Influence of service life on Life Cycle Assessments

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Summary

Environmental assessment is part of present decision making. But, because of difficulties the assessments are not as profound as could be. Life Cycle Assessment (LCA) is a cradle-to-grave approach and consequently a time factor is embedded. Until now this time factor is fixed and calculations are based on index figures. One of these index figures is the service life of a product. The accuracy of this service life can be questioned.

The service life is influenced by many aspects. Three of these aspects also have an influence on the environmental burden: premature replacement, sequential use and subdivision of environmental burden. These aspects lead to a service life different from the index figures and as a result the environmental burden of the building (or component) will differ as well. Aim of this article is to indicate the value of knowledge about service life. Only with a valid service life further assessments are useful and profound environmental assessments can be carried out.

Keywords: Service life, life cycle, environmental burden, time, sequential use, replacement, service life prediction, factor method, index figures, Life Cycle Assessment (LCA),

1. Introduction

Building regulations are present since a long period. Starting with safety regulations, but gradually covering fields like size, convenience, and inventory as well. One of the aspects that is not (yet) put in legislation is the environmental burden of a building. Blind spots like allocation, data quality, general (political) consent, service life, weighting and calculation method make it difficult to execute an environmental assessment. This article concentrates on one of the blind spots: the role of service life within determining the actual use of components in a life cycle. This is a necessity for accurate environmental assessment.
2. Environmental awareness

2.1 Environmental burden

Defining the environmental burden is becoming a field of expertise in the building sector. The awareness has risen that in order to preserve the environment and ‘to fulfil the needs of the present without compromising the ability for future generations to fulfil their own needs’ [1] the building sector has to take environmental choices into account. Most methods for calculation of environmental burden are based on a Life Cycle Assessment (LCA), and use a cradle-to-grave approach. Every aspect between the extraction of materials until the waste scenario is included in the assessment. Within a LCA the amount of materials used is calculated and translated by characterisation factors into the environmental effects. The procedure a LCA has to be performed is documented in the ISO 14000 series [2], where definitions are given and the structure of a LCA is shown.

A complete LCA consists of all the materials used throughout the complete life cycle of the building. Replacing a component increases the amount of materials used in the building. Because of the increase of materials it is important to know how many products are necessary in a life cycle. A lot of the environmental calculation programs currently available fail to determine the exact number of components.

2.2 Materials in building

LCA is widely used in different sectors, like for example the consumers industry. In it’s origin it is not meant for the building sector. In most other sectors the total life cycle of a component is limited to a couple of years, like consumer products which have an average service life of 5-10 years. These periods can be overseen and replacements only take place once or twice in the entire life cycle. Buildings are designed to last longer. The (theoretical) life cycle of a building lies at 50, 75 or sometimes even 100 years. During this life cycle, replacements will take place. Because of replacements and maintenance the actual amount of materials used in a building is more than the initial amount of materials in the building. Concentrating on the building phase only is not accurate enough. Time has a crucial influence on a life cycle. Klunder and Van Nunen [3] discern six aspects that indicate the influence of time on LCA.

1. design, (current design extrapolated through the life cycle)
2. production technology, (new materials or concepts used)
3. re-design, (the possibility for reuse)
4. waste treatment technology, (advanced techniques in the future )
5. technical service life (replacements based on technical aspects)
6. functional service life (replacement based on other aspects)

Main conclusions of their article is that a LCA is based on a building, built at this moment and replacements are calculated with today’s products. The production technology will develop and a replacement necessary over 20 years will probably be done with more advanced products than the ones used at this moment. Using LCA in the building industry is complicated, because each building has its own characteristics, buildings have extremely long life cycles and incremental changes are a feature of building industry. Therefore, the factor of time is of major importance in whole building assessment.

