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Rode, Carsten; de Place Hansen, Ernst Jan

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Carsten Rode[1, a)] and Ernst Jan de Place Hansen[2, b)]

[1]*Technical University of Denmark, Department of Environmental and Resource Engineering, Building 118, DTU, 2800 Kgs. Lyngby, Denmark*
[2]*Aalborg University, Department of the Built Environment, A.C. Meyers Vænge 15, 2450 København SV, Denmark*

a) Corresponding author: car@byg.dtu.dk
b)deplace@build.aau.dk

Abstract. Assessment of service life of buildings has for several decades been a theme of interest for researchers and building practitioners internationally, e.g. as evidenced by CIB Committee W080. Service life assessment has received renewed interest recently, being a crucial parameter in assessing the sustainability of structures. Furthermore, the increased interest in circular construction and "design for disassembly" principles call for a revisit of how service life is assessed. A new project wishes to establish a common definition and understanding of the concept of service life of buildings and their components in a Danish context. The project strives to establish a service life model for relevant types of buildings and building components, widely accepted in the Danish building sector, based on the most common classification systems and with a reasonable measure of safety. The vision is to be able to ensure quality and robustness of the built environment to reduce the use of resources and to minimize environmental and economic consequences. A closer understanding and prediction of "real" service life of buildings is needed, i.e. also considering non-technical reasons for end of service life, by uncovering and modelling reasons why buildings or parts of buildings are preserved or demolished. The project aims to move from a deterministic to a stochastic approach concerning service life data. The goal is to establish evidence-based key figures for reference service life, maintenance needs, replacement intervals, etc., based on register data and generated, new data with a view to optimizing both the environmental impact and the overall economy of a building. Although the project will involve as many stakeholders of the Danish building sector as possible, it should also be well founded in international development and cooperation in its field. It is therefore of great interest to present and discuss the new project with participants of CESBP 2022.

STATE-OF-THE-ART AND VISIONS OF NEEDS

Estimation of service life of building products is becoming increasingly relevant and necessary. For instance, the Danish Building Code will from 2023 require buildings to be assessed for sustainability, and the service life of building products is an inevitable parameter in this counting. A voluntary sustainability classification has existed in Denmark since 2020 [1], and life cycle assessment (LCA) is an inherent component of such assessment. Estimation of end of service life is crucial for the LCA.

On service life estimation

Internationally, service life estimation has been a vibrant topic of research and development centered around CIB W080 on *Prediction of Service Life of Building Materials and Components* [2] and ISO TC59/SC14 *Design Life of Buildings* [3], consolidating service life estimation in the ISO 15686-nn series of standards. ISO 15686-1:2011 [4] gives the general principles and framework for the methodology, and ISO 15686-8:2008 [5] stipulates the fundamental concepts of reference service life and estimated service life, with the so-called factor method to make quantitative service life determinations. Foundations of the factor method were outlined in [6]. CIB W080's publication on the

factor method as a general framework for service life prediction [7] gives the most recent account of the trends of development of the factor method.

According to the factor method, estimated service life of a building component (ESL) is determined based on a reference service life (RSL) as follows:

$$ESL = RSL \times A \times B \times C \times D \times E \times F \times G$$

where, A-G are different categories of factors that specify fractions by which a component is estimated is to have shorter (<1) or longer (>1) service life than in the reference case. The categories are the following:

A: Inherent performance level (quality of material)
B: Design level (layout)
C: Work execution level (avoidance of faults and improper methods in the making)
D: Indoor environment (e.g. considering risk of condensation, chemical and mechanical exposure)
E: Outdoor environment (exposure to weather, pollution, and mechanical impact)
F: Usage conditions (wear impacted by humans)
G: Maintenance level (proper care and replacement of degraded parts may prolong service life vastly)

ISO 15686-8:2008 gives guidance on determination of the reference service life of a building component, which is very much an issue of data selection, assessment, and handling.

