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Buildings and constructed assets — Service life planning —
Part 7: Performance evaluation for feedback
of service life data from practice

прийнято як національний стандарт
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Частина 7. Оцінювання характеристик для зворотного зв’язку
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Buildings and constructed assets — Service life planning —

Part 7:
Performance evaluation for feedback of service life data from practice

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

Partie 7: Évaluation de la performance de l'information en retour relative à la durée de vie, issue de la pratique

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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 15686-7 was prepared by Technical Committee ISO/TC 59, *Building construction*, Subcommittee SC 14, *Design life*.

This second/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

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

— Part 1: *General principles and framework*

— Part 2: *Service life prediction procedures*

— Part 3: *Performance audits and reviews*

— Part 4: *Service Life Planning using Building Information Modelling*

— 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*

— Part 9: *Guidance on assessment of service-life data* [Technical Specification]

— Part 10: *When to assess functional performance*

— Part 11: *Terminology*

Introduction

ISO 15686, with the general title *Buildings and constructed assets — Service life planning*, of which this document is Part 7, is an important contribution to the development of a policy for design life. A major impetus for the preparation of the parts of ISO 15686 is the concern over the inability to predict service life, costs of ownership and maintenance of buildings and constructed assets. Common methods and standards for performance assessment and proper feedback of data from practice are decisive in order to make experience data from the building stock more consistent and comparable.

This part of ISO 15686 provides a framework to channel information, collected as part of building performance surveys and assessments, into structured data that can be used in various aspects of the service life planning process.

By applying the generic protocol and terms from this part of ISO 15686, to evaluate the service life performance during a building's life cycle, practitioners can generate "in-use" service life data, as referenced in ISO 15686-2 and ISO 15686-8 .

The inspection and reporting procedures described in this part of 15686, acknowledge that both the condition, of any given building, component or system, as well as performance requirements, can change during the lifecycle. Those changes typically result in corrective actions, maintenance or re-commissioning, to rectify the performance gaps. While commissioning, re-commissioning and maintenance planning are beyond the consideration of this document, the interactions and significance of initial inspection data, maintenance-driven inspections, changed performance expectations, performance surveys, service life predictions and service life planning are discussed.

Part 10 of ISO 15686 stipulates that functional performance is to be assessed at various stages during the whole life, most critically during the project delivery phase, and at commissioning. Functional performance assessments are to continue during the property management phase and when considering disposal, to compare actual serviceability profile of the facility to the generic or typical functional requirement profile of potential occupants or buyers. This part of ISO 15686 provides essential input to the functional performance review process of ISO 15686-10 and as such is of importance to all members of the building team.

Part 4 of ISO 15686 lays out procedures for the application of Building Information Modelling (BIM), specifically to provide a consistent computerized structure for the retention and use of service life planning information and service life predictions. Coupled with the emergence and inherent capabilities of BIM, the techniques described in this part of ISO 15686 will become more useful, lead to better service life estimations and generally improve service life planning.

Buildings and constructed assets — Service life planning —

Part :
Performance evaluation for feedback of service life data from practice

1 Scope

This part of ISO 15686 provides a generic basis for performance evaluation for feedback of service life data from existing buildings and constructed assets, including a definition of the terms to be used and the description of how the (technical) performance can be described and documented to ensure consistencies.

The purpose of this part of ISO 15686 is to describe the principles for service life performance surveys and evaluation with an emphasis on technical recommendations. It aims to describe a generic methodology, including the terms to be used, that provide guidance on the planning, documentation and inspection phases, as well as on analysis and interpretation of performance evaluations, both on the object (single building) and network (stock of buildings) level. While maintenance planning is outside the scope of this part of ISO 15686, this standard acknowledges that maintenance-driven inspections, and subsequent recommended actions, could have significant effects upon service life and performance.

ISO 15686-7 is intended for all members of a building team, e.g. building owners and developers, professional advisors, constructors, assessors, manufacturers of building products, insurers, managers of both publicly and privately owned constructed assets.

2 Normative references

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

ISO 6241:1984, *Performance standards in building — Principles for their preparation and factors to be considered*

ISO 15686-1:2011 , *Buildings and constructed assets — Service life planning — Part 1: General principles and framework*

ISO 15686-2:2012 , *Buildings and constructed assets — Service life planning — Part 2: Service life prediction procedures*

ISO 15686-3:2002 , *Buildings and constructed assets — Service life planning — Part 3: Performance audits and reviews*

ISO 15686-4:2014 , *Building Construction — Service Life Planning — Part 4: Service Life Planning using Building Information Modelling*

ISO 15686-8:2008 , *Buildings and constructed assets — Service-life planning — Part 8: Reference service life and service-life estimation*

ISO 15686-10:2010 , *Buildings and constructed assets — Service life planning — Part 10: When to assess functional performance*

ISO 15686-11:2014, *Buildings and constructed assets — Service life planning — Part 11: Terminology*

3 Terms and definitions

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

3.1
commissioning
systematic process of functional performance testing, verification, documentation and training intended to ensure that the building and its systems operate in accordance with the defined objectives and criteria of the project

Note 1 to entry: Commissioning is an integral part of the design and construction process and is also intended to be undertaken throughout the service life.

3.2
consequence degree
expression of the significance and impact(s) of failure, or failures, or loss of performance, relative to a defined reference level

Note 1 to entry: Impacts that should be considered include any changes to aesthetics, structural integrity, the provision of healthy and safe surroundings, economic factors and environmental loadings.

3.3
network level
stock of objects under management and maintenance of an owner

Note 1 to entry: Objects could include facilities, for example bridges, tunnels, power plants, and buildings.

3.4
object level
basic unit of the network serving a specific function

3.5
performance survey
total review (defining of the task, planning, examination, evaluation and reporting) at a given time in accordance with this part of ISO 15686

3.6
performance assessment
all material that accounts for an item's capability to provide a quality or function throughout its service life

3.7
performance degree
expression of the capability of an item to provide functionality in relation to a defined reference level

3.8
performance control
comparison between capability to provide functionality and predefined functional requirements

3.9
refurbishment
modification and improvements to an existing item to bring it up to an acceptable condition

[SOURCE: adapted from ISO 6707-1:2014, definition 7.1.50]

3.10
repair
return a product/component/assembly/system to an acceptable condition by renewal or replacement of worn, damaged or degraded parts

[SOURCE: adapted from ISO 6707-1:2014, definition 7.1.52]

3.11
renewal
demolition and rebuilding of an existing item

3.12
replacement
change of parts of an existing item to regain its functionality

3.13
risk
probability of an event occurring multiplied by its consequences

Note 1 to entry: Events can include failure, or damage.

Note 2 to entry: Consequences can include cost, fatalities, or exposure to personal or environmental hazard.

3.14
symptom
indicator of the loss of performance of an item

3.15
in-use condition
any circumstance that can impact the performance of a building or a constructed asset, or a part thereof under normal use

[SOURCE: ISO 15686-8:2008, definition 3.5]

3.16
usage conditions
in-use conditions (3.15) due to users of a building/constructed assets, and human activity adjacent to a building/constructed assets

3.17
factor category
label of an in-use condition (3.15) indicating which factor of the Factor method the condition will influence

Note 1 to entry: See Clause 4 for the Factor method.

3.18
in-use condition grading
act of applying collective judgement of all qualitative information of an in-use condition(3.15) within a factor category (3.17)

[SOURCE: ISO 15686-8:2008, definition 3.6]

3.19
in-use condition grade
designation representing a qualitative description of an in-use condition (3.15)

[SOURCE: ISO 15686-8:2008, definition 3.7]

4 Methodological framework

4.1 Service life planning

In ISO 15686-1:2011 , the concept of reference service life (RSL) is defined as the "service life of a product, component, assembly, or system which is known to be expected under a particular set, i.e a reference set, of in-use conditions and which can form the basis of estimating the service life under other in-use conditions" (3.22 of ISO 15686-1:2011).

A person working with the service life planning (SLP) of a design object is faced with the challenge of forecasting the service life of its components. Even if there are certain service life data available, i.e. RSLs, these can rarely be used directly. This is because the project-specific in-use conditions, to which the object's components are subjected, are usually different from those under which the service life data are valid, i.e. the reference in-use conditions.

In ISO 15686-8 , the Factor method is described as a means to overcome this problem. The Factor method is used to modify an RSL to obtain an estimated service life (ESL) of the components of a design object, while considering the difference between the project-specific and the reference in-use conditions. This is carried out by multiplying the RSL by a number of factors, each of which reflect the difference between the two sets of in-use conditions within a particular factor category:

ESL = RSL × Factor A × Factor B × Factor C × Factor D × Factor E × Factor F × Factor G

The factor categories are given in Table 1.

Table 1 — Factor categories of the Factor method

Factor category	Designation
A	quality of components
B	design level
C	work execution level
D	indoor environment
E	outdoor environment
F	usage conditions
G	maintenance level

The evaluation of an ESL according to the Factor method requires the input of an RSL as well as the numbers of the Factor categories A to G. A proper choice of the numbers of the factors depends on the difference between the project-specific and the reference in-use conditions. Therefore, in order to enable estimations of the Factor categories A to G jointly with RSL, the reference in-use conditions in terms of the factor categories should, as far as possible, be included when providing data.

