditions.

5.3.3.5 Form of data

If the data selected are not given as RSL data records, such formatting should be carried out in accordance with 5.4. The purpose of this is threefold.

a) Having all the RSL data in the same format facilitates the systematic work of the service-life planning, particularly when it comes to comparison with alternative data.

b) A common data format facilitates the structuring of the documentation of the service-life planning, and assists when possible future revisions occur.

c) The reporting of data used in the form of RSL data records prepares the basis to create or expand individual and third-party databases of RSL data.

5.4 Formatting general data as reference service-life data

5.4.1 General

It is intended that 5.4 assist

- providers of general data in the structuring and formatting of data into an RSL data record,
- users of RSL data in reading formatted data,
- users of data on how to structure and format selected general data into an RSL data record.

RSL data are comprised of service-life data and reference in-use conditions, as well as corresponding data on critical properties and performance requirements, of which all available data should be recorded. For each individual in-use condition listed, the factor and related factor category it belongs to should also be indicated. Statements indicating the data quality should be included.

EXAMPLE 1 "RSL data have been generated on the basis of a systematic study."

EXAMPLE 2 "Data are critically reviewed by a third party."

5.4.2 Reference in-use conditions

5.4.2.1 General

A quantitative description of the reference in-use conditions in terms of the individual factor categories described in Annex A should be given.

Regarding the factor categories "indoor environment" and "outdoor environment", the reference in-use conditions for whichever factor category is applicable, or both, should be quantified in terms of agent intensities, thereby characterizing the reference in-use conditions of the environment(s) that can cause degradation. Alternatively, for discrete values, ranges of such agent intensities or standardized classes corresponding to certain ranges of agent intensities are accepted and may be directly applied.

NOTE References are given in the Bibliography on information related to systems for classification of exposure environments for families of materials in terms of corrosivity, i.e. ISO 9223, which classifies time of wetness, SO_2 and chloride, ISO 12944-2 and ISO/DIS 11844 (all parts).

Quantitative information provided by the source should be used, where available, for the reference in-use conditions corresponding to each of the factor categories for factors A, B, C, F and G, respectively.

EXAMPLE If possible, for the factor category "inherent performance level," a detailed description of the material or component should be given, such as mild sheet steel, hot-dipped zinc-coated to 600 g/m^2.

NOTE This is different from the level of detail suggested for the general description to be given in entry a) of the RSL data record, see 5.4.4.1).

5.4.2.2 Grading of in-use conditions of factor categories for factors A, B, C, F and G

When, and only when, quantitative information is lacking for the in-use conditions within a factor category relating to any of the factors A, B, C, F or G, a qualitative grading of the in-use conditions within that factor category should be made. Any qualitative information provided should be valued and interpreted to correspond to one of the in-use condition grades, 1 to 5, in accordance with Table 1. If no quantitative or qualitative information is available, this is indicated by the grade 0. If a factor category is not applicable, it is indicated by NA.

Table 1 — Grades, descriptions and guidelines for grading in-use conditions of factor categories related to factors A, B, C, F and G

In-use condition grade	Description (level/effect)	Guideline
0	not available	Should never be applied for the factor category “inherent performance level”
1	very high/very mild	
2	high/mild	
3	normal	
4	low/severe	
5	very low/very	
NA	not applicable	Should not normally be applied. A case where it may be appropriate to designate the grade as ‘NA’ is under the factor category “maintenance level,” when dealing with a structural element for which maintenance is not possible.

NOTE In-use condition grading is a means to quantify qualitative (or fuzzy) information of reference in-use conditions. An in-use condition grade is not the same as, and it is necessary not to confuse it with, the value of the corresponding factor; it is information required to estimate this factor.

If no quantitative data are provided by the source, when using the general information of the material or component tested, it should always be possible to quantify the in-use condition(s) corresponding to the factor category “inherent performance level” into one of the in-use condition grades, 1 to 5.

5.4.3 Units

Values related to the service lives, reference service lives, etc., should be expressed in a period of years, whether they consist of discrete values, such as mean values and standard deviations, or full distributions. For the description of the in-use condition(s), where applicable, the International System of units (SI) should be used. Symbols for quantities should be chosen, wherever possible, in accordance with the various parts of ISO 31 (all parts).

NOTE For further guidance on application, see ISO 1000.

5.4.4 Data record

5.4.4.1 Data record entries

A data record for the RSL should include the following entries, along with relevant information, as noted:

NOTE An example of an RSL data record is provided in Annex B.

a) general information (information to help identify the record), including

- a unique number or code referring to the database or filing system utilized for record-keeping,
- the date of evaluation or compilation,
- the assessor’s name(s) and qualification(s);

b) scope (information providing a general overview of the assessment, including any exclusions, and for whom and for what purpose the assessment was commissioned);

c) material/component (information providing a general description of the material or component);

EXAMPLE Hot-dipped, zinc-coated sheet steel.

d) methodology (information detailing which of the following methodologies has been mainly used to predict or estimate the service life. If more than one methodology has been used, this should be declared):

- fundamental studies,
- field exposure,
- inspection of buildings and constructed assets (feedback from practice),
- exposure in experimental buildings,
- in-use exposure,
- accelerated short-term exposure,
- short-term in-use exposure;,
- judgement based on expert experience (e.g. by means of the Delphi method),
- judgement based on experience on the market (i.e. among manufacturers, designers, constructors, clients),
- other (should be specified),
- unknown;

e) reference in-use conditions (information for each set of reference in-use conditions providing a quantitative description of the reference in-use conditions in terms of the factors and related factor categories) as follows:

- for factors A, B, C, F and G, single quantitative or qualitative figures may be given (e.g. in-use condition grades),
- for factors D and E:
  - numerical expressions describing RSL as a function of the agent intensities of significant degradation agents included (i.e. so called damage functions),
  - agent intensities of significant degradation agents included,
  - a simplified description such as a climatic zone, a specific site or area, etc.;

f) degradation agents: information stating that the degradation agents that are included

- are all of the agents that are expected to be of significance,
- are all of the agents that are expected to be of significance with a list of exceptions, if applicable,
- might not be all of the agents that are expected to be of significance;

g) critical properties and performance requirements: information listing the critical properties encompassed, including the assumed performance requirements, and a statement that the listed properties that are included

- are all expected to be critical in the reference in-use conditions,
- are all expected to be critical in the reference in-use conditions with a list of exceptions, if applicable,
- might not be all the properties expected to be critical in the reference in-use conditions;

h) reference service life: information for each set of reference in-use conditions and each critical property encompassed stating the mean value of the RSL and, if possible,

— its statistical distribution,

— a measure of its statistical distribution, e.g. the standard deviation or a confidence interval;

i) data quality: information regarding the data quality stating that data are generated on the basis of:

— a systematic procedure and a critical review by a third party,

— a systematic procedure but no critical review by a third party,

— scattered information and a critical review by a third party,

— scattered information but no critical review by a third party;

j) reliability of data: information regarding the reliability of the data source and that data are provided by

— an independent source of high reliability, such as an accredited testing laboratory, a national building code, a board of agreement, a technical assessment body or reviewed public research documentation,

— a non-independent source, such as a manufacturer or a business organization, while being subject to audit by an accredited body,

— an independent source of moderate reliability, such as non-reviewed, public research documentation,

— a non-independent source, such as a manufacturer or a business organization, not being subject to audit by an accredited body;

k) additional information considered: information providing a schedule of detailed annexes/evidence considered, which may include product literature, copies of testing protocols, photographs, drawings, etc.;

l) references such as information sources, where applicable/available.