2.3 State-of-the-art

At this moment each country has it’s own environmental program for the building sector. In the report ‘Comparative study of national schemes aiming to analyse the problems of LCA tools and the environmental aspects in harmonised standards’ [4] a first step towards possible harmonisation of all these methods in Europe is studied. However before harmonisation really can take place some difficulties within the LCA-techniques have to be overcome. Allocation, data reliability and weighting are examples of these difficulties. The previous section mentioned the importance of time in building assessment. The service life is used to take time into account in LCA. Until now the service life of a component is based on experiences, practical values or databases. The accuracy of this service life can be questioned.
3. Three kinds of service life

When looking at the service life of a component in most cases an average result will be shown. However not much data about reference service life is available. In Britain a publication about minimum service life is published by Housing Association Property Mutual (HAPM) [5]. The work originated with an insurance company that indicates the service life a component must at least fulfil over a period of 35 years. The service lives given by HAPM are low, because they are minimum standards which all products have to acquire. In the Netherlands a report is published by SBR (Foundation for Building Research) which contains reference service life’s for over 500 materials and/or components. This report is developed by a board of experts, each giving their opinion of the expected service life of a certain component. This way a reference (average) service life is agreed upon. Some remarks about this type of acquiring reference service life’s (i.e. spread and gathering data) are mentioned in the SBR report as well. These reference service life’s are used to calculate the environmental burden of a component. However there is more about service life than finding a reference. There are three characteristics concerning service life that influence the environmental burden. These three are:

1. premature replacement; replacing products before it is a technical necessity;
2. sequential use; replacement of (identical) products within the overall service life of the building;
3. subdivision of environmental burden; regarding environmental burden as a linear process, instead of dividing it in different phases.

In the next paragraphs these will be discussed.

3.1 Premature replacement

The service life of a product will end at the moment the product reaches its End Of Life (EOL). There are many ways in which a product can reach its EOL. Van Nes et al. [6] mention six different ways of obsolescence for consumer products. In ISO standards [7] three kind of EOL for the building sector are discerned. Concentrating on the building sector the following three EOL scenario’s will be distinguished: technical, economical and functional EOL. The best known type (and most easy to comprehend) is the technical service life. When looking at the reference service life published by SBR, it is the technical service life that is displayed. This is because for centuries this was the aspect that determined the replacement. However, looking at the figure 1 technical service life will in (most cases) occur last. The technical service life is over when the component can no longer fulfil the performance it needs to (i.e. a leaking roof, a broken window). Another type of EOL is the economical EOL. This occurs when another component can fulfil the same (or better) function but with lesser costs. (i.e. central heating system, maintenance). The EOL that probably occurs first is the functional End Of Life. This occurs when the component does not fulfil the function people demand of the component. In this case function can be a very wide range: the door doesn’t open any more, the living room isn’t large enough or the colour of the tiles doesn’t please the user anymore. These three EOL’s define the moment that a component will be replaced. Regarding the three EOL’s the following can be concluded: at his moment it is not longer the product that indicates the end of (technical) service life of a product, but it is the occupant who decides that the (functional) service life of the product is over.

![Fig. 1 Different kinds of End Of Life](image)
3.2 Sequential use

A second characteristic concerning service life is called sequential use. The life cycle of a complete building covers a long period. During this life cycle components that have a shorter service life will have to be replaced. Each component has a reference service life (RSLC), but this service life is liable to deviations. To get a grip on this deviation a (normal) distribution can be used. A certain percentage of components will fail prior to the reference service life and a percentage will fail well after the reference service life. If it is only one product this spread will not cause a huge problem. However when multiple products follow after each other with positive and negative deviations it is hard to estimate the amount of components needed. In the figure below the effect of deviations is shown in an example of components with a reference service life of 15 years used in a building with a total life span of 50 years. Scenario 1 shows the reference service life, scenario 2 the positive approach and scenario 3 the negative. In the best case three products will do, but in the average and worst case four products are necessary. Looking at the average scenario a new product is required in year 45. In practice this will be dealt with by keeping the third product in shape for a couple of years or accepting a lack of quality. The worst case really needs four products. When more products are used in a sequential way the influence can be large.

3.3 Subdivision of environmental burden

Until now the discussion has been about defining the service life. There is a relation between the environmental burden of component and time. Three different phases can be distinguished: mounting, use and demounting. Mounting a building will have a relative high level of environmental burden, partly because of the production of materials. In the use phase the environmental burden will only slightly increase because of maintenance (energy consumption by habitants is not taken into account). The last phase is demounting and there the waste creates the
highest burden. In figure 3 this subdivision is illustrated. In the use phase the increase of environmental burden is small compared to the prolonged service life. In the example this is shown by the light coloured graph. When prolonging the service life the average environmental burden will decrease.