There are a limited number of systematic studies on service life prediction and there is a need for data. For the provision of RSL data, the capturing of existing data of any kind is acceptable. ISO 15686-2:2012 , 5.4.3.3 identifies methodology to evaluate the service life of building components through inspection of buildings and suggests that, by means of statistical sampling methods, as many buildings as necessary be included in the study. See also ISO 15686-2:2012 , A.2.3.1.2.

In addition, ISO 15686-2:2012 stipulates that a critical review of service life planning studies is to be conducted whenever the results are to be publically disclosed and discretionary in other instances. The critical review process, as described in Clause 6 of ISO 15686-2:2012 , ensures the technical and scientific validity, consistency of the service life planning methods implemented, as well as the appropriateness and soundness of external data used.

4.2 Performance assessment of service life in the course of the construction life cycle

4.2.1 Relation to service life design and reference service life (RSL)

The performance levels of the construction and its components change during the life cycle of the construction (see Figure 1). The in-use conditions can also be subject to change. Therefore, a proper assessment of the service life during the construction life cycle should include a thorough assessment of the existing in-use conditions, and record any changes to the levels used in the design process, if applicable.

A main objective of this part of ISO 15686 is to provide a basis for objective assessment and to describe how information retrieved during performance assessments can become new input in the RSL data, as described in ISO 15686-8 . As such, this part of ISO 15686 adds further to the data generation via inspection.

4.2.2 Life cycle performance of construction

Figure 1 illustrates scenarios in the development of the performance (bold line) of construction works from delivery through the operation and maintenance phase. There is a deviation (gap) in performance from the client's expectations and requirements from the brief (initial) phase until the delivery ("as built") phase, often due to failures or damage during fabrication. The expectation gap is increased further due to the continuous rise in new requirements and upgrading, business development, etc.

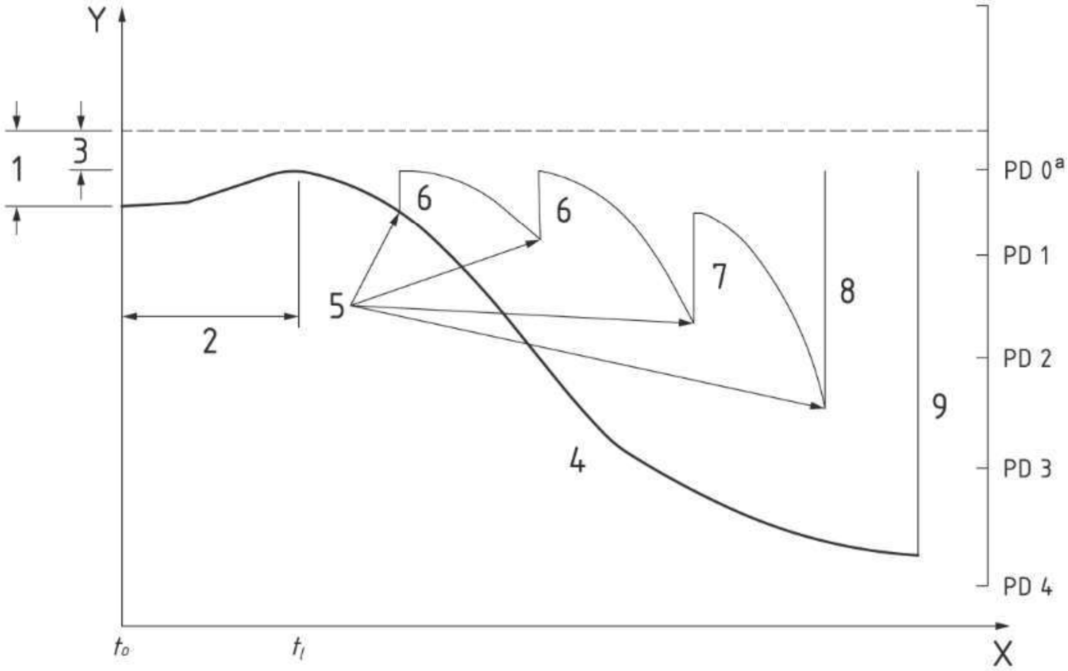
After the delivery, performance decreases during operation, due to wear and tear, or simply the age factor, if left with no maintenance. Therefore, the construction and its components are subjected to various corrective actions, or maintenance, in order to keep up with required performance. These actions can be proactive, which is preferred, or reactive, which is largely the current practice. In both cases, inspections and performance assessments should be the basis for maintenance planning. This applies to all functionalities.

This part of ISO 15686 defines a generic protocol and terms for how to evaluate the service life performance during this life cycle. Maintenance planning is outside the scope of this part of ISO 15686, but for the sake of illustration, Figure 1 relates the assessed performance levels to various known maintenance actions, as defined in ISO 15686-1 . The content of, and relations between, such levels and actions should be defined by users separately.

Commissioning is a systematic verification, documentation and training process undertaken to increase the likelihood that the built work operates in conformity with the owner's project requirements and the basis of design as described in the contract documents.

Commissioning (when executed thoroughly) is applied to all activities during the design, construction, static verification, start-up, and functional performance testing of building equipment and systems. It ensures that the building operates as intended and that the operation and maintenance team is adequately prepared to keep the building performing as intended.

As a building enters its service life, the expectations of the level of performance that it needs to provide could shift (positively or negatively) either as a result of public and market driven pressures or due to changed business demands. Typically, these new requirements, as graphically depicted by the dashed line (10) in Figure 2, will eventually rise until upgrading is warranted at t_j to the meet the new requirements. See 5.3.5.1.



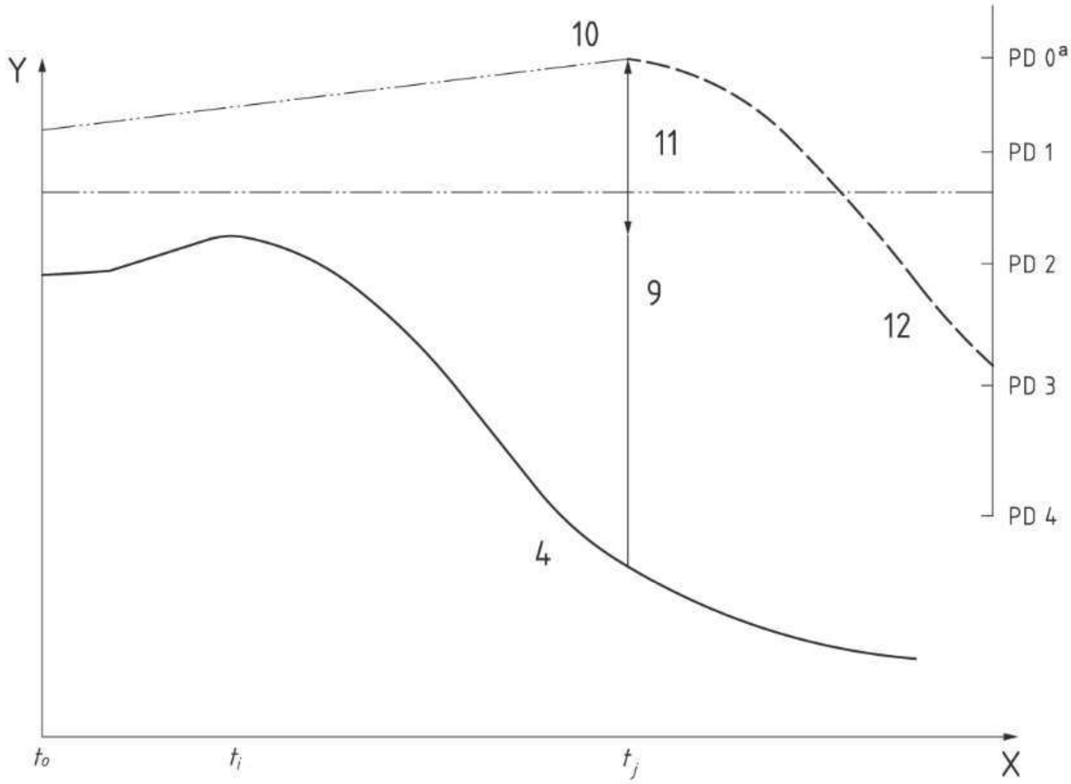
Key

Y	quality/function	7	refurbishment or repair
X	time	8	replacement
1	expectation/achievement gap	9	renewal
2	commissioning		
3	initial performance gap	a	Performance degrees (PD) are defined in 5.3.4.2.2.
4	performance without preventative actions	t_0	time of initial "as built"
5	limit states	t_i	time at start of "in-use" (operation & maintenance) stage
6	preventative and periodic maintenance		

Figure 1 — Life cycle performance of construction

NOTE 1 Dependent upon the legal and contractual framework governing the building and its operation, Performance degree 0 could be required at t_0, the time of initial as-built. In such instances the Y axis of Figure 1 is effectively shifted to the right and t_0 and t_i coincide.

NOTE 2 When considering commissioning for domestic systems installed in typical single family dwellings, the duration between t_0, the time of initial as-built, and t_i, the time to occupancy and operation, can be very short (hours or days rather than months and years) in comparison to industrial or commercial systems.