5.4.4.2 Detailed issues/notes

Whenever necessary to clarify data or statements, comments should be given in direct connection with the various entries. In particular, issues related to the quality of data, such as obvious deviation from an ideal set of data or shortcomings, should be identified.

6 Service-life estimation using the factor method

6.1 General

Guidance on service-life estimation in general is provided in ISO 15686-1. One specific tool that can be used in service-life estimation is the factor method, while the application of other possible methods should also be generally acceptable as long as they provide reliable estimations.

NOTE 1 The factor method originates from work carried out in Japan, details of which are published by the Architectural Institute of Japan [7].

The factor method is used to obtain an ESL of a component of a design object by modifying an RSL by considering the differences between the object-specific and the reference in-use conditions under which the RSL is valid. The differences are classified into seven factor categories.

NOTE 2 The factor method is a way of bringing together consideration of agents or conditions that are likely to affect service life. The method enables a systematic assessment when reference in-use conditions do not fully match the anticipated in-use conditions, which is normally the case. Its use can bring together the experience of designers, observations, intentions of managers, and manufacturers' assurances, as well as data from test houses.

NOTE 3 This part of ISO 15686 does not give guidance on how to estimate the modification part or the values of factors A to G, using given reference in-use conditions and the object-specific in-use conditions.

6.2 Factors and factor categories

For a description of the factors and the factor categories, refer to Annex A

Any factor category that by its nature, or due to a small difference between the object-specific and the reference in-use condition, is safely assumed to have a negligible influence on the service life, i.e. does not jeopardize the final accuracy required, may be omitted in the further estimation.

6.3 Application of the factor method

Not all components require estimates based on the factor method, and the project team and the building/constructed asset owner should agree on which components will be assessed based on their criticality to the use and cost of the building/constructed asset.

Particular consideration should be given where two or more agents interact (or counteract) to produce an effect greater or smaller than the sum of their individual effects.

EXAMPLE Plastic rainwater drainage pipes can be subject to UV degradation and physical impacts during maintenance access. While these two hazards might not be enough individually to cause any damage, a combination of both of them can result in a higher possibility of breakage. However, the presence of sheltering overhanging elements and use of paint as a protective coating can reduce this risk.

The factor method can be applied to both components and assemblies. When applied to assemblies, the interfaces (e.g. joints) between components as well as the components themselves should be considered.

The information taken into account should be recorded, so that it is clear whether the estimate is particularly robust or not.

NOTE For further general remarks on the factor method, see Annex E.

6.4 Levels of application

6.4.1 General

The factor method can be applied at different levels of sophistication, from working as a simple checklist to complex calculations. The level should be selected taking into account factors such as the actual purpose of the estimation, type and quality of available data and models, skill level and type of expertise of the user(s) making the estimation and resources and time available for the calculation.

6.4.2 Checklist level

At this level, a step-by-step procedure should be carried out, in which the difference between the object-specific and the reference in-use condition within each factor category (see Table A.1) is considered and estimated separately in consecutive steps.

Using experience, in combination with consideration of the overall set of differences between the object-specific and reference in-use conditions and their influence on the RSL, an estimation of the ESL should be made.

EXAMPLE An RSL of 20 ± 3 years is estimated to be changed by a factor of $1{,}3 \pm 0{,}15$, i.e., the ESL becomes 26 ± 5 years (for guidance on the calculation of the confidence interval of ± 5 years, see Example 2 in 6.6.2).

NOTE While the checklist level represents the lowest level of sophistication, generally this level requires the highest skill or experience of the user in order to obtain a reliable result to ensure that all aspects influencing the service life are considered.

6.4.3 Multiplication level

On this level, the estimation of the ESL should be carried out by multiplying the value of RSL by numerical factors A to G designated ϕ_A, ϕ_B,…. ϕ_G, each of which reflect the relative dependence on the service life of the difference between the object-specific and the reference in-use condition within a respective factor category as given in Equation (1) (refer to Annex C):

$$t_{ESL} = t_{RSL} \times \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \times \phi_F \times \phi_G \qquad (1)$$

Theoretically, a numerical factor can have a value between 0 and infinity, but should realistically have values close to unity. Preferably, all factor values should be in the interval of 0,8 to 1,2. More preferably, all factor values should be in the interval of 0,9 to 1,1.

NOTE 1 A factor value of less than 1 has a reducing effect on the value of the ESL and a factor value of more than 1 has an increasing effect.

NOTE 2 For any factor category, a factor value of 1 is obtained if, in this category, there is no dependence of the in-use condition on the service life, or there is no difference between the object-specific and the reference in-use condition.

NOTE 3 The factor values ϕ_A, ϕ_B,…. ϕ_G are up to the user to set or find. The user can set factor values from their experience, in which case the multiplication level can be regarded as a refined checklist level. Factor values are often based on known actions of the environment on specific materials (e.g. increased corrosion in salt atmospheres), or on known effects of poor workmanship and maintenance. Alternatively, the user can find documented factor values or, more likely, data enabling the calculation of factor values. When several sources of information are found, weighing and/or interpolation/extrapolation techniques can be useful. Possible sources of information are manufacturers, results of testing, feedback from practice through condition assessment, and modelling. Other possible sources are expert panels according to the Delphi method and knowledge compilations like failure mode and effects analysis (FMEA) studies.

NOTE 4 One reason for this is that the factor method, in general, is imparted with a substantial uncertainty. Using the multiplication level, it can be assumed that each factor partly contributes to the relative level of uncertainty by an increasing amount as the deviation of the factor value from unity increases (in fact by an amount proportional to the absolute value of the logarithm of the factor value). Another reason is that effects determining the factor values are often dependent upon each other. The relative importance of this interdependence increases with increasing deviation of the factor value from unity.

NOTE 5 In order for the factor values to become close to unity, it is necessary to find an RSL for which the reference in-use conditions of importance to the service life are sufficiently close to the object-specific conditions.

NOTE 6 Striving for reference in-use conditions that are close to the object-specific conditions has to be balanced against the quality and uncertainty of an RSL. For example, an RSL for which the reference in-use conditions deviate more from the object-specific conditions when compared to another RSL, can still be preferred because of the much lower uncertainty of the former.

NOTE 7 Larger deviations from unity are possible to accommodate the case where all factors but one are 1, or if just a few factors deviate from unity and can be assumed independent from each other.

If it is necessary for the factor values to represent larger differences between the reference and the object-specific in-use conditions, the user should first verify that no other RSL representing reference in-use conditions that are closer to the specific in-use conditions can be made available.

EXAMPLE 1 If the RSL of a window in a sheltered position and subjected to normal maintenance is 20 years, a modifying factor ϕ_E of 0,8 can be used to estimate the window's service life in an exposed position, assuming normal maintenance. The ESL would then be 20 times 0,8, or 16 years. But if a particularly rigorous inspection and maintenance regime were applied to ensure that minor defects did not develop into more serious problems, then a further modifying factor ϕ_G of 1,4 can be applied. The ESL would then become 20 times 0,8 times 1,4, or 22 years.

EXAMPLE 2 If the service life of carpet in an entrance hall has been found to be 25 % less than the carpet in general circulation areas, then this observation can justify the application of a factor ϕ_D of 0,75, provided that the RSL applied is valid for general circulation areas.

6.4.4 Function level

In this case, the estimation of the ESL should be carried out by multiplying the value of RSL by an appropriate mathematical function, Φ ,of variables a, b,…. g, each of which reflects a dependence on the service life of the difference between the object-specific and the reference in-use condition within a respective factor category, as given by Equation (2):

$$t_{ESL} = t_{RSL} \times \Phi(a, b, c, d, e, f, g) \qquad (2)$$

NOTE 1 The function level is a generalization of the multiplication level, and the variables a, b,…. g are in turn a generalization of the numerical factors ϕ_A, ϕ_B,…. ϕ_G.