Considering non-technical factors

A view upon service life including four types of service life was suggested in [8]:
1. Technical service life
2. Functional service life
3. Economic service life
4. Aesthetical service life

While the factor method refers to the technical service life, the first three types of view are also recognized in ISO 15686-1:2011 [4] as types of obsolescence of components with typical occurrences:

Type of obsolescence	Typical occurrence
Functional	Function no longer required (obsolete)
Technical	Better performance available from modern alternatives
Economic	Changing pattern of building use
	Fully functional but less efficient
	More expensive than alternatives

The four types of view have been further elaborated in [8], with the first three characterized as (translated quote):
- 'Technical service life' means the time from the installation of the building component in the structure where the building part is technically and physically able to fulfill its original function. The technical service life is determined by the impacts on the building part and the building part's resistance to these influences.
- 'Functional service life' means the time from the installation of the building component in the structure where the original function of the building component is needed. The functional service life is determined by the changes to requirements and wishes for performances that occur due to development in both society in the broadest sense as in the wishes and needs of the users.
- 'Economic service life' means the time from the installation of the building component in the structure, where it is economically justifiable to maintain and replace parts of the building component. The economic life can often be shorter than the technical service life. The economic life is determined by cost and interest rates.

The 4th view on Aesthetical service life is interesting in the sense that it brings in some other considerations, which are of more subjective nature (translated quote from [8]):
- By 'aesthetic service life' is meant the time from the installation of the building part in the structure where the aesthetic standard of the building component can be maintained. The aesthetic service life is determined by socio-technical and psychological conditions, for example, the aesthetic service life may end when a building component patinates in an unaesthetic way, or if it no longer meets users' wishes regarding appearance.

Nevertheless, it may be quite relevant to consider also such non-technical or non-economic reasons why building owners decide that service life is exhausted, as these reasons can be decisive.

Recent trends and needs

Recent trends and interests in building products highlight the need for considering the aspect of circular economy. Direct reuse of materials and components after their initial life in buildings, or their re-use in an upcycled or down-cycled form is nowadays of paramount interest and must be considered in service life assessment. This aspect seems not to have been sufficiently considered in previous methods for service life assessment.

So-called "Design for disassembly" is another concept that has gained interest in recent years. We should increasingly see building products as assemblies rather that monolithic objects and acknowledge that individual constituents can be replaced or simply moved.

Furthermore, there is much more need for adopting stochastic rather than deterministic methods in assessing service life. This is not a new recognition, but we need to further elaborate upon and base tools, assessment and communication on methods that acknowledge, handle, and present the stochastic data.

Finally, it will be increasingly important that concepts of service life are widely understood and used by virtually all members and stakeholders of the building sector: Designers, manufacturers, building owners, building operators, users, financial and insurance institutions, and authorities. From the above techno-economic and human/subjective deliberations, we would like to express an aspiration that we should be able to come close to what may be understood as the "real service life" of building components.

For this reason, a new Danish framework programme was suggested on "DECAY - reference values, calculation methods and causal analyses of the service life of buildings and building components". The programme and the first financed 2½-year project to be carried out jointly by Aalborg University and Technical University of Denmark from Oct 2021 aim at having a strong involvement of relevant members of the building sector, as it will be further outlined in the remainder of this paper.

Despite of its national conception, it will be obvious that the project should go along with and contribute to international research and development in its area. For this reason, and to gauge the philosophy of the project with international peers, we are presenting this project and invite for reactions.

PROGRAMME DESCRIPTION

The basic question that DECAY seeks to answer over the coming 10 years is as follows, illustrated by Fig. 1:

Why does our building stock decay - or persist?

FIGURE 1. Illustration of the dilemma: The building block on the left is under refurbishment, while the building block on the right, from the same neighbourhood, is awaiting demolishment. What technical and non-technical reasonings enable us to determine the real service life? On what basis was it decided to renovate the building on the left and not the one on the right? Photos: Eva B. Møller.