Key

Y quality/function

X time

4 performance without preventative actions

5 limit state

9 renewal

10 new requirements (public, market, business)

11 construction upgrade

12 performance projection following upgrade

a Performance degrees (PD) are defined in 5.3.4.2.2.

t_0 time of initial "as built"

t_i time at start of "in-use" (operation & maintenance) stage

t_j time of redevelopment/upgrading

Figure 2 — Life cycle performance expectation following construction upgrade

5 Performance surveys

5.1 General

The main purpose of this part of ISO 15686 is to be an aid in the planning and preparation of required general and specific working documents for the performance survey of items of various character and different purpose. General and specific working documents supplementary to carrying out performance surveys, can be described in three levels, as given in Table 2.

General working documents provide reference levels for performance of building products, materials and assemblies.

Specific working documents provide function-based direction on how specific items (refer to Table 2) should be addressed as well as providing performance degree reference levels for that item.

Table 2 — Overview of document levels

Document	Main function	Content
This part of ISO 15686	Provides a standardized framework for planning and for terms and methods	Definitions, method and content
General working documents for performance surveys	Provides agreed (objective) fixed terms (reference level) for the performance of a building product or construction method	General symptom lists and/or illustrated catalogues, for example: — concrete; — masonry; — external wood; and — steel. Checklists for likely locations of failure prepared on the basis of this part of ISO 15686
Specific working documents for performance surveys	Provides specific directions on how a type of item should be handled. Should also provide the reference level for performance degrees for the relevant type of item	Complete work guidance for the performance survey of a type of item, for example: — bridges; — old town buildings; — stave churches. These should be prepared by those who request the survey for a type of item (facility manager, property owner, etc.) on the basis of the standard and general working documents

Functional performance is assessed at various stages during the whole life. It is most critical during the project delivery phase to ensure that the design continues to meet the functional requirements as the project progresses from conceptual to detailed design, and at commissioning to verify that the facility still satisfies the functional requirements. During the property management phase functional performance is assessed to affirm continued satisfaction or to determine whether the functional performance requirements have changed. When considering disposal, the actual serviceability profile of the facility shall be compared to the generic or typical functional requirement profile of potential occupants or buyers.

NOTE Refer to ISO 15686-10:-, Table 2 Actions required by ISO 15686 (all parts) at each stage of the whole life.

This part of ISO 15686 can be used:

a) directly as an aid for performance surveys when no other working documents exist, or as a supplement when the working documents are incomplete;

b) to prepare general working documents;

c) to prepare specific working documents.

5.2 Registration level and user-oriented types of inspection

There are four levels of registration as follows.

a) Level 1 (preliminary): Performance registration of a general character consisting of visual observations combined, if necessary, with simple measurements.

b) Level 2 (regular): Performance registration of a general character, but more exhaustive and detailed than Level 1. It includes examination of supporting data, e.g. drawings, specifications and other documentation. More extensive registrations or measurements should be carried out to establish the construction and performance of the item when required.

c) Level 3 (maintenance-driven): Performance registration of the conditions that exist at the time of a loss of function. Dependent upon the significance of the component or system being considered and the severity of the failure, the requirements of the registration and measurements should be carried out to either Level 1 or Level 2.

d) Level 4 (detailed): Performance registration of a special character that includes only specific items (building elements, construction elements, work sections) or specific problems. Such performance registration implies the application of especially accurate measurement or test methods and, if appropriate, laboratory testing.

Types of inspection should be designed from these various levels of registration according to user needs and required competence of inspectors, as given in Table 3.

Table 3 — Type of and purpose of inspection

Level of inspection	Purpose
Preliminary	Introductory inspection of a general character consisting of visual observations and basic measurements to get a very rough overview
Regular	Inspection at regular intervals, such as: a) every 1 to 2 years, for analysis of weak points or failures in the construction; and b) every 3 to 10 years, for: — design and preparation of tenders in restoration and rehabilitation project, — defining the inspection plan, programming the object-individual questions for inspection, and — planning of renovation, control of adequate use, and cost estimates for maintenance measures.
Maintenance-driven	Inspection following an unexpected minor failure (loss of function), e.g. water penetration through building envelope, operating limit warnings.
Specific/detailed (ordered from the levels above)	Special tasks, such as: — detailed specification of the extent of any damage; — difficult and/or unusual situations; and — research work.
NOTE Inspections should be conducted by personnel having the relevant technical credentials for the domains being surveyed. Competency requirements of inspectors should be in accordance with the jurisdiction having authority.	

5.3 Phases and activities in the performance survey

5.3.1 General overview

A performance survey should consist of the following main phases:

a) defining the task;

b) planning;

c) examination;

d) evaluation;

e) reporting.

NOTE A more detailed analysis of this process is given in Table 4.

Performance surveys should be carried out by personnel having the relevant technical background within the field being surveyed (see Note to Table 3). All fields that are relevant to the purpose of the performance survey should be covered.

5.3.2 Defining the task

5.3.2.1 General

The purpose, extent and resources required for the performance survey should be established, described and documented.

5.3.2.2 Purpose

A prerequisite of the performance survey is to define the purpose of the survey, i.e. to clarify what the survey should be used for. For example, the purpose of performance surveys in relation to construction works or construction work elements can be to:

a) provide performance documentation and RSL data for manufacturer's product documentation;

b) form the basis for maintenance plans;

c) determine (in the case of urban city renewal) whether a construction works should be demolished or renovated;

d) inspect for completion and for notification of defects;

e) assist with purchase and sale;

f) assist in undertaking valuation (technical part); and

g) assist in preparing conservation documentation.

Table 4 — Phases and activities in the performance assessment protocol

Main phase	Activity/content	Examples/elaboration
Defining the task	Purpose	Planning of maintenance, repair and renovation. Evaluation of damage and Residual Service Life. Valuation. Conservation documentation
	Extent/level	Item: field, building, construction work, elements. Evaluate, define the registration level. Sampling. Cost calculation of action
	Cost of analysis	Own cost and purchased services
Planning	Basic material	Drawings, specifications, performance documentation
	Registration scheme	Systematic, orientation system, statistical selection, aids
	Plan	Examination, inspection, meetings information, access
Examination	Recording of age, in-use conditions and performance levels	Symptoms, in-use conditions
	Performance degree	Description of performance via pictures and measurements
	Documentation	Photographs
Evaluation	In-use conditions	Critical properties and performance requirements/prediction of service life
	Performance control	Requirements set by authorities, regulations. Requirements set by the client/user requirements
	Failure	Definition from reference level, insufficient documentation
	Probabilities and consequences	Reconsider the extent of the registration, failure distributions and consequence degrees
	Risk	Evaluated and used as a basis for action profiles
	Actions	Recommendations, priorities/costs if appropriate

Main phase	Activity/content	Examples/elaboration
Reporting	Introduction	Purpose. Identification of the item, main structure, construction age, extent/level, time of survey, client and contractor, other parties involved.
	Executive Summary	Main conclusion, summary, performance, recommended actions, costs, economy, recommendation for further progress
	Main report	Definitions, reference level, registrations, inspections, evaluations, recommendations and conclusions, costs
	Enclosure	Basic material, supplementary material, drawings, photographs, forms

5.3.2.3 Extent and costs

The extent of the survey is determined by:

a) what items and fields are included in the performance survey;

b) the registration level; and

c) whether a calculation of costs of the recommended actions is to be carried out.

The extent of the performance survey should be subject to continuous reassessment. Choice of registration level is dependent on the purpose of the performance survey and on the performance of the construction works. Before the registration level is chosen, it should be considered whether there is a need for a preliminary inspection. An estimate of quantities should be included if the costs of the recommended actions are to be calculated.

In the use of sampling examinations, i.e. that the performance registration only includes a limited selection of items on the network level, or a limited part of a larger item on the object level, the number of samples should be determined based on the:

a) required reliability/certainty;

b) consequences of failure (economy, safety); and

c) costs of extended examination (larger number of samples).

It should be decided whether all items of each type that exist within the area covered by the performance survey (the entire population) should be included in the performance registration or whether a selection (sample) should be made. If the area for performance survey includes a large number of identical items or large areas of identical structure, it can be appropriate, in terms of both work and costs, to limit the performance registration to a selection.

For some items there might be standards or regulations that determine the sample size.

Costing calculations of the recommended actions is a highly comprehensive task involving the preparation of an estimate of quantities and research into the cost of earlier similar work. In order to determine the extent of the overall task and the required use of time, it is important to clarify whether costing calculations are necessary at all.

5.3.3 Planning

It should be established whether drawings and/or specifications of the item "as built", and/or "as" commissioned or rebuilt exist, and whether there is any documentation on operating and maintenance-related performances, e.g. repairs, maintenance work and improvements that have been made. The amount of basic material that needs to be provided or prepared should be determined, depending on the type of documentation that exists and on the extent of the performance survey.

If compliance with ISO 15686-3:2002 was required prior to construction, there will be audit and/or review reports on the detailed design stage, and if ISO 15686-3 was in force at later stages (initial design, construction, commissioning, operation, and alteration) reports of comparable format will be available for the building in the latter stages.

The collection of data via Building Information Modelling (BIM), ranging potentially from initial "as-built" information, reference service life data to current inspection conditions, provides a consistent structure for the retention and use of service life prediction information and predictions (see ISO 15686-4:2014 , 6, 7, Annex A, and Annex B).