If it is assumed that there is no dependence or difference of the in-use condition within a particular factor category on the service life, the corresponding variable may be omitted. On the other hand, any of the variables a, b,…. g may be expanded into a subset of variables, as required.

EXAMPLE It is assumed that the in-use conditions of the factor categories represented by the variables b, d and f have no influence on the service life. Furthermore, the variable a is expanded into the subset a_1, a_2, a_3, and e is expanded into the subset e_1, e_2, which can be expressed as given in Equation (3):

$$t_{ESL} = t_{RSL} \times \Phi(a_1, a_2, a_3, c, e_1, e_2, g) \qquad (3)$$

NOTE 2 Usually, the function level is employed only in particular cases when a service-life model is available, based either on theory or a vast amount of data, for instance a damage function. In general, the variables are measurable, physical quantities.

Care should be taken not to stress the variables outside the valid range of a service life model employed. This implies that reference in-use conditions should be chosen that are close enough to the object-specific conditions.

6.4.5 Combined level

An ESL may be estimated by combining the multiplication and function level for groups of different factor categories, in which case the value of the RSL is multiplied by one or more functions and one or more factors.

6.5 Probability distributions

Any of the quantities in the set of t_{RSL}, ϕ_A, ϕ_B,…. ϕ_G, or in the set of t_{RSL}, a, b,…. g, together with the function Φ itself, may be applied in the form of a probability distribution or probability function, in which case the resulting quantity t_{ESL} also describes a probability distribution (see Clause D.2).

6.6 Format of estimated service life

6.6.1 Value of estimated service life

The ESL should be estimated as a single number of years. This number may be the mean service life or the service life at any particular significance level, α, whatever the underlying value of RSL stands for (see Clause D.1). Alternatively, the value of the ESL may be chosen as the time at any significance level of an ESL probability distribution.

NOTE 1 The significance level is the probability that the ESL, after all, is not reached.

NOTE 2 The significance level of 50 % is the median.

NOTE 3 The adapted significance level is normally between 0 % and 50 %.

NOTE 4 Usually, the median service life is equal or close to the mean service life.

6.6.2 Confidence of estimated service life

For each ESL value estimated, a confidence interval should be estimated as well.

EXAMPLE 1 An ESL equals 25 years ± 5 years, where ± 5 years is the confidence interval.

The estimation of the confidence interval should be based both on the confidence of data used for the estimation of the value of the ESL and on the estimated inherent uncertainty in the procedure of estimating this value. In the cases using the multiplication level or function level approaches, this should be determined by using confidence intervals for the variables or factors included.

EXAMPLE 2 At the multiplication level, an estimation is made as given by Equation (4):

$$t_{\mathrm{ESL}} = t_{\mathrm{RSL}} \times \phi_{\mathrm{E}} \times \phi_{\mathrm{G}} \tag{4}$$

while for the other factor categories, there is no dependence of the in-use condition on the service life. Estimating the confidence interval of t_{ESL}, ϕ_{E} and ϕ_{G} to Δt_{ESL}, $\Delta\phi_{\mathrm{E}}$ and $\Delta\phi_{\mathrm{G}}$, respectively, the confidence interval of t_{ESL} becomes as given by Equation (5):

$$\Delta t_{\mathrm{ESL}} = t_{\mathrm{ESL}} \times \sqrt{\left[\left(\Delta t_{\mathrm{RSL}} / t_{\mathrm{RSL}}\right)^2 + \left(\Delta\phi_{\mathrm{E}} / \phi_{\mathrm{E}}\right)^2 + \left(\Delta\phi_{\mathrm{F}} / \phi_{\mathrm{F}}\right)^2\right]} \tag{5}$$

NOTE The confidence of an estimate to actually be within a confidence interval is called confidence level. In general, the confidence level is chosen to be 95 % (corresponding to ± 2 standard deviations of a normal distribution).

Annex A
(normative)

Description of the factors and factor categories

A.1 Factors and factor categories

A.1.1 General

The seven factors and related factor categories are given in Table A.1.

Table A.1 — Factors and factor categories of the factor method

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.1.2 Factor A — Factor category: inherent performance level

Factor A and the related factor category, inherent performance level, represent the grade of the component as supplied.

EXAMPLE Specific durable softwood species, together with timber preservation, jointing and applied coatings for a softwood window lead to a very high inherent performance level.

A.1.3 Factor B — Factor category: design level

Factor B and the related factor category, design level, reflect the component’s installation in the building/constructed asset and is typically based on the level of shelter and protection from agents provided by the design of the building/constructed asset.

EXAMPLES An overhanging roof can provide extra protection to the wall below; a reflective coating can prevent cladding exposed to sunlight reaching a critically high temperature.

A.1.4 Factor C — Factor category: work execution level

Factor C and the related factor category, work execution level, consider the level of skill and control in sitework. It is based on whether the sitework is (or likely to be) in accordance with manufacturers' recommendations and tightly controlled, including issues such as storage, protection during installation, ease of installation, number of trades required for each activity, site applied coatings, etc.

A.1.5 Factor D — Factor category: indoor environment

Factor D and the related factor category, indoor environment, considers the exposure of the object to indoor agents of degradation and their severity. The general use of the building/constructed asset is taken into account, together with relevant local aspects (e.g. locations subject to wetting, such as kitchens and bathrooms).

NOTE 1 EOTA GD 003 [8] contains tables of both indoor and outdoor environments, together with degradation agents, which can be taken into account for various materials.

NOTE 2 Indoor and outdoor environments are separated and for most components only one such factor category applies; but certain components (e.g. those embedded in the building envelope) can be subject to degradation from both internal and external agents.

A.1.6 Factor E — Factor category: outdoor environment

Factor E and the related factor category, outdoor environment, consider the exposure to outdoor agents of degradation and their severity. A meso- or local-level designation can be adequate (e.g. coastal, polluted) for this factor category. However, for detailed design it can be necessary to take into account the microenvironment (e.g. southern elevation, wind suction or uplift at high-level, salt-spray zone). A combination of the agents can have a critical effect (e.g. a combination of wetting and freezing). Observe also that components can be exposed to both external weathering and below-ground water.

NOTE Indoor and outdoor environments are separated and for most components only one such factor category applies; but certain components (e.g. those embedded in the building envelope) can be subject to degradation from both internal and external agents.

A.1.7 Factor F — Factor category: usage conditions

Factor F and the related factor category, usage conditions, reflect the effect of the use of the building/constructed asset. The specific use of the space where the component is installed or the assembly constructed is likely to be relevant (e.g. communal areas are subject to greater wear and tear). Activities present outside (adjacent to) the building/constructed asset can also be relevant (e.g. delivery areas subject to mechanical impacts by vehicles).

A.1.8 Factor G — Factor category: maintenance level

Factor G and the related factor category, maintenance level, reflect the level of maintenance assumed. For certain components that are inaccessible or require special equipment for access, a particularly low maintenance level should be considered. The expertise of cleaning and the risk of the introduction of agents not normally found (e.g. alkalis) can also be taken into account.

Annex B
(informative)

Example of a reference service-life data record

Figure B.1 gives an example of an RSL data record for site-painted, hot-dipped, zinc-coated sheet steel to illustrate the outline and content of RSL data records. General reference is being made to 5.4.4, in particular to 5.4.4.1. After each entry in this example, notes are included to indicate why the particular information is included and/or how it should be used. In contrast to the “comments”, these “notes” do not belong in the data record itself.