Another issue that is tied to this fractional approach of environmental burden lies in the calculation programs. Most programs use the average environmental burden of a component. When a product with a service life of 50 years will be used in a building with a life cycle of 75 years it is common practice to use $75 \div 50 = 1.5$, so one and a half components. However the last component has to be built and demolished as well. The actual environmental burden lies therefore closer to the environmental burden of two components. Calculating an environmental burden his way has a more positive result than the situation actual is. But some programs still use this way of calculating.

![Environmental burden divided in mounting, use and demounting](image)

**Fig. 3 Environmental burden divided in mounting, use and demounting**

### 4. Factor Method

In the previous sections difficulties concerning service life are mentioned. The need for accurate service life prediction is elaborated in the introduction. The joint committee CIB W080 /RILEM 175-SLM has written draft reports on this topic [8]. In three different approaches research of service life prediction were done. These different approaches are:

- stochastic design;
- engineering design;
- factorial method.

Each approach is being dealt with in a CIB-study. When defining the service life of a component a lot of factors have an influence on the service life. When an environmental assessment is carried out, the actual service life’s need to be known. Looking at the three approaches, the factor method is the method that is most simple to use. However the results with the Factor Method may have a larger variation. Despite this disadvantage the Factor Method is used for further service life prediction.

The Factor Method uses seven factors to compensate for specific situations. These factors are:

A  Quality of the component

B  Design level
For each factor a value must be used whereas the mean is 1.0. i.e. a product consisting of high quality raw materials will be more resistant to influences from outside. So in order to compensate this, factor A (quality of the component) will be 1.2 instead of 1.0. Another example can be the location of the building. With a building near to the sea the outdoor environment (factor E) will be more severe than the average. Factor E will become lower than 1.0. When these factors and the reference service life are all multiplied a specific service life, more accurate for the specific situation can be predicted. The details of this method are described in ISO 15686. To come to a service life prediction that is even more accurate the factor method is evaluated with a statistical approach. Aarseth and Hovde [9] use a statistical approach on the outcome of the multiplication, the entire outcome is judged on its variation and the predicted service life is given with boundaries. Moser [10] uses a statistical distribution on every factor. The factors all have different distributions, because not all factors are distributed in the same way. All these separate factors, with their boundaries are multiplied and the result is a mean with boundaries. This is the actual predicted service life, calculated with the Factor Method.

5. Further research

The Factor Method is a new area of service life prediction. Up to now just few researches have been done in this field of expertise. It is the advantage of a simple method against the disadvantage of accuracy. Future developments should minimize the disadvantages. What kind of service life is predicted is an aspect that is not taken into account in the Factor Method at this moment is. The section premature replacement describes three ways that can initiate replacement. With the Factor Method the technical replacement can be estimated. Functional replacement is another area. One of the conclusions of section 3.1 is that technical service life is not always initiating replacement. To make that accountable in the factor method, two factors are added: Trends (T) and Reuse (R). The factor Trends is used to indicate the liability for replacement because of a trend. A trend in this case could be colour, shape, interests, fashion or other reasons. An example is a front door with a reference service life of 15 years. But after 12 years people want to change their door, because they want a door with a window. The existing door still functions (technically), but people want another door, the function has expired. In this case the factor will be 0.8 (12 of 15). The second factor (Reuse) takes into account the possibility to demount a component. If a component can be easily demounted, it will be done more often than a component that only with rough measures can be demounted. An example are internal wall panels which will be changed more often than the concrete structure of the building. The liability to change has to be translated in the factor Reuse. The implementation of these new factors is the next step to be taken. First of all the independency of all the factors must be checked. The different statistical approaches in the method must be reviewed. If the model is working a case study will be done for an existing building stock. Looking back at a fifty year old neighbourhood with uniform buildings, what replacements have taken place in the last decades, and using the factor method, what results do we get?

6. Conclusion

The service life of a component is information that will be used often. Sometimes an estimate will do, but more often an accurate figure is required. When looking at environmental assessments like LCA, the influence of materials can be huge. Just little grams of material can cause an enormous environmental burden. When only reference service life’s are used the outcome will not be as accurate as desired. The three examples of premature replacement, sequential use and subdivision of environmental burden illustrate this. LCA has its own problems, one of them being defining of the service life. Using the factor method, in an extended way with two new factors, the service life can be more precise and consequently the environmental assessment can be more accurate. Knowledge of the influence of the service life can make it easier to execute the environmental assessment and decision making can be done on a calculated base with sound methods.
7. References