NOTE To-date, the typical specification and application of BIM has been focused upon retention of initial contract documentation and as-built information. The capabilities of most BIM frameworks encompass strong processing and computational capabilities that will, coupled with the application of ISO 15686-4 , enhance the usefulness of survey information collected with the procedures described in this standard, assist with estimation of service life, and ultimately lead to improved service life planning.

ISO 15686-8:2008 , 5.2 provides guidance on the provision of reference service life data. The historical performance data should first be assessed in accordance with ISO 15686-8:2008 , 5.2.3 and it should be ensured that data are appropriate to use for the object of the service-life planning process. If necessary, the available general data shall be formatted into appropriate reference service life records by applying the procedures described in ISO 15686-8:2008 , 5.4.

For sampling examinations, the items should be selected at random, i.e. selected without the influence of any prior knowledge about the items.

A plan for the performance survey should be prepared that includes:

— preliminary meetings;

— inspection forms;

— reporting, including documentation level;

— any presentation of results; and

— suggestions for further action.

It should be agreed who is responsible for notifying the user and for providing the necessary access.

5.3.4 Examination

5.3.4.1 General — in-use conditions

As stated, RSL data comprise service-life data and reference in-use conditions, as well as corresponding data on critical properties and performance requirements for subsequent service life evaluations. For each individual in-use condition listed, the factor category it belongs to should be indicated. Statements indicating the data quality should be included, for instance, information that the RSL data have been generated on the basis of a systematic study, or that data are critically reviewed by a third party.

A quantitative description of the reference in-use conditions in terms of the factor categories shall be given (see ISO 15686-8:2008 , Annex A).

The reference in-use conditions corresponding to Factor category D, indoor environment, and/or Factor category E, outdoor environment, whichever is applicable, are to be quantified in terms of degradation agent intensities characterizing the reference in-use environment. Alternatively to discrete values, ranges of such intensities or standardized classes corresponding to certain ranges of intensities are accepted (see Annex D).

NOTE For further information, references are given 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 11844. Such systems can be directly applied.

Recording environmental exposure and impact should consist of collecting existing or in-field measurements and models of important climatic and pollution degradation agent's data (i.e. temperature, rain, wind, local pollution). Models should be used directly for assessment on network level, while evaluation of the microenvironmental conditions should be carried out for single objects. In order to do so, local exposure conditions such as topography, shelters, surroundings, etc. should be registered (see A.3.4).

5.3.4.1.1 Grading of Factor categories A, B, C, F and G

For the reference in-use conditions corresponding to each of the Factor categories A, B, C, F and G, quantitative information provided by the source should be used whenever available.

If possible, a detailed description of the material or component should be given for Factor category A: quality of components.

When, but only when, quantitative information is lacking for the in-use conditions within any of the Factor categories A, B, C, F and G, a 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 5. If no information is available, this is indicated by the grade 0. Occasionally, if the factor category is not applicable, it is indicated by NA.

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 is not to be confused with, the value of the corresponding factor, but is information required to estimate this factor.

From general information of the material or component tested, it should always be possible to quantify the in-use condition corresponding to Factor category A into one of the in-use condition grades 1 to 5 (if no quantitative information is provided by the source).

Table 5 — Options of grading in-use conditions of Factor categories A, B, C, F and G

In-use condition grade	Description	Comment
0	not available	Should never be applied for Factor category A. Not to be applied for Factor categories B, C, F and G when service life data are based on ageing tests in accordance with systematic studies such as ISO 15686-8 .
1	very high/mild	—
2	high/mild	—
3	normal	—
4	low/severe	—
5	very low/severe	—
NA	not applicable	Should not normally be applied.
NOTE An in-use condition rating is not the same as the value of the corresponding factor, but a piece of information to estimate this factor.		

5.3.4.2 Performance recording

5.3.4.2.1 Critical property and performance requirements

As the service life of a component is always related to a required function of that component, the service life should be defined and related to a critical property, see ISO 15686-8 .

5.3.4.2.2 Performance degrees

The performance recording should be done on building and/or component level, and is expressed by means of performance degrees (PD). The performance degree should be based on an evaluation of one or more individual symptoms or on an overall evaluation of a set of symptoms and their level of deterioration and/or level of performance (see Annex B). The symptoms should indicate the performance in relation to the reference level on which the evaluation of the performance is based. Five performance degrees with the following main significance should be used.

— Performance degree 0: No symptoms
— Performance degree 1: Slight symptoms
— Performance degree 2: Medium
— Performance degree 3: Strong symptoms
— Performance degree 4: Totally unacceptable, including collapse and malfunction

Significance and determination of performance degrees may be based on symptom descriptions. The use of symptom descriptions contributes to an increased objectivity in the expression of performance. Such symptom descriptions may, for instance, be formatted as illustrated catalogues.

5.3.4.2.3 Performance degrees and in-use condition gradings

The performance degrees may be related to the quantitative description of the in-use conditions in terms of the factor categories, see Annexes A and D. In practice, however, the observed PD is due to the influence of one or more critical factors.

The performance (and failure) should be documented, with specifications, drawings, sketches and photographs, if appropriate. The extent of the symptoms may be specified in writing as a percentage of the total amount, as specific quantities, or with a reference to normative references.

The reference level on which the significance and determination of performance degrees are based should be specified. If the reference level is not generally available, this should be specifically documented. The assignment of in-use condition grades to respective performance degrees may be defined by users in accordance with individual needs.

In practice, parts of the performance control are carried out at performance registration. If failure is registered, it should be specified together with the reference level on which the evaluation of failure is based.

5.3.5 Evaluation

5.3.5.1 Performance control

The registered performance should be checked against the predefined requirements, e.g. requirements set by the authorities, the client and user requirements. If a negative deviation from the defined reference level is proven, this constitutes a registered failure.

During the service life, the predefined performance requirement may shift (upward or downwards) as a result of the influences described in 4.2.2, and as depicted upwardly as point 10 in Figure 2. If such a case arises the new “shifted” performance requirement shall be considered as the defined reference level, as specified by the authorities, the client and user requirements.

The set of performance requirements for the defined reference level shall be in accordance with the information obtained by applying ISO 15686-2:2012 , 5.1.2.1.

NOTE ISO 15686-2:2012 , 5.1.2.1 stipulates that a specific or generic set of in-use conditions shall be identified to account for the specific use of the component, the design consequences, and shall include a description of the environment, including static and dynamic mechanical stress, at the building site. A description of the effects of occupancy (such as water vapour, heat or abrasion) and the principles on which the building is operated (e.g. high or low thermal inertia) shall also be included as appropriate.

5.3.5.2 Prediction of (residual) service life

The (residual) service life should be predicted from the performance assessment of distributions of performance degrees over the construction, and the limit states or acceptance levels. The level of degradation of a component can be related to the performance degrees directly, and when the damage functions are known, the service life can be directly calculated (see Annex B and ISO 9223 [[13]]). The development over time of the performance degree and, subsequently, the service life, can be calculated by using the Markovian chain model (see Annex C). Distributions of in-use condition factors (and performance degrees) can also be used to calculate the service life distributions of components of a construction (see Annex D, ISO 12944 [[18]] and ISO 11844 [[17]]). This is extensively dealt with in ISO 15686-8 , Clause 5. The performance degrees can also be correlated with exposure environment to develop damage functions, which are the basis for mapping service life data (see Annex D and ISO 11844 [[17]]).

5.3.5.3 Causes and effect evaluation

Evaluation of causes should be considered important for SLP and evaluation of actions, as one action can result in the removal of the causes/agents.

Failure mode and effects analysis (FMEA) is a method of analysis that can be applied to buildings and their components to infer all potential degradation paths. The analysis is iterative and based-upon the properties and connectivity of components, sub-components and the environment in which they are to be used. FMEA typically results in a list of failure scenarios. It is useful in cases when there is limited information on the in-use performance of innovative products. Further information on the technique is available in ISO 15686-2:2012 , 5.6 .

5.3.5.4 Failure

The performance survey should contain an evaluation of any failure during the performance registration or performance control. If no failure is registered, the performance survey should still indicate that the evaluation has been carried out to establish this.

Failure is of significance for the evaluation of actions and should be classified as follows.

a) No failure: Failure has not been registered and correct execution has been documented;

b) Possible hidden failure: Insufficient documentation to establish whether failure exists or not;

c) Failure: Failure has been registered (also used about an incorrect execution that has been documented).

In the case of failure or possible hidden failure, it should be specified which type of defects have generated the comment.

NOTE In the case of possible hidden failure, it is the responsibility of the client to decide whether to carry out further examinations, including any destructive actions necessary to establish whether real failure exists.

In insufficiently documented construction works, there are numerous possibilities of hidden failure. In such cases, it can be appropriate to state that the documentation is generally insufficient, i.e. assign the value 0 (see 5.3.4.1.1), and that it does not satisfy existing requirements and to carry out a general evaluation of whether the possible hidden failure is real, instead of listing all possibilities for hidden failure.

EXAMPLE 1 If the render loosens then there is an unsatisfactory performance and the performance degree indicates the extent. If this lies within the limit that can be accepted by the client and the authorities, no failure exists. If it is not acceptable in relation to the defined reference level, a failure exists.