Figure B.1 — Example of an RSL data record

a) General information

— 123456789;

— March, 1989;

— Nikolaj Tolstoy, Gösta Andersson, Vladimir Kucera and Christer Sjöström.

b) Scope

Data are based on an inventory of external building materials of buildings in Greater Stockholm, Sweden. Material quantities were assessed for different types of buildings, age classes, and areas of different concentrations of air pollution agents. Deterioration levels of roofs, facades and windows were estimated for different materials and surface finishes. The survey method of inspecting a statistical sample has been carefully reviewed.

The inventory is a part of Nordic project initiated by a joint governmental body of the Nordic countries with the aim of estimating reductions of corrosion damage as a consequence of reduced SO_2 emissions.

c) Material

Site-painted, hot-dipped, zinc-coated sheet steel

NOTE This information is needed to identify which type of material/component data is valid. These details facilitate the judgement as to whether data are reasonably applicable to the material/component under study, and make it possible to take care of any differences in material/component by adjusting the factor A of the factor method. Here, the description is not very specific because data are based on a broad survey accepting all types of paint.

d) Methodology

Inspection of buildings and constructed assets (feedback from practice)

NOTE Together with the information provided below under list item i), Data quality, and list item j), Reliability of data, this entry provides useful information to assess the credibility of the data record. Information relating to how the data have been produced can also be needed to understand the way data are presented.

e) Reference in-use conditions

Factor E — Factor category: outdoor environment

The outdoor environmental conditions refer to the local scale and are given by the conditions prevailing in Greater Stockholm in the mid-1980s. Service-life data are resolved into two geographical sub-areas, “Inner city” and “Outer areas,” as defined in Table B.1.

Table B.1 — Reference in-use conditions related to factor E for factor category “outdoor environment”

Sub-area	SO_2 concentration (winter average)
Inner city	$\geqslant 20$ µg/m^3
Outer areas	< 20 µg/m^3

COMMENT Correlation to concentrations of other degradation agents are likely to apply but are not reported.

Factor D — Factor category: indoor environment

Not applicable.

In-use condition grades for factors A, B, C, F and G are given in Table B.2.

Table B.2 — In-use conditions grades of factors A, B, C, F and G

Factor – factor category	In-use condition grade
A — inherent performance level	3
B — design level	3
C — work execution level	3
F — usage conditions	3
G — maintenance level	3
NOTE As the data are based on a survey study of buildings sampled by a random technique, on average the factors are all likely to be characterized as “normal”. In particular, for factor A, the inherent performance level, including the colour of the paint, is not specified.	

NOTE The reference in-use conditions given here are to be compared with the corresponding in-use conditions of the object under study. If the conditions deviate too much, the user of the data may choose not to use the data record, or otherwise to take the differences in in-use conditions into account by adjusting the corresponding factors of the factor method. Observe that, while being based on such a difference, it is up to the user of the data to calculate or judge the particular size of any adjustment. In this case, the only in-use condition that has been tracked is the outdoor environment in terms of SO_2 concentration, the average of other in-use conditions is assumed as normal.

f) Degradation agents

All of the degradation agents that are expected to be of significance are included.

NOTE On one hand, this entry is intended to give allowance to declare any limitation of degradation agents applied in an artificial ageing programme. On the other hand, for data based on natural ageing, degradation agents of importance to the material/component in general, while not being present in the climate type in question, are listed here. For example, salt exposure would be an extremely limited agent in a steel-corrosion study carried out in an area distant from the sea, which in turn would limit the use of data to non-saline conditions.

g) Critical properties and performance requirements

Critical properties and the corresponding performance requirements expressed in classes of certain standards are given in Table B.3.

Table B.3 — Performance requirements of critical properties

Critical property	Performance requirement	Reference
Blistering	> 6F	SIS 18 41 93
Cracking	> 4	SIS 18 41 95
Chalking	> 4	SIS 18 41 97
Flaking	> 4	ASTM D772-47

These properties are usually the ones that are expected to be critical, except for gloss, when particularly high aesthetic performance is required.

COMMENT RSL is determined from the failure to meet any of the four performance requirements.

NOTE This information is needed to enable the user of data to check if the critical properties and performance requirements of the data record and the case under study correspond. If the critical properties deviate, the use of the data becomes questionable; however, different performance requirements, i.e. levels of required performance, may be maintained by adjusting the service life.

h) Reference service life, RSL

RSL and the corresponding standard deviation, σ, expressed in years, are given in Table B.4.

Table B.4 — RSL and standard deviation

Inner city		Outer areas	
RSL years	σ years	RSL years	σ years
6,3	4,1	8,0	0,6

NOTE RSL constitutes the major data and the other entries of an RSL data record represent RSL metadata (data on RSL data).

i) Data quality

Data are generated on the basis of a systematic procedure but are not critically reviewed by a third party

NOTE The purpose of this entry is to facilitate a rough estimation of the data quality. If a more detailed estimation is desired, the user should be referred to original documents listed in References [10] to [15].

j) Reliability of data

Data are provided by non-reviewed, public research documentation

NOTE The purpose of this entry is to facilitate a rough estimation of data reliability. If a more detailed estimation is desired, the user should be referred to original documents listed in References [10] to [15].

k) NOTE Further information considered

Data obtained from the inventory according to list item b) were further processed by Tolstoy [11] from which document RSLs referenced here were retrieved.

NOTE See References [10] to [15] to enable the user of data to go back to original documents for any detailed information not included in an RSL data record. References are also a part of quality control.

Annex C
(informative)

Worked examples of service-life estimation using the factor method

C.1 General

Worked examples of two typical components are given in Clauses C.2 and C.3 to illustrate the use of the factor method at the multiplication level/refined checklist level. The examples demonstrate how various factors affecting component lives can be taken into account. The examples chosen deal with two different types of materials, i.e. timber and steel, and involve typical considerations that can be necessary for many different components. The calculations show in turn how typical, poor- and high-performance components are assessed. The examples generally include typical UK environments and assumptions. Generally, the standards referenced are the current British national standards (BS).

In the examples, simplified assumptions are made to set the factor values and the corresponding confidence intervals. In order to emphasize that there is no general principle for this purpose, different assumptions are used in the two examples, with the second being somewhat more complex. Despite the simplifications, the examples work satisfactorily to illustrate cumulative effects.

C.2 Example 1 — Pressed steel lintel

Example 1 concerns a pressed steel lintel. Possible in-use condition ranges of the various factor categories are listed in Table C.1.

Table C.1 — In-use condition ranges of the factor categories applicable to steel lintels

Aspect of interest	Factor	Factor category	To consider	In-use conditions		
				Poor	Normal	Good
Inherent quality characteristics	A	Inherent performance level	Material type and/or grade	Not to BS 5977	Mild steel sheet, pressed and welded as BS 5977	Stainless steel or heavy duty mild steel
			Durability features, e.g. protection system	Less than G275 galvanizing and BS 5977 paint/coating	Pre-galvanized (G275), and coated with BS 3416 bitumen or 25 µm BS 5493 HF paint or pre-galvanized (G600)	Post-galvanized to BS 729 (920 g/m^2 or 1 420 g/m^2)
	B	Design level	Details of construction, e.g. joints, fixings	Inadequate weatherproofing (joints not fully filled, inadequate cavity tray provision, no cladding over lightweight blocks)	Embedded in cavity wall with either brick outer skin or cladding over lightweight blocks; all joints fully filled	Additional DPC tray and/or bitumen coating provided during installation
	C	Work execution level	Site work, e.g. not to BS 8000, with specific examples	No repair to site alterations and/or damage	No repair of damage associated with storage or installation, but no site alterations	All site damage fully repaired
Environment	D	Indoor environment	Special features, e.g. condensation	Browning plaster to inner skin with condensation risk	Browning plaster to inner skin with no condensation risk	Sand/cement or browning or metal lathing plaster
	E	Outdoor environment	Special features, e.g. marine or polluted	Polluted industrial or marine environment	Urban, inland environment but not particularly polluted	Rural, inland and unpolluted environment
Operation conditions	F	Usage conditions	Special features, e.g. vandalism	Not applicable	Not applicable	Not applicable
	G	Maintenance level	Cyclical, including quality	Not applicable	Not applicable	Not applicable

The RSL is assumed to be 125 ± 25 years and apply for normal in-use conditions for steel lintels as given in Table C.1. That is, the reference in-use conditions are all considered normal. The object of concern is a typical lintel installed into a brick/block cavity wall in a UK industrial environment. In addition to the external environment, there is the risk of degradation internally caused by condensation.