Thus, goals of DECAY are:
- To establish a common, wider definition and understanding of the concept of service life
- To establish a widely accepted common service life model for relevant types of buildings and building components calculated according to the most common classification systems and with a reasonable measure of certainty.
- To establish evidence-based key figures for reference service life, maintenance needs, replacement intervals, etc., based on register data and generated, new data with the purpose of optimizing both the environmental impact and the overall economy of a building.
- To identify and model reasons why buildings or parts of buildings are preserved or torn down. For example, individual houses built in the 1960s are being demolished, not because they necessarily are obsolete, but because they often prove difficult to rebuild and make energy efficient in an appropriate way. At the same time, older multi-story buildings are often preserved.
- To develop technical solutions that are buildable, robust, sustainable, and operationally friendly, and where the service life can be predicted. Maintenance shall be planned before damage occurs, by easily replacing worn out parts, and by having a building envelope that effectively protects the main structure.
- To advise authorities, members of the building sector and others on how the building legislation can relate to operation and maintenance, e.g. by proposing minimum requirements for durability of selected building parts, where the durability is determined by one uniform method.
- To communicate with the industry about key figures, concepts, models, and experiences about service life via digital solutions.
- To ensure international anchoring through collaboration with international research and international organizations in the field.

A new service life model must consider that many components are so complex that individual parts cannot be replaced, which is why the service life must be assessed for the entire component. It must be considered that not only technical reasons determine how much is replaced, even though technically only a single component is worn out. The focus must be on the building parts that are worn, i.e. the building envelope. A prototype of the model must be described unambiguously and operationally, so that it can be tested, evaluated, and adjusted in collaboration with all stakeholders. The completed service life model must be documented and commissioned together with the official authority and the central industry organizations.

The ambition is that the final service life model can be used in different contexts, depending on whether the user's focus is on sustainability, flexibility, or something else. The model must as far as possible include both the technical service life and the "real" service life.

SHORT-TERM CHALLENGES AND HOW THEY WILL BE ADDRESSED

In the short run, two new, central development trends place increased focus on service life:
- The certification scheme DGNB [9] based on the UN definition of sustainability, has gained quite some attention in recent years. The DGNB scheme's latest manual from 2020 [10] contains the criterion ECO2.1 on robustness, which aims to choose robust long-lasting solutions for roofs, facades, and windows. A DGNB-certified project can either choose to look up the service life in [8] as documentation for robustness, or make a calculation of service life for roofs, facades and windows adapted to the specific construction via the website levetider.dk [11] (in English: "service life.dk"), launched in 2008, using the concept of the factor method.
- The voluntary sustainability class, including requirements relating to life cycle cost (LCC) and environmental assessment (LCA), launched in 2020 by the Minister of Housing [1], will become part of the Danish building regulations in 2023. Service life of building components is important in relation to how often building parts must be maintained and replaced, and thus crucial for the building's LCC and LCA.

This increased focus on buildings and the service life of building components raises several challenges that should be addressed in the short term.

First, the Danish website https://levetider.dk/ [11] originally funded and operated by the Landowners' Investment Fund, requires a technological update. As this website is quite known in the Danish building sector, it will be relevant

to disseminate new experiences and knowledge on service life through this site after being redesigned. The aim is to let it become the central Danish 'repository' for knowledge about service life of buildings and building parts.

Secondly, both the website https://levetider.dk/ and the service life table [8] are based on the classification system SfB, but service life tables have also been developed based on other systems [12], [13]. Subsequently, other classification systems have been added, e.g. [14], without necessarily having an accompanying service life table. A translation between the different classifications and definitions of service life is needed as the different tables and tools do not use the same reference for service life. They do not cover all relevant building parts, they are not developed for the same purpose, and they were developed several years ago. This makes it difficult to work across systems.