EXAMPLE 2 If it cannot be established how a building is attached to its foundation and there is no documentation on this, a possible hidden failure exists.

5.3.5.5 Consequences

As a basis for risk analysis and recommendation of actions, the consequences of the registered performance should be evaluated. The consequences are expressed by means of consequence degrees. The consequence degree is established for one or more individual consequences or collectively for a set of consequences.

Five consequence degrees should be used as follows.

a) Consequence degree 0: No consequences;

b) Consequence degree 1: Minor consequences;

c) Consequence degree 2: Medium consequences;

d) Consequence degree 3: Serious consequences;

e) Consequence degree 4: Catastrophic consequences.

The type of consequences on which the evaluation is based should be specified in each individual case.

EXAMPLE Consequences that can be used as a basis for evaluation include:

1) safety (e.g. load-bearing capacity, fire safety);

2) health/environment (e.g. air quality, noise level);

3) aesthetics (e.g. surfaces); and

4) economy (e.g. maintenance, renovation).

5.3.5.6 Risk

The risk (probability of an event occurring multiplied by its consequences) should be evaluated and reported, and used as a basis for recommendation of actions. The risk attached to a building element, construction element or work section is determined by the probability that a non-acceptable performance (failure) or situation will occur or develop. This failure/situation inevitably has resulting consequences.

The risk should be specified as low, medium, or high, and the consequences that have been used as a basis for the specification of risk should be identified as per 5.3.5.5.

NOTE Low probability combined with serious consequences give the same risk assessment as high probability combined with minor consequences.

The following two scenarios can occur.

a) Performance degree 0 but with registered failure or possible hidden failure. In this case, the probability that performance degrees 1, 2, 3 or 4 will occur, and the resulting consequences, should be evaluated.

b) Performance degrees 1, 2, 3 or 4. The probability that the performance will deteriorate further, and the resulting consequence should be evaluated.

EXAMPLE 1 Render on an exterior wall with performance degree 1, slight symptoms. The consequences with regard to aesthetics are serious, the consequences with regard to economy/maintenance are medium, and the consequence with regard to safety depends on location. The probability that the performance will degrade is high. The risk is high or medium depending on the type of consequence on which the evaluation is based.

EXAMPLE 2 Possible hidden failure with regard to how a house is attached to its foundation. Consequences with regard to economy and safety are serious if the house is blown away. The probability that this will happen depends on the location of the house. The risk is low or high depending on the location of the house.

5.3.5.7 Actions

Recommended actions should be specified and given priority in accordance with the purpose of the survey. When making recommendations for actions, it should be specified at what time the actions should be implemented.

Actions can be of the following nature:

a) widening the scope of the performance survey;

b) detection of registered possible hidden failure; and

c) planning of maintenance work in accordance with strategic goals and the action profiles linked to the performance degrees.

5.3.6 Reporting

5.3.6.1 General

The report should contain the following main items:

a) introduction;

b) executive summary;

c) main report; and

d) enclosure.

5.3.6.2 Introduction

The introduction should provide the following information:

a) the purpose of the performance survey;

b) identification of the item, e.g. with address, identification in the land register;

c) main structure, construction year/age;

d) extent and level of registration;

e) time of survey;

f) name of the client and contractor (and their representatives, such as the responsible inspector, etc.); and

g) name of other parties involved (and their representatives).

5.3.6.3 Executive Summary

The conclusion should contain the following items:

a) main conclusion/summary;

b) performance;

c) recommended actions;

d) costs/economy; and

e) recommendations for further progress.

5.3.6.4 Main report

The main report should contain the following items:

a) the critical properties, the performance requirements (the reference level) on which the significance and determination of performance degrees and failure are based;

b) the in-use conditions registrations;

c) evaluation of performance by checking against requirements/reference level;

d) assessment of residual service life;

e) evaluation of consequences;

f) evaluation of risk;

g) conclusions

h) evaluation, recommendation and priority of actions; and

i) any calculations of costs.

For all these items, the amount of documentation that should be included in the main report should be assessed. What material should be included as enclosures should also be assessed (see 5.3.6.5).

5.3.6.5 Enclosure

Any basic material describing the item as built or rebuilt which is not part of the performance survey, and supplementary material from the performance survey which is not necessary to include in the main report, should be enclosed with the report.

Annex A
(informative)

Guidance on Factor E — Environmental classification systems and methods for assessment in microenvironments

A.1 General — Classification of aggressivity and corrosivity

The implied basis for ISO 9223 [[13]] is that the classification of degradation should be founded upon knowledge of the damage functions for the materials in question. However, there are also approaches based on a generic classification of the environment, which aim to define a generic aggressivity of the exposure. Such an approach was used by the European Organization of Technical Approvals (previously referred to as EOTA). Some details are provided in A.2 and A.3.

NOTE 1 EOTA is now recognized as referring to the European Organization of Technical Assessment

NOTE 2 A.2.1, A.2.2 and A.2.3 are quoted from the EOTA Guidance Document 003, Assessment of Working Life of Products.[[32]][[54]]

A.2 EOTA Guidance Document

A.2.1 General

The wide variation in European climatic conditions and in the user stresses imposed on structures depending upon type of structure and use intensity makes it necessary with many construction products to restrict their usage to defined situations in order that these achieve the predicted working life.

A.2.2 and A.2.3 contain examples of possible subdivisions.

A.2.2 Climatic subdivisions of Europe

The sphere of activity of EOTA is approximately between latitudes 35° N and 70 °N, which covers a wide range of differing climatic conditions. The most important of these in terms of working life are the differences in ambient temperature and the differences in solar energy intensity at different locations. The combination of these factors indicates that the ratio of rates of chemical reactivity from the north to the south of Europe can be of the order of 1:4.

Although it is possible to produce a Euromap sub-divided by iso-chemical reaction rate lines, this is more complicated than is presently required and a simple subdivision of Europe into three temperature zones based upon general climatic conditions is given in Table A.1.Table A.1 — European temperature subdivision

Zone	**Winter conditions** (December, January, February)	**Summer conditions** (June, July, August)
A	Cold winters Several months temperature rarely above 0 °C Average daily temperature below 0 °C Min. temperatures may be below −30 °C	Max. temperature rarely above 30 °C
B	Moderate winters Frequent frosts Average daily temperature 0°C to 5 °C Min. temperatures may be below −20 °C	Max. temperature occasionally above 30 °C

Zone	Winter conditions (December, January, February)	Summer conditions (June, July, August)
C	Warm winters Infrequent frosts Average daily temperature above 5 °C	Max. temperature frequently above 30 °C. Occasionally above 40 °C
Mountainous regions above 1 000 m	Zone A conditions	Zone C or B conditions

A.2.3 Special conditions (examples)

a) Industrial regions (high SO_2, H_2S, NO_x levels, etc.);

b) Coastal regions (high chloride levels);

c) Regions with high wind and driving rain (possibly in combination with freezing conditions).

Table A.2 gives an example of a climatic subdivision developed by CEN/WG 4/02/01 relating temperature and UV radiation. Other subdivisions are possible.

Table A.2 — Subdivision relating temperature and UV radiation

Parameter	Moderate climate	Severe climate
Annual radiation on horizontal surfaces, GJ/m2	< 5	W 5
Average temperature of the warmest month of the year, °C	< 22	W 22

A.3 Classifications

A.3.1 Global climatic classification

A.3.1.1 General

A simplified classification method is to consider the climate in terms of its two main factors, rainfall/humidity and temperature.

A.3.1.2 Rainfall/humidity

Rainfall/humidity can be divided into four main classifications to reflect the global climate, as follows:

a) dry: rainfall less than 400 mm per year or average yearly 9:00 am relative humidity of < 50 %;

b) sub-humid rainfall is between 400 mm and 800 mm per year or average yearly 9:00 am relative humidity of > 50 % and < 70 %;

c) humid rainfall is between 800 mm and 1 300 mm or average yearly 9:00 am relative humidity is > 70 % and < 80 %; and

d) very humid rainfall exceeds 1 300 mm or average yearly 9:00 am relative humidity of > 80 %.

A.3.1.3 Temperature

The temperature dimension can be divided into the following ranges.

a) Cold: The average monthly minimum temperature is < −5 °C for more than two months of the year. Alternatively, the average monthly maximum temperature for the hottest month is below 10 °C.

b) Temperate: The average monthly minimum temperature is < −5 °C for no more than one month of the year and the average monthly maximum temperature is > 35 °C for no more than one month.

c) Hot: The average monthly temperature is > 35 °C for more than one month of the year.

A.3.2 Global pollutant classification

The pollutant classification is divided into two main areas, industrial pollution and marine pollution with the following definitions.