In each factor category, a good in-use condition is assumed to increase the service life by a factor of 1,2 compared to a normal in-use condition, whereas a poor in-use condition is assumed to decrease the service life by a factor of 0,8 compared to a normal in-use condition. The confidence interval of each of the factors is assumed to be ± 10 % of the respective factor value. Thus, for instance a factor of 1,2 has a confidence interval of ± 0,12.

The actual object-specific and reference in-use conditions as detailed in Table C.1 are summarized in Table C.2 together with the resulting factor values.

Table C.2 — Object-specific and reference in-use conditions and resulting factor values for steel lintels

Factor	Object-specific in-use condition	Reference in-use condition	Factor value ϕ
A	Normal	Normal	1,0
B	Normal	Normal	1,0
C	Normal	Normal	1,0
D	Poor	Normal	0,8
E	Poor	Normal	0,8
F	(Not applicable)	(Not applicable)	—
G	(Not applicable)	(Not applicable)	—

The calculation is carried out using a variation of Equation (1) as given in Equation (C.1):

$$t_{ESL} = t_{RSL} \times \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \tag{C.1}$$

$$= 125 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 0{,}8 \times 0{,}8$$

$$= 80 \text{ yr}$$

And using a variation of Equation (5) as given in Equation (C.2):

$$\Delta t_{ESL} = t_{ESL} \times \sqrt{\left[\left(\Delta t_{RSL}/t_{RSL}\right)^2 + \left(\Delta\phi_A/\phi_A\right)^2 + \left(\Delta\phi_B/\phi_B\right)^2 + \left(\Delta\phi_C/\phi_C\right)^2 + \left(\Delta\phi_D/\phi_D\right)^2 + \left(\Delta\phi_E/\phi_E\right)^2\right]} \tag{C.2}$$

$$= \pm\, 80 \times \sqrt{\left[\left(25/125\right)^2 + 5\left(0{,}1\right)^2\right]}$$

$$= \pm\, 24 \text{ years}$$

Suppose that the design life, DL, is set to 100 years, considering that the component is load bearing and not accessible to repair. Then, a selection of an enhanced specification or closer control over site repairs is required in order to reach a value of ESL greater than 100.

C.3 Example 2 — Softwood window

Example 2 concerns a softwood window. The main factors affecting its durability are the inherent durability of the timber and the quality of the timber treatment, together with the quality of maintenance of any coating and the design of the window to achieve a good protective coating layer and sheltered installation. Possible in-use condition ranges of the various factor categories are listed in Table C.3.

Table C.3 — In-use condition ranges of the factor categories applicable to softwood windows

Aspect of interest	Factor	Factor category	To consider	In-use conditions		
				Poor	Normal	Good
Inherent quality characteristics	A	Inherent performance level	Material type and/or grade	Non-durable sapwood, not joinery quality	Non-durable sapwood, joinery quality to BS EN 942	Very durable/durable heartwood; joinery class 2 + to BS 1186-2
			Durability features, e.g. protection system	Mixed species or non-permeable sapwoods impregnated to permeable schedule, or dipped/ immersed only	Mixed species pressure impregnated with organic solvent to appropriate schedule; some planing/cutting after preservation	Permeable species double vacuum pressure impregnated; no planing/cutting after preservation
	B	Design level	Details of construction, e.g. joints, fixings	External exposed horizontal surfaces not weathered and/or arrisses not rounded	Horizontal surfaces weathered, arrisses rounded	Horizontal surfaces weathered; installed into recess
	C	Work execution level	Site work, e.g. not to BS 8000	Any site alterations. Site glazed/stained/ painted with little control over quality	No site alterations, site glazed/painted; normal control over quality	Sitework avoided, factory glazed and painted to specified quality
Environment	D	Indoor environment	Special features, e.g. condensation	High risk of condensation	Occasional risk of condensation, no aggressive internal agents	Low risk of condensation, building rarely occupied
	E	Outdoor environment	Special features, e.g. marine or polluted	Regular cycling between dry and damp; high risk of particulates	Occasional cycling between dry and damp	Sheltered from exposure to rain/particulates
Operation conditions	F	Usage conditions	Special features, e.g. vandalism	Regular access by children to locality	Occasional access by children but low risk of impact damage, etc.	No access by children
	G	Maintenance level	Cyclical, including quality	Infrequent renewal of paints/stains and/or low control of application/ preparation	Stained or painted every 3 years to 6 years	Paint or stain renewed every 3 years to 6 years; high control

The RSL is assumed to be 30 ± 5 years and applies for normal in-use conditions in the factor categories “design level,” “work execution level,” “indoor environment,” “usage conditions” and “maintenance level.” In the factor category, “inherent performance level,” the reference material grade is non-durable redwood with a non-joinery quality. In the factor category, “outdoor environment,” the reference in-use condition is representative of sheltering from wind/rain/particulates. That is, the reference in-use conditions are all considered normal except for factor categories, “inherent performance characteristics” and “outdoor environment,” which are poor and good, respectively. The object of concern is a softwood window characterized by high inherent performance and design levels and favourable outdoor environment.

In each factor category, other than design level, a good in-use condition is assumed to increase the service life by a factor of 1,1 compared to a normal in-use condition, whereas a poor in-use condition is assumed to decrease the service life by a factor of 0,9 compared to a normal in-use condition. For the factory category, "design level," a good and poor in-use condition is assumed to change the service life by a factor of 1,2 and 0,8, respectively, compared to a normal in-use condition. The confidence interval of each of the factors is assumed to be ± 50 % of the deviation from unity of the respective factor value. Thus, for instance, a factor of 0,9 has a confidence interval of ± 0,05, whereas a factor of 1,0 has a null interval.

The actual object-specific and reference in-use conditions as detailed in Table C.3 are summarized in Table C.4 together with the resulting factor values.