Third, very few studies have made causal analysis and provided explanations of real service life of buildings and building components. or studied which factors may be the most significant for the "real" service life, e.g. [15], [16]. A deeper state-of-the-art will uncover important factors, as well as a delimitation and clarification of the service life concept. This will include how climate change and circular possibilities such as recycling and upcycling affects previous assumptions about technical service life.

Fourth, only a few Danish studies have attempted to determine the service life of buildings and building parts through systematic statistical analyses of e.g. accounting data for the operation of public housing, or changes to records in the Danish Building and Dwelling Register (BBR). Very little data is available to specify how large a maintenance effort is required to extend the service life of a given structure, as well as the extent to which factors other than technical service life, are decisive for the actual service life. An initial screening of existing data sources is required to assess whether data can be extracted in an easy way, and how valid they may be.

Fifth, the website levetider.dk is based on ISO 15686 using a deterministic principle for determining service life. However, the standard is largely unknown in Denmark, and there is a tendency among international researchers to favour a probabilistic approach. An assessment of these new models will be a relevant step towards ensuring the best possible basis for a new Danish service life model for selected building parts, focusing on building parts that are worn out, i.e. the building envelope.

And sixth, Danish contributions to international networking, development and standardization within the area shall be facilitated, for example under the auspices of CIB, EU, and ISO/CEN.

The first project being part of DECAY is organized into several work packages responding to these challenges, including dedicated work packages ensuring a dialogue with the building sector and developing a catalogue of subsequent, independent projects that go deeper into specific tasks.

TARGET GROUPS AND DISSEMINATION ACTIVITIES

The primary target group of the first project is the national building sector and knowledge communicators, including building owners, operation and maintenance managers, consultants, contractors, insurance and financial institutions, national, regional and municipal authorities and planners, standardization organizations, environmental certification organisations, and knowledge institutions involved in dissemination. Knowledge institutions will be able to apply and disseminate the acquired knowledge through training, course activities and dissemination products, including instructions and tools such as the Danish tool for calculating life cycle cost (LCCbyg) [17].

Another target group is the international research community, especially the members of CIB W080 'Prediction of Service Life of Building Materials and Components'. DECAY will also be used as a key to collaborate on European research (e.g. within Horizon Europe), where relevant calls occur, and if possible, to influence European research programmes so that the concept of service life becomes more eminent.

The most important dissemination activity both during the first subproject and for the rest of DECAY's duration will be a redesign and continuous update of the existing website levetider.dk with new experiences and knowledge, as described previously.

Furthermore, industry-oriented activities such as interviews, workshops, webinars and development activities will be included to ensure a dialogue with as many stakeholders in the building sector as possible about, for example, the concept of service life, to have it more firmly constituted. Workshops or webinars are expected to be held quarterly, while a reference group mainly consisting of building owners and operators, and consulting engineers and architects, being those who should demand the use of service life, is expected to be convened for semi-annual meetings. In addition, the project will include distribution of press releases and newsletters, publicity on LinkedIn and other SoMe, participation and presentations at conferences, etc.

Finally, the project's results are disseminated in the form of teaching - both for students in master's programmes, and in courses for the industry. In addition, it is expected that the project's results will be published internationally in journals and with special focus on CIB W080 'Prediction of Service Life of Building Materials and Components'.

CONCLUSIONS

The paper proposes work done on the well-known concept of service life for building structures such that it can better accommodate contemporary needs to assess circular construction and regarding buildings as composite structures that will be partly renovated over their lifetime. Furthermore, there is need to consider as well non-technical reasons for demolishing buildings or their components, and to consider better the stochastic nature of the involved processes and decisions. The paper has given an outline of a framework programme to develop these ideas between knowledge institutions, companies and stakeholders in the Danish building sector. However, as we believe that the ideas should resonate internationally, we would hereby like to invite for a dialogue on the path that this initiative will pursue.

ACKNOWLEDGEMENTS

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