Table A.3 — Definition of the classes of the global pollutant classification

Class	Class number	Abbreviation	Description
Severe marine and severe industrial	1	SM + SI	Airborne salinity exceeds a daily average of 300 mg/m2/day, and airborne SOx level exceeds 200 mg/m2/day.
Severe marine and industrial	2	SM + I	Airborne salinity exceeds a daily average of 300 mg/m2/day, and airborne SOx level is between 60 mg/m2/day and 200 mg/m2/day.
Marine and severe industrial	3	M + SI	Average daily airborne salinity exceeds 300 mg/m2/day and SOx level exceeds 200 mg/m2/day.
Light marine or industrial	4	M + I	a) Airborne salinity is between 15 mg/m2/day and 60 mg/m2/day or b) Airborne SOx level is between 10 mg/m2/day and 80 mg/m2/day or c) Rain water has a pH < 5,5.
Severe marine	5	SM	Airborne salinity exceeds a daily average of 300 mg/m2/day.
Marine	6	M	Average daily airborne salinity is between 60 mg/m2/day and 300 mg/m2/day.
Severe industrial	7	SI	Airborne SOx level exceeds 200 mg/m2/day.
Industrial	8	I	Airborne SOx level is between 60 mg/m2/day and 200 mg/m2/day.
Benign	9	B	a) Airborne salinity is < 15 mg/m2/day, and b) Airborne SOx is 10 mg/m2/day, and c) Rain water pH is > 5,5.

From those classes, a combined system can be established by combining the climate with its subclass versus the pollutant source; see Table A.4. The environment can be defined by a three-figure number where the first number [ranging from 1 (severe marine and severe industrial, SM+SI) to 9 (benign, B) as defined in Table A.3] defines the pollutant sources; the second number defines the major climatic class (1 for dry to 4 for very humid as defined in A.3.1.2); the third number defines the subclass (1 for cold to 3 for hot as defined in A.3.1.3).

Table A.4 — Matrix classification system for environmental data

Class	Pollutant classification a								
	SM+SI	SM+I	M+SI	M+I	SM	M	SI	I	B
DC	1-1-1	2-1-1	3-1-1	4-1-1	5-1-1	6-1-1	7-1-1	8-1-1	9-1-1
DT	1-1-2	2-1-2	3-1-2	4-1-2	5-1-2	6-1-2	7-1-2	8-1-2	9-1-2
DH	1-1-3	2-1-3	3-1-3	4-1-3	5-1-3	6-1-3	7-1-3	8-1-3	9-1-3
SC	1-2-1	2-2-1	3-2-1	4-2-1	5-2-1	6-2-1	7-2-1	8-2-1	9-2-1
ST	1-2-2	2-2-2	3-2-2	4-2-2	5-2-2	6-2-2	7-2-2	8-2-2	9-2-2
SH	1-2-3	2-2-3	3-2-3	4-2-3	5-2-3	6-2-3	7-2-3	8-2-3	9-2-3

a The first number indicates the pollutant source (see Table A.3); the second number, the major climatic class, e.g. humidity (the numbers 1,2, 3 and 4 are assigned to the classes dry, semi-humid, humid, and very humid, respectively, in A.3.1.2); the third number, the climatic subclass, e.g. temperature (the numbers 1,2 and 3 are assigned to the classes cold, temperate and hot, respectively, in A.3.1.3).

Class	Pollutant classification a								
	SM+SI	SM+I	M+SI	M+I	SM	M	SI	I	B
HC	1-3-1	2-3-1	3-3-1	4-3-1	5-3-1	6-3-1	7-3-1	8-3-1	9-3-1
HT	1-3-2	2-3-2	3-3-2	4-3-2	5-3-2	6-3-2	7-3-2	8-3-2	9-3-2
HH	1-3-3	2-3-3	3-3-3	4-3-3	5-3-3	6-3-3	7-3-3	8-3-3	9-3-3
VC	1-4-1	2-4-1	3-4-1	4-4-1	5-4-1	6-4-1	7-4-1	8-4-1	9-4-1
VT	1-4-2	2-4-2	3-4-2	4-4-2	5-4-2	6-4-2	7-4-2	8-4-2	9-4-2
VH	1-4-3	2-4-3	3-4-3	4-4-3	5-4-3	6-4-3	7-4-3	8-4-3	9-4-3

a The first number indicates the pollutant source (see Table A.3); the second number, the major climatic class, e.g. humidity (the numbers 1,2, 3 and 4 are assigned to the classes dry, semi-humid, humid, and very humid, respectively, in A.3.1.2); the third number, the climatic subclass, e.g. temperature (the numbers 1,2 and 3 are assigned to the classes cold, temperate and hot, respectively, in A.3.1.3).

A.3.3 Modelling of pollutants — Models of SO_2

When evaluating the performance of buildings and constructed assets, knowing the exposure environment is essential in order to assess the cause and effect relationship. Data on the pollutants level can be obtained for various geographical scales (i.e. regional, local and micro) from air pollution monitoring and information networks existing in most developed countries.

The measuring, testing and evaluation of air quality are assuming growing importance in developed countries, as elements of a comprehensive clean air policy and initiatives towards sustainable development. A huge bulk of data is therefore generated on the various geographical levels. Point measurements are very expensive and are needed for policy development and assessment, public information, etc. Measured data need to be combined with modelling based on emission inventories to assess properly the exposure to, and thus the effects of, the pollution on public health or on buildings. Such air-dispersion models exist, and the results can be mapped and exhibited by modern information technology (see Annex D).

A.3.4 Assessment of microenvironments

NOTE This is the same classification scheme as for ISO 15927-3 .[[4]]

The available regional exposure data can be used for characterization of the local and microenvironment at a building or construction object.

The micro-climate is heavily influenced by the macro-climate. The importance of various factors varies for different types of construction objects and depends upon where these objects are used in relation to the orientation of construction and their position on or within the construction.

The moisture content or water availability is important for the corrosion processes. Precipitation and relative or absolute humidity in the air are measured at a meteorological station. Time of wetness can be calculated from meteorological data.

Different methods can be used to describe or express the quantity of water at a wall or construction. In addition to methods using the measured data directly, there are standards such as BS 8104 ,[[2]] which specifies a procedure for analysing hourly rainfall and wind data, derived from meteorological observations, to provide an estimate of the quantity of water likely to impact on a wall of any given orientation. It takes into account topography, local sheltering and the type of building and wall. It specifies the method of calculating the following:

a) annual airfield index, *IA*, which influences the moisture content of a masonry wall;

b) spell index, *IS*, which influences the likelihood of rain penetration through a masonry wall.

The airfield index is the quantity of driving rain that would occur during one hour at a height of 10 m above ground level in the middle of an airfield, at the location of the wall. The airfield annual index is the airfield index for a given direction accumulated over one year.

A spell index is defined as the period, or sequence of periods, with wind-driven rain on a vertical surface of a given orientation, and the airfield spell index is the airfield index for a given direction accumulated over the worst spell likely to occur in any three-year period.

After calculating the *IS* for a period of time, the next step is to estimate the actual building location and exposure compared to an airfield. That is performed by estimating the values of the following four different parameters:

— the roughness coefficient, *C*R;

— the topography coefficient, *C*T;

— an obstruction factor, *O*; and

— a wall factor, *W*;

and converting the airfield indices into wall spell indices, *I*WS, by Equation (A.1):

$IWS = IS \times CR \times CT \times O \times W$ (A.1)

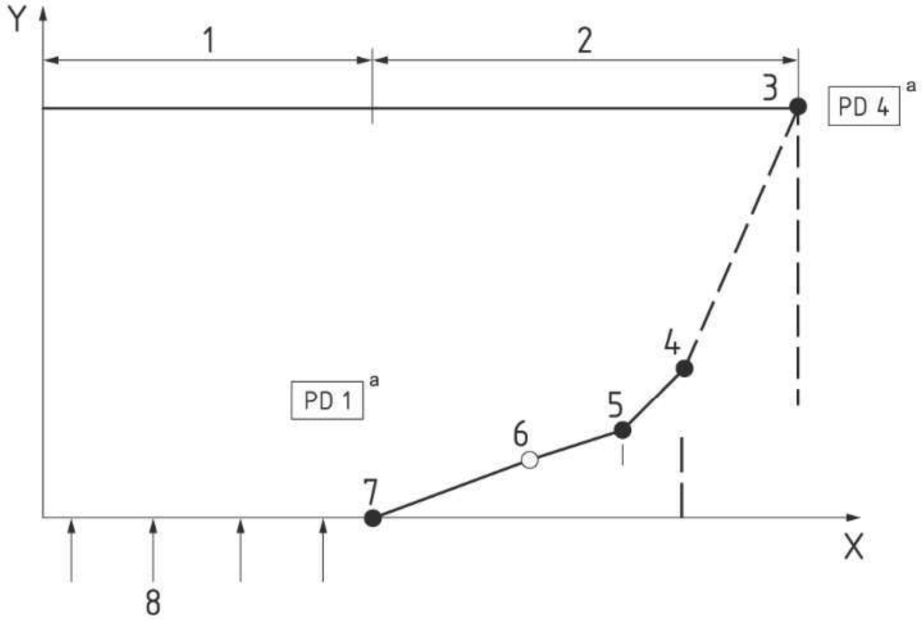
BS 8104 categorizes, describes and illustrates the *C*R, *C*T, *O* and *W* factors.

Annex B
(informative)

Prediction of (residual) service life on the object (single building) level and on the network level (population of buildings)

B.1 Performance degrees related to level of deterioration

In an example of service life prediction and maintenance planning for the concrete structure of the Olympic Tower in Munich, the levels of deterioration of concrete were related to the performance degrees directly; see Figure B.1.