Table C.4 — Object-specific and reference in-use conditions and resulting factor values for softwood windows

Factor	Factor category	Object-specific in-use condition	Reference in-use condition	Factor value ϕ
A	Inherent performance level	Good	Poor	1,1/0,9 = 1,22
B	Design level	Good	Normal	1,2/1,0 = 1,2
C	Work execution level	Good	Normal	1,1/1,0 = 1,1
D	Indoor environment	Normal	Normal	1,0/1,0 = 1,0
E	Outdoor environment	Good	Good	1,1/1,1 = 1,0
F	Usage conditions	Normal	Normal	1,0/1,0 = 1,0
G	Maintenance level	Good	Normal	1,1/1,0 = 1,1

The calculation is carried out using a variation of Equation (1) as given in Equation (C.3):

$$t_{ESL} = t_{RSL} \times \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \times \phi_F \times \phi_G \quad \text{(C.3)}$$

$$= 30 \times 1{,}22 \times 1{,}2 \times 1{,}1 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}1$$

$$= 53 \text{ yr}$$

And using a variation of Equation (5) as given in Equation (C.4):

$$\Delta t_{ESL} = t_{ESL} \times \sqrt{\left[\begin{array}{l}\left(\Delta t_{RSL}/t_{RSL}\right)^2 + \left(\Delta\phi_A/\phi_A\right)^2 + \left(\Delta\phi_B/\phi_B\right)^2 + \left(\Delta\phi_C/\phi_C\right)^2 + \left(\Delta\phi_D/\phi_D\right)^2 + \ldots \\ \quad \ldots + \left(\Delta\phi_E/\phi_E\right)^2 + \left(\Delta\phi_F/\phi_F\right)^2 + \left(\Delta\phi_G/\phi_G\right)^2\end{array}\right]} \quad \text{(C.4)}$$

$$= \pm 49 \times \sqrt{\left[(5/30)^2 + (0{,}11/1{,}22)^2 + (0{,}1/1{,}2)^2 + (0{,}05/1{,}1)^2 + 0 + 0 + 0 + (0{,}05/1{,}1)^2\right]}$$

$$= \pm 11 \text{ years}$$

Suppose that the DL is set to 30 years, considering that the component is accessible to maintenance and not load bearing. The high durability of the preserved timber, the design of the component, avoidance of sitework and its installation into a recess, together with the regular maintenance, extends ESL well above the DL. There may, however, be the option of reducing the material specification or factory finishing and thereby making a cost saving.

Annex D
(informative)

Worked examples of service-life estimation using the factor method in conjunction with statistical methods

D.1 Example 1 — Wood-framed windows in dwellings

D.1.1 General

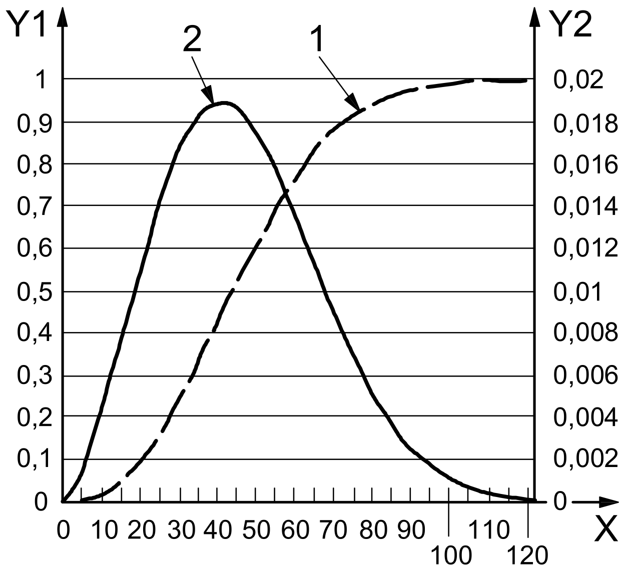
This example is based on work undertaken by Björn Marteinsson, Icelandic Building Research Institute, Iceland and the University of Gävle/KTH, Sweden.

D.1.2 Purpose

The task is to estimate the service life of wood-framed windows of dwellings in order to determine if the windows in two different climates (but not specific locations) meet a requirement of a design life, DL, of 35 years.

D.1.3 Reference service life

The RSL distribution shown in Figure D.1 is available, based on the average performance of wood-framed windows of dwellings in general in an area with a coastal climate:



Key

Y1	cumulative function	1	cumulative
Y2	density function	2	density
X	Service life, expressed in years		

Figure D.1 — Service-life distribution of wood-framed windows

Curve 1, the bold curve having a maximum at approximately 40 years, is the so-called probability density function of the service-life distribution. The values on the right Y-axis belong to this curve. This should be interpreted such that during, for instance, the 40th year, a share of approximately 0,019, i.e. 1,9 % of the total, of the windows is expected to fall below the imposed performance requirements.

Curve 2, the hatched continuously increasing curve, is the so-called the cumulative distribution function of the service-life distribution. This curve describes the total share of windows expected to have fallen below imposed performance requirements up to a certain point of time as given by the values on the left Y-axis. After, e.g. 40 years, the probability is that a share of approximately 0,4, i.e. 40 %, will have failed.

There is a simple mathematical relationship between the two curves (the probability density function is the derivative of the cumulative distribution function). For the purpose of this example, the cumulative distribution function is utilized.

The inferior part of the distribution, i.e. the tail to the left of short service life, is regarded as due primarily to poor quality of the original wood material. The variation in design, workmanship and indoor environment is regarded as small. In the study from which data are taken, it turns out that the outdoor environment and maintenance are mutually dependent: a larger environmental influence calls for increased maintenance. Detailed quality requirements on material and production are regarded as resulting in a more reliable and longer service life.

Risk of damage to the windows, as well as to wood in general, is assumed to depend largely on the temperature and the dampness of the material. In the coastal area, the average temperature is above + 10 °C during 45 days of the year and the probability of daily precipitation during the same time is 55 % (in other words, it rains during slightly more than half of these warm days). In the study, no considerations have been taken to prevailing wind directions or variations in the microclimate.

To represent the RSL conservatively, the service life that is exceeded at a probability of 80 % is chosen, i.e. the point of time when only 20 % of the windows have failed. In other words, the significance level selected here is 20 %.The RSL can be determined from Figure D.1 from the left Y-axis at 0,2 (i.e., 20 %), following the line towards the right until it intersects the curve of the cumulative distribution function. The point of intersection yields an RSL of 28 years. (Note that a precision of integer years is fully sufficient.)

D.1.4 Climatic cases

The information above is used to make a service-life estimation of two different cases:

a) in the same climate as for the RSL, i.e. a coastal climate (above + 10 °C during 45 days of the year with the probability of daily precipitation during the same time being 55 %);

b) in a colder, dryer area (above + 10 °C during 38 days of the year with the probability of daily precipitation during the same time being 50 %).

D.1.5 Service-life estimation in coastal climate

The factors in the factor method are determined in accordance with Table D.1:

Table D.1 — Factor values in coastal climate

Factor	Factor category	Condition	Factor value ϕ
A	Inherent performance level	Since particularly high demands are being made on material quality and a quality check will take place when receiving goods, this is assumed to give a 25 % longer service life than is currently the case with products on the market.	1,25
B	Design level	The design level is estimated to be equivalent to the average level.	1,0
C	Work execution level	Also here, the level is estimated to be equivalent to the average level.	1,0
D	Indoor environment	The indoor environment is not expected to be different from that for dwellings in general.	1,0
E	Outdoor environment	The climate is the same as that for the RSL.	1,0
F	Usage conditions	Here, also, the conditions are not expected to be different from those for dwellings in general	1,0
G	Maintenance level	The maintenance level is expected to be the same as the average for the RSL.	1,0

The calculation for the ESL is carried out using a variation of Equation (1) as given in Equation (D.1):

$$t_{ESL} = t_{RSL} = \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \times \phi_F \times \phi_G \tag{D.1}$$

$$= 28 \times 1{,}25 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}0$$

$$= 35 \text{ yr}$$

D.1.6 Service-life estimation in colder and dryer climate

With the exception of factors E and G, the factors are set to the same values as given in Table D.1. For E and G, the values are obtained according to Table D.2:

Table D.2 — Deviating factor values in colder and dryer climates

Factor	Factor category	Condition	Factor value ϕ
E	Outdoor environment	As there is a lack of more accurate information, it is assumed that the performance is in inverse proportion to the period when precipitation occurs and the temperature at the same time is above + 10 °C (compare, e.g. Scheffer's index). Based on this $\phi_E = 1{,}0 \times (45 \times 55)/(38 \times 50)$	1,30
G	Maintenance level	Since this climate is less aggressive than the coastal climate, the maintenance level is expected to be somewhat lower (less frequent maintenance) than the average level for the RSL.	0,9

Thus, the ESL is calculated using a variation of Equation (1) as given in Equation (D.2):

$$t_{ESL} = t_{RSL} = \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \times \phi_F \times \phi_G \tag{D.2}$$

$$= 28 \times 1{,}25 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}3 \times 1{,}0 \times 0{,}9$$

$$= 41 \text{ yr}$$

D.1.7 Conclusion

In both cases the requirement of the DL of 35 years is met, i.e. ESL is larger than or equal to DL, even though just at the borderline in the coastal climate.