Key

Y level of deterioration
X time of exposure, years
1 initiation period
2 propagation period
3 collapse of the structure through bond failure or reduction of the cross section of the load bearing reinforcement
4 spalling of the concrete cover
5 formation of cracks
6 deterioration recognizable through non-destructive measuring methods
7 depassivation of the reinforcement
8 condition can be comprehended by monitoring
a Performance degrees (PD) are defined in 5.3.4.2.2.

Figure B.1 — Levels of deterioration of concrete as related to performance degrees and limit states [[48]]

When parameters of the models for carbonation or chloride deterioration are known or measured, the residual service life can be calculated after an assessment of the performance degrees on the construction.

Annex C
(informative)

Prediction of the performance development over time by Markov Chain

C.1 General Description

The Markovian degradation models [[42]][[46]] are transition probability matrices which describe the likelihood for a structure, characteristic or property to shift from condition state A to condition state B within one time unit (usually a year). They describe the average rate of degradation in a probabilistic form. These models enable the user to reproduce mathematically the effects of protective maintenance actions and heavy repair actions to the condition and rate of degradation. The Markov chain method facilitates the evaluation of the probability of the structure to be in any condition state at any moment during the treated time-frame.

Maintenance, repair and restoration (MR&R) action models are also Markovian matrix models that show the probability of a structure that is shifted from condition state A to any other condition state as a result of the MR&R action. The influence of coatings and other protective maintenance methods are included in the degradation and MR&R action models.

C.2 Example

The following example contains a synopsis of the content of a "Service Life Prediction of Surface Finishing Coating Systems Based Upon Markov Chain Model"[[49]] and parts herein are reprinted with the approval of the authors and the written consent of CIB International. The survey and evaluation project was carried out in conjunction with the activities of the Sub-Committee 'Reference Service Life' in the Architectural Institute of Japan (AIJ).

C.2.1 Scope of study

The survey and evaluation was done on the external coating systems on a sample of nine reinforced concrete buildings ranging in age from 5 to 16 years. The buildings were publically-owned multi-family high-rise dwellings in the Greater Tokyo Metropolitan zone, exposed to fairly similar environmental conditions in three distinct areas of the zone. Table C.1 presents the building age and the distribution in the areas.

Table C.1 — – Survey buildings

Area	Age (years)
A	9
	12
	16
B	11
	14
	16
C	5
	7
	9

Three types of multi-layer rendering coatings, widely applied as surface coating for concrete, cement mortar and inorganic sidings in Japan, were included in the study. These systems, typically consisting of primer, undercoat, main layer and a top coating, are applied via spray and troweling techniques. Representative surface textures for these types of coatings are presented in Figure C.1.

C.2.2 Performance characteristics survey and evaluation procedures

Five key performance degradation characteristics were examined in the study:

1) gloss reduction;

2) discolouration;

3) chalking;

4) cracking; and

5) air permeability.

Gloss levels were measured using a gloss checker. The gloss levels observed in areas of the buildings that were not exposed to sun and rain were considered to be initial values. Gloss level retention values were then evaluated relative to the initial values, and determined in accordance with JIS K 5600-47(1999) [[23]] and JIS Z 8741(1997) [[25]].

The CIE L*a*b* colour scale [[50]] was applied to the survey samples. The colour phase, brilliance, and chroma of finishing materials were measured with a colour-difference meter. By comparing these values with initial values, determined comparably to that done for gloss level retention, the colour difference was calculated as per JIS Z 8722(2009) [[24]].

In order to measure chalking levels, powders from the surface walls were gathered using a peel-off vinyl tape (5×10cm). Chalking was examined in terms of area and density in keeping with JIS K 5600-8-6(1999) [[22]].

Cracking was evaluated and categorized by visual investigation. The crack degradation grades used in the study, from level 0 to level III, are depicted in Figure C.1.

C061149efig12.EPSAir permeability of the samples was measured using the Torrent permeability tester,[[51]] whereby air permeability is measured by changes in pressure in the inner chamber of the tester. All the excess air flowing into the outer chamber is evacuated, so the air flow into the inner chamber is considered to be unidirectional and unaffected by unwanted ingress of air along the building skin.

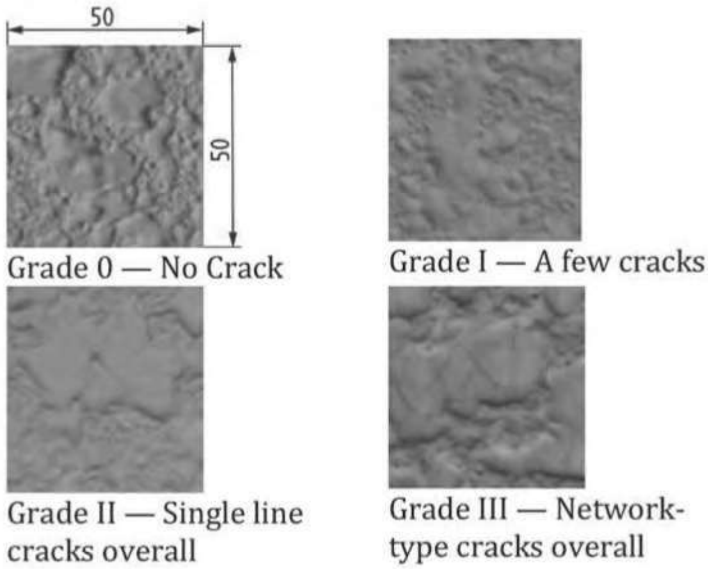


Figure C.1 — Grades of Crack Degradation

C.2.3 Survey results

Histograms of the values for each of the identified performance characteristics were plotted for the cardinal directions (approximating the sample exposure/locations) and each Area. This graphic presentation facilitated identification of tendencies related to physical deterioration and provided some insight as to the potential causes of the degradation.

C.2.4 Markov Chain Model

The Markov Chain Model is a probability theory model in which a future condition is decided only by the present condition, unrelated to past conditions. This model is employed in cases in which the mechanisms and factors at work are not clearly defined, such as in pier maintenance and as a management tool in civil engineering. Figure C.2 a) presents a conceptual diagram of this model, in which two definitions can be seen. First, there are 4 grades of degradation, ranging from 0 to III. Second, X_n is the probability of transition from one grade to the next grade after any time (t) passes. Using this model (Figure C.2 b)), it is possible to simulate ageing degradation. In this study, X_n is derived from the survey results for each area.

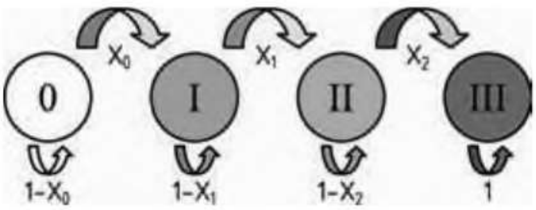


Figure C.2 a) — Conceptual Diagram

$$\begin{pmatrix} 0 \\ I \\ II \\ III \end{pmatrix} = \begin{pmatrix} 1-x_0 & 0 & 0 & 0 \\ x_0 & 1-x_1 & 0 & 0 \\ 0 & x_1 & 1-x_2 & 0 \\ 0 & 0 & x_2 & 1 \end{pmatrix}^t \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Figure C.2 b) — Determinant Representation

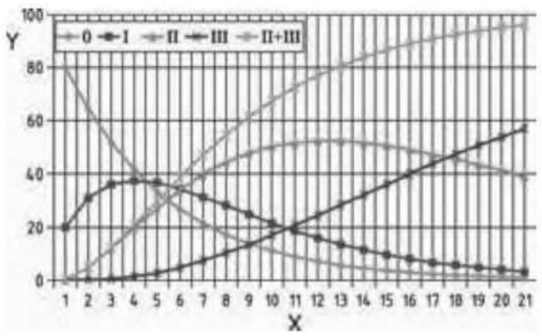
Figure C.2 — The Markov Chain Model

Each condition of degradation is subdivided into each of the grades (Table C.2), and the transition probabilities are calculated in accordance with the principles that all degradation grades are present.

Table C.2 — Classification of Degradation Grade

Degradation Grade Survey Items	0	I	II	III
Gloss Level Retention	80 – 100	50 – 80	20 – 50	0 – 20
Colour Difference	0 – 1,5	1,5 – 3	3 – 4,5	4,5 –
Chalking	0 – 9	9 – 18	18 – 27	27 –

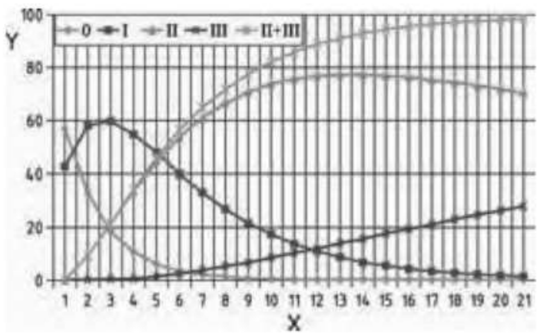
Figures C.3 a) to C.3 f) show the results of the simulation based on the Markov Chain Model. The building ages used are shown in the parentheses. It has been assumed that the service life of the finishing material is the time for II+III to reach 80 % in each degradation phenomenon (gloss level retention, colour difference, and chalking), except for cracking, for which a value of 60 % was assumed. Based upon these assumptions, the estimated service life is 10 years for gloss level retention (Figures C.3 a), C.3 b)), 12 years for colour difference (Figure C.3 c)), 17 years for cracking (Figure C.3 d)), and 23—28 years for chalking (Figures C.3 e), C.3 f)). Thus, a rational maintenance tool may be constructed when sufficient data has been gathered for multiple finishing materials.



X - Elapsed years   Y – Degradation Rate (%)

Transition probability	x0	x1	x2
	0.197	0.240	0.074

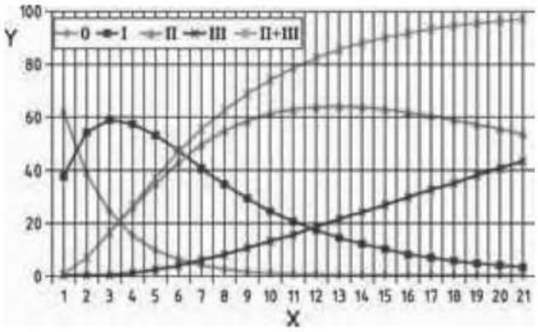
Figure C.3 a) — Gloss Retention – Area B (16 yrs. old)



X - Elapsed years   Y – Degradation Rate (%)

Transition probability	x0	x1	x2
	0.427	0.214	0.024

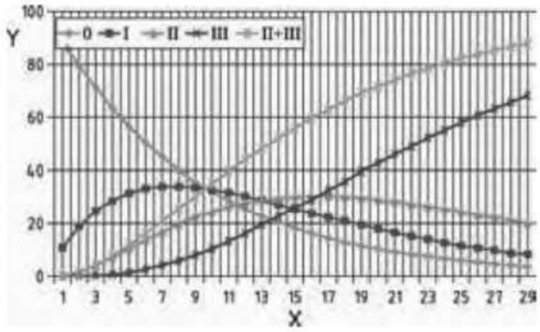
Figure C.3 b) — Gloss Retention – Area C (5 yrs. old)



X - Elapsed years Y – Degradation Rate (%)

Transition probability	x0	x1	x2
	0.373	0.179	0.045

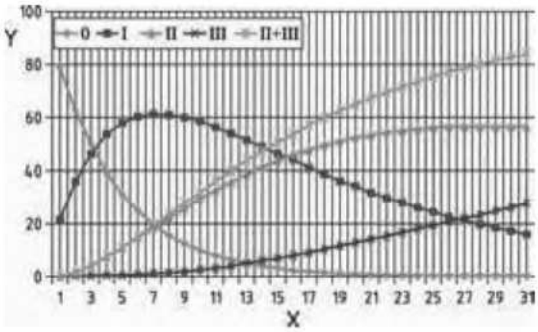
Figure C.3 c) — Colour Difference – Area A (5 yrs. old)



X - Elapsed years Y – Degradation Rate (%)

Transition probability	x0	x1	x2
	0.107	0.140	0.112

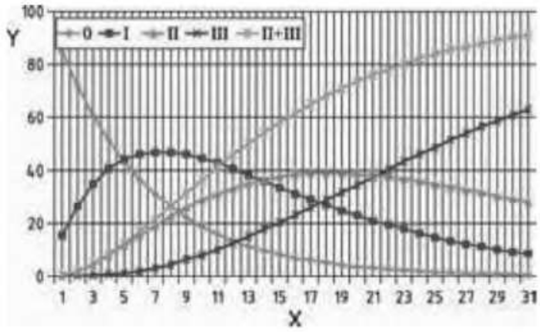
Figure C.3 d) — Cracking – Area A (16 yrs. old)



X - Elapsed years Y – Degradation Rate (%)

Transition probability	x0	x1	x2
	0.207	0.070	0.025

Figure C.3 e) — Chalking – Area A (9 yrs. old)



X - Elapsed years Y – Degradation Rate (%)

Transition probability	x0	x1	x2
	0.154	0.106	0.074

Figure C.3 f) — Chalking – Area C (7 yrs. old)

Figure C.3 — Results of the simulation based on the Markov Chain Model

C.2.5 Conclusions

The Markov Chain Model can be used to predict the service life of finishing materials in various degradations.

Gloss level retention and chalking have little correlation to the ageing degradation.

Colour difference can't be used as a direct indication of ageing deterioration.

Longer-term integration of field survey observations into the Markov Chain Model will improve the accuracy of the probability of transition X_n.

Annex D
(informative)

Worked example of RSL data records from "Inspection of buildings"

D.1 General

Worked examples of two materials/components are given in this annex to illustrate the outline of RSL data records from performance assessment surveys.

D.2 Example 1

a) Material/component

Site painting of hot-dipped zinc-coated sheet steel. Quality and colour of the paint are not specific.

b) Methodology

ISO 15686-2:2012 , 5.4.3.3, Inspection of buildings (see also ISO 15686-2:2012 , A.2.3.1.2)

c) Reference in-use conditions

The outdoor environmental conditions addressing Factor category E refer to the local scale, and are given by the conditions prevailing in Oslo, Norway, in the mid-1990s and previous years. The decisive pollutant is SO_2, which is modelled and mapped and exhibited in GIS systems by the pollution authorities.[[34]] Isolines for five levels of SO_2 are given in Figure D.1.

Figure D.1 — Modelling and mapping of SO_2 in Oslo-network level

Other decisive environmental agents are ozone (O3), time of wetness (TOW), acidity (H+) and amount of rainfall, with values, respectively, of:

— O3 = 34 µg/m3 ± 17 µg/m3;

— H+ = 0,025 mg/l;

— rainfall = 0,6 m/year; and

— TOW = 0,32 % of total time.

Correlations to concentrations of other degradation agents are not reported.

Factor category D is not applicable. As data are based on a survey study of buildings sampled by a random technique, on average the remaining factor categories are all likely to be characterized as "average"; see Table D.1.

Table D.1 — In-use condition rating of factors

Factor category	In-use condition rating
A — quality of components	3
B — design level	3
C — work execution level	3
D — indoor environment	NA
F — usage conditions	3
G — maintenance level	3

d) Degradation agents

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

e) Critical properties and performance criteria

Critical properties and the corresponding performance criteria are expressed in classes of certain standards; see Table D.2:

Table D.2 — Performance criteria for critical property

Critical property	Performance criterion	Reference
Blistering	> 6F	as shown in ISO 4628-2
Cracking	> 4	as shown in ISO 4628-4
Chalking	> 4	as shown in ISO 4628-6
Flaking	> 4	as shown in ISO 4628-5

These properties are all expected to be critical in the reference in-use conditions, while the RSL corresponds to any of the four performance requirements, whichever is violated first.

f) Reference service life (RSL)

Based upon the dose-response functions reported from the UN ECE exposure program and the values of the degradation agents [see d)], as well as the performance criteria [see e)], the service life can be modelled for the Oslo area and exhibited in GIS, as shown in Figure D.2.

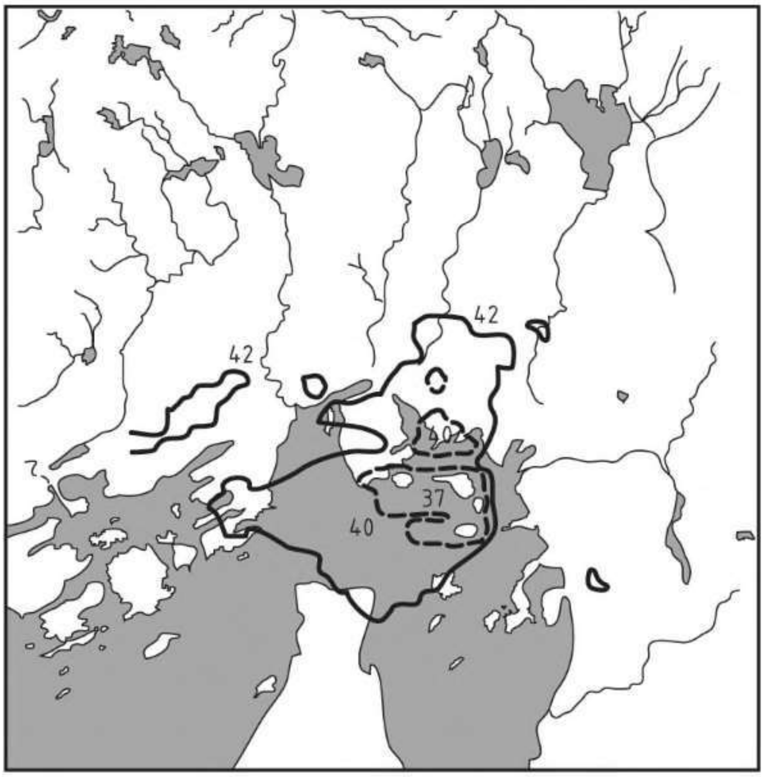


Figure D — 2 — Modelling and mapping of service life for zinc coated steel on network level in Oslo, year 1994, based on UN ECE-derived damage functions [[48]]

g) Data quality

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

h) Reliability of data

Data are provided by non-reviewed public research documentation.

i) Rating code

3-11-21-21

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