D.2 Example 2 — Wood-framed windows of softwood material

D.2.1 General

Example 2 is based on work undertaken by Konrad Moser, EMPA, Switzerland [6].

D.2.2 Purpose

With the purpose of providing data for maintenance, in this case the task is to estimate service-life distributions of wood-framed windows of softwood at the four cardinal points. The example is a further elaboration of Example 2 in Annex C.

D.2.3 Reference service life

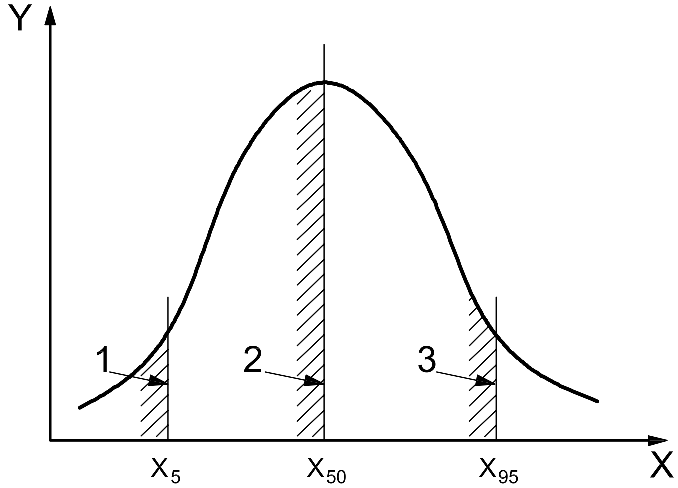
The RSL is assumed to be a single value of 25 years and applies in the current climate and “normal” reference in-use conditions in other respects.

D.2.4 Statistical distribution of factors

Here, not all of the factors in the factor method are single values but are attributed to statistical distributions. The distributions are established by means of adopted expert opinions according to the so-called Delphi method.

Hence, for each factor, each expert rates a “median” value, a “minimum” value and a “maximum” value. For any factor, 50 % of the windows are expected (per definition) to fall below the median factor value, while 5 % and 95 % of the windows are expected to fall below the minimum value and maximum value, respectively.

Furthermore, a likely shape of the statistical distribution of each factor has been assigned by the experts. By means of the median, minimum and maximum values in combination with the likely curve shape, the statistical distribution in question can be established. This is illustrated schematically in Figure D.2 for an arbitrary factor X. In the figure, the distribution outlined is a normal distribution, but other types are quite feasible.



Key

X	density	1	5 %
Y	factor value	2	50 %
		3	95 %

Figure D.2 — Illustration of a statistical distribution of factor X

D.2.5 Expert opinions

The expert opinions are as tabulated in Table D.3.

Table D.3 — Factor values and types of distributions

Factor	Factor category	Directions	Conditions	Factor values			Type of statistical distribution
				ϕ_{X5}	ϕ_{X50}	ϕ_{X95}	
A	Inherent performance level	All	Good quality with normal variations	1,2	1,5	1,8	Normal
B	Design level	All	Good design without variations	—	1,2	—	None
C	Work execution level	All	Normal variations but bigger mistakes fixed	1,0	1,2	1,5	Gumbel [a]
D	Indoor environment	S	Small risk of condensation	0,9	1,0	1,2	Log-normal
		W	Average risk of condensation	0,8	0,9	1,1	"
		N	High risk of condensation	0,7	0,8	0,95	"
		E	Average risk of condensation	0,8	0,9	1,1	"
E	Outdoor environment	S	Occasional fluctuations wet/dry	0,8	1,0	1,3	Log-normal
		W	Frequent fluctuations wet/dry	0,6	0,8	1,0	"
		N	Rain sheltered	1,0	1,2	1,5	"
		E	Occasional fluctuations wet/dry	0,8	1,0	1,3	"
F	Usage conditions	S	Rare access by children	0,8	1,0	1,2	Normal
		W	Frequent access by children	0,6	0,8	1,0	"
		N	Access by children at times	0,7	0,9	1,1	"
		E	Rare access by children	0,8	1,0	1,2	"
G	Maintenance level	All	Re-painting according to manager's assessment	0,9	1,0	1,1	Normal

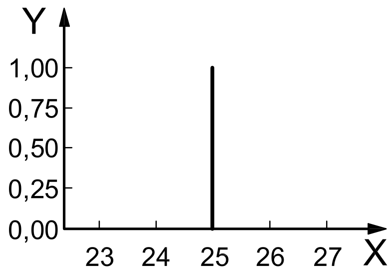
[a] Measures in order to correct bigger mistakes typically result in a strongly asymmetrical distribution having a steep left flank, which appropriately may be represented by a Gumbel distribution.

.

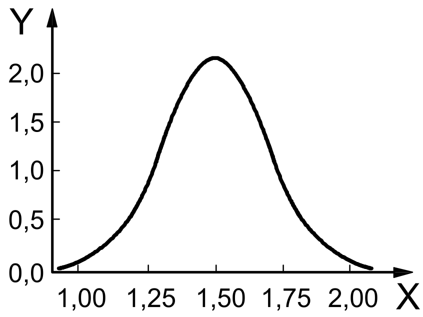
D.2.6 Calculated distributions of factors

By means of the expert opinions, i.e. ϕ_{X5}, ϕ_{X50} and ϕ_{X95} and type of distribution, a unique distribution can be calculated for each factor and compass direction using standard mathematical software packages.

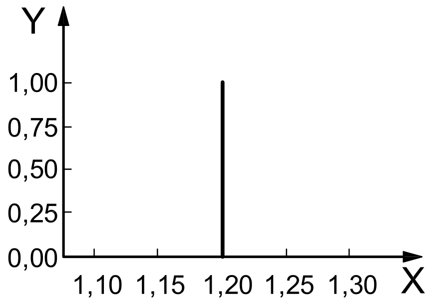
In Figure D.3, as an example, the calculated distributions of the facade directed towards south are shown.



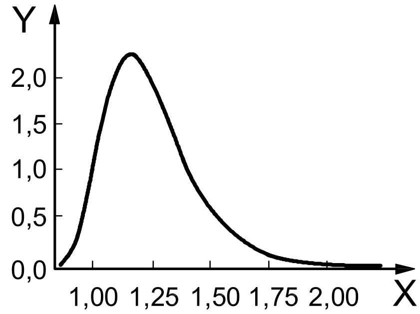
a) RSL — Reference service life of a component



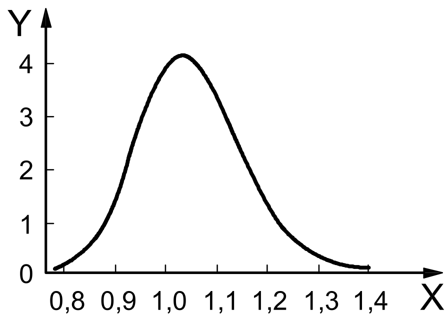
b) Factor A — Inherent performance level



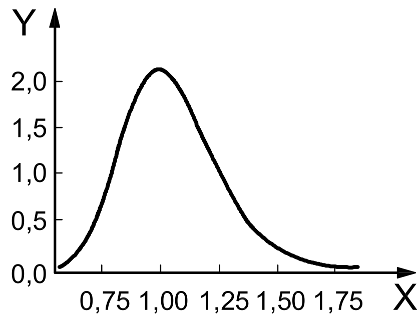
c) Factor B — design level



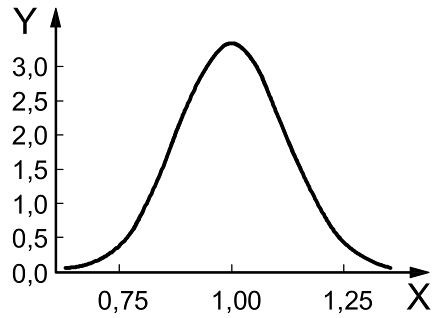
d) Factor C — Work execution level



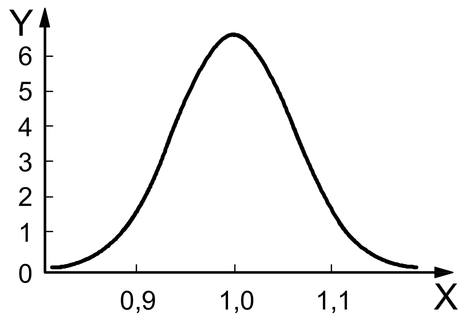
e) Factor D — Indoor environment



f) Factor E — Outdoor environment



g) Factor F — Usage conditions



h) Factor G — Maintenance level

Key

X density

Y Factor values, ϕ

Figure D.3 — The south facade — Distributions of reference service life and factors

Observe that factor B, associated with the factor category “design level,” is described as a spike since it is assumed to have a fixed value. The same applies to the RSL also included in Figure D.3. The corresponding distributions can also be generated for the other compass directions.

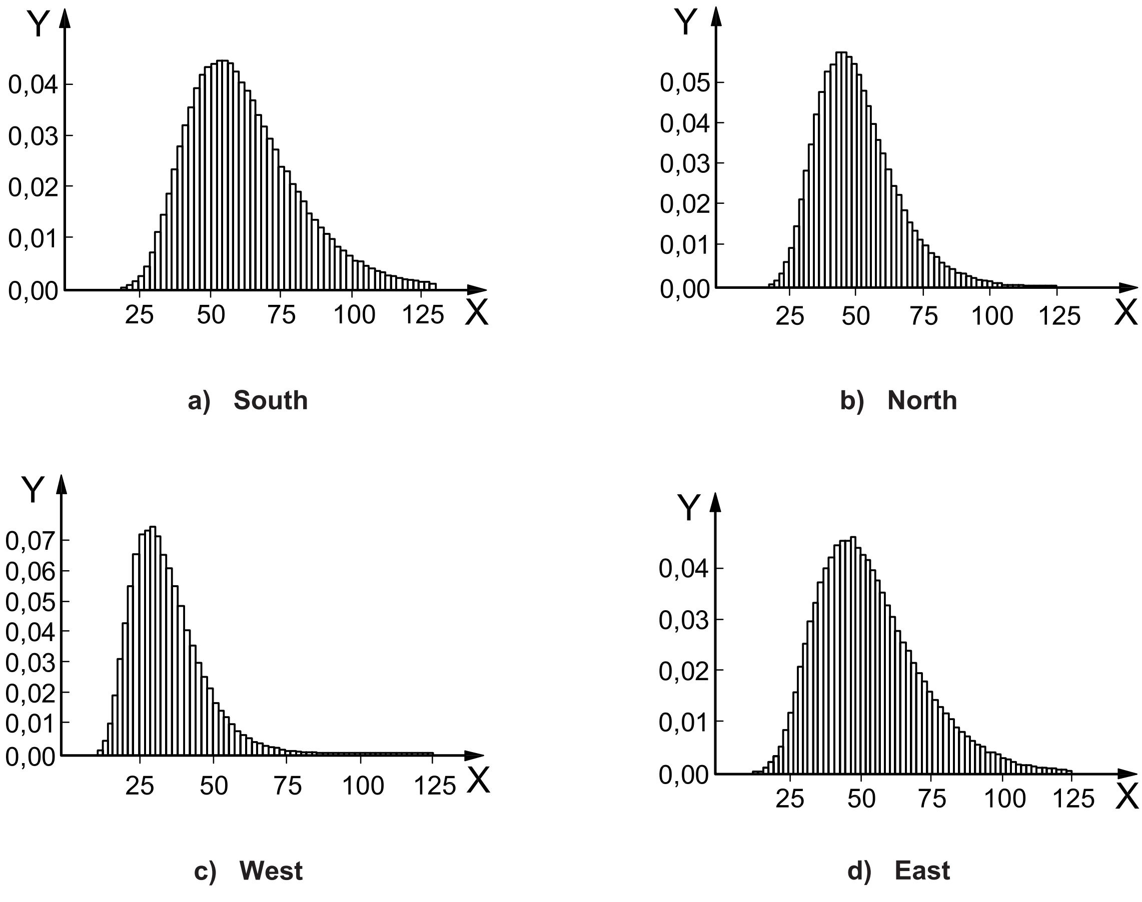
D.2.7 Estimated service-life distributions

In order to estimate the service life of windows on the facades in respective directions, use is made of the factorial expression, which is a variation of Equation (1) as given in Equation (D.3):

$$t_{ESL} = t_{RSL} = \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \times \phi_F \times \phi_G \quad \text{(D.3)}$$

But since the individual factors do not generally consist of a single value but distributions, the resulting ESL also becomes a distribution. Neither is it possible to perform a simple multiplication. It is necessary to use a mathematical artifice called a convolution. No details are described here, as it is necessary to refer to standard software packages in order to carry out the calculation according to, for instance, the Monte Carlo method [9].

Figure D.4 shows service-life distributions, estimated from such calculations, of windows on each of the facades.



Key

X density

Y ESL, expressed in years

Figure D.4 — Estimated service-life distributions of windows in different directions

Annex E
(informative)

Remarks on the factor method

The factor method does not provide an assurance of a service life; it merely gives an empirical estimate based on what information is available. Thus, the method is not intended for use in implementing contractual liabilities and the expectation is that while "best efforts" are applied, the estimates cannot be expected to always be either accurate or precise.

A combination of factors that might result in less modification can have a significant effect overall. It is, therefore, essential to keep the overall picture in view when applying the factor method. The advantage of the method is that it allows the examination at the same time of everything that is likely to contribute to variations in service life and a consideration and documentation of the relative importance of each. This is especially important when degradation is affected by a combination of conditions (e.g. poor workmanship and exposure to driving rain). Separately these conditions might have little impact on the service life but, taken together, they are likely to lead to failures.

It is important not to "double-count" conditions under more than one factor category. This can give an unduly cautious ESL.

EXAMPLE 1 If it is considered unlikely that site mixes of concrete will match that assumed for the RSL applied, this is allowed for under either the materials-related factor category, "inherent performance level," or the workmanship-related factor category, "work execution level," but not both.

It can be desirable to consider the consequences of failure when estimating service lives using the factor method. This can be used as a guide both to those components that are included in estimates and in deciding those where failure is most critical. The method itself does not indicate the seriousness of failures, but interpretation of results can suggest components whose use is too "risky" without either enhancing the specification or providing for regular condition monitoring. For these, it is necessary to be extra-cautious, either by critically reviewing (and possibly changing) the design life or, typically, by being particularly rigorous in assessing the factors.

EXAMPLE 2 A whole assembly that relies on sealants to weatherproof the joints between factory-made cladding units can have external environment and maintenance factors different from those which apply to each of the individual cladding units.

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