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Abstract

What is the average lifespan of dwellings?
Though of decisive importance for the provision, maintenance and management of housing stocks, and despite a choice of research papers about the subject, the last word about this question is far from said.
At first a distinction should be made between the technical lifespan and the functional service life. The technical lifespan is decisive for the physical existence of a dwelling, the service life for the length of time that a dwelling fulfils the functional needs of households.
This distinction is not always clear in the available research sources which show a wide range of approaches, varying from ex-ante assessment of the physical condition and estimation of the residual technical lifespan, financial analyses of the profitable service life and/or depreciation period through ex-post mortality analyses in analogy to human mortality. Most ex-ante approaches start from a limited scope; an all-encompassing interdisciplinary approach is missing. On the other hand ex-post analyses suffer from the fact that – in contrary of human populations – buildings are man-made, -managed and -demolished; the vast majority of housing stocks is very young and consistent longitudinal series are missing. As a result, none of these approaches leads up to now to useful results, let alone reliable predictions.
As the technical lifespan of a dwelling as a whole strongly depends on its numerous different components, knowledge of technical lifespans of dwellings and building component is also of decisive importance for ex-ante environmental life cycle assessments and life cycle cost calculations.
Based on an overview of the available sources, the paper discusses the pros and cons of the existing knowledge, possible improvements and alternatives.

Keywords: Lifespan, Dwellings, Housing management, Housing Statistics, Obsolescence

1. Introduction

What is the average lifespan of dwellings?
Though of decisive importance for the provision, maintenance and management of housing stocks, and despite a choice of research papers about the subject, this question still fails reliable answers.
This paper is an enquiry into what is known about the life span of residential buildings, what is still to be explored and where and in what way the answers can be found.

1.1. Relevance

As stated above, knowledge of the lifespan of residential buildings is of decisive importance for the provision, maintenance, management and sustainability of housing stocks, ranging from the level of stock owners through neighbourhoods, local-, regional and national authorities. But also for the building production sector, the finance and insurance sector, the waste processing and recycling sector and last but not in the least the research and education sector, in particular for life cycle analyses to reduce the ecological footprint of the housing stock.

1.2. Problem definition and research questions.

The problem definition underlying this paper reads as:
What is the average lifespan of dwellings, what factors determine this lifespan and how can the life span be assessed?

Following this problem definition, the research questions to be answered in this paper are:
1) What do we know about the average lifespan of residential buildings?
2) What factors determine this lifespan?
3) How can this lifespan be assessed?
4) What conclusions can be drawn about the average life span of residential buildings, what knowledge is still to be explored and where and in what way the answers can be found?

1.3. Research approach

In this paper the research question will be enquired by analysis of the available literature, completed with own expertise.
Research question 1) and 2) will be answered in section 2 and question 3) and 4) in section 3 resp. 4. To limit the extent of this paper, only relevant sources are referenced; an all-encompassing systematic overview of the literature search is left behind.

2. Life cycle and lifespan of buildings, concepts, definitions and approaches

The life cycle and lifespan of buildings have been studied by a wide range of researchers from different disciplines, in particular building technology, property economy and finance, statistics and policy analyses, resulting in an accordingly range of research papers. The vast majority of these sources sticks to the author's discipline, broad interdisciplinary approaches are rare if not missing. Nevertheless, some definitions and concepts are broadly supported, in particular the distinction between physical life span and service life, e.g. (Awano 2006, ISO 2000) and between physical, functional (social) and economic decay / obsolescence and accordingly life span(Grover and Grover 2015).

2.1. Concepts and definitions

2.1.1. Lifespan, life cycle and service life

As the word lifespan (or lifetime) indicates, the lifespan of buildings is habitually approached in analogy to that of living beings. But unlike these, buildings are man-made, man-controlled and man-destroyed artefacts and so is their lifespan.
Buildings vary in a multitude of different types, size, quality, use, age, construction, location, architecture, tenure etc. resulting in numerous different species. Buildings are composed of a multitude of building elements and building materials with each a different lifespan, necessitating regular maintenance and/or replacement. As such the physical life span of a building is also a composite result of maintenance and partial replacement which can in principle be infinite with eventually the foundation and ultimately the land piece as permanent footing. Even without maintenance the (physical) life span of buildings can be very long as the ruins of old castles and settlements show.
The (physical) life span of buildings can thus be defined as the time span a building e.g. dwelling is physically existent, or in economic terms, as the time span a building is economically valid.

But, apart from protected heritage, the life span of most buildings will not be endless but determined to their fitness for use, being the extent to which the building is able to fulfil its purpose, that is the service for which it serves. This time span is generally called the (real) service life, defined by Awano (2006 p. 22) as the period during which buildings actually meet (its) space demand.

As the main purpose of residential buildings is to provide human shelter - being not only bare space but also qualities as safety, usability, comfort and identity - the service life of a dwelling can be defined as the timespan during which it actually meets resident demands. Lifespan assessment of dwellings is commonly targeted on this definition.
As for residential buildings, the sequence of maintenance and replacement is generally planned, resulting in successive cycles of maintenance, major repairs, deep renovations and/or transformations and finally demolition, depending on the life cycles of the different building parts and elements, their adequacy and fitness for use. These cycles can be recognised as life cycles of a dwelling, defined as periods of continued service life unto ineluctable physical intervention, either in-depth renovation, adaptive reuse or demolition.

2.1.2. Causality: physical, functional and economic lifespan

As stated above, the lifespan of buildings can be approached from different disciplinary viewpoints, related to the main causes of failure and decay with consequences for the lifespan. As such three different kinds of decay, obsolescence and lifespan can be distinguished: 1) technical/physical, related to the technical qualities and physical performance, 2) functional/social, related to the functional qualities and social performance, and 3) economic, related to economic performance of the building (IVSC 2014, Grover and Grover 2015, Mansfield and Pinder 2008). The latter authors add to this locational obsolescence: where an area suffers from devaluation, either by market changes, earthquake risk or urban planning. Specific end of life causes that are not included in these concepts are disasters (fire, explosion, collapse etc.). In fact, processes underlying ageing and decay are much more complex, consisting of continuous series of interrelated cause-effect processes (Bradley and Kohler 2007, Thomsen and van der Flier 2009).

Following the causal perspective, three definitions of lifespan are commonly used (Hermans 1999):
1) Technical or physical lifespan or physical service life, defined as: the period over which the asset may be expected to last physically, to when replacement or major rehabilitation is physically required (Woodward 1997);or more recent and formal: Period of time after installation during which a building or its part meet or exceed performance requirements (ISO 2000). The awareness that the conditions for the lifespan in this sense are largely determined in the design phase has led to the introduction of the term design lifespan, being: The assessment of a structure, both as a complete building and individual components, which predicts its potential lifetime based on levels of design, workmanship, maintenance and the environment (Kelly 2007).
2) Functional or social lifespan, defined as: The period over which the need for the asset is anticipated (Woodward 1997). Though widely mentioned in the literature, specific definitions are hardly found and descriptions show great similarity with the afore cited ISO definition, be it with an emphasis on the user c.q. residents.
3) Economic lifespan: the period over which the asset may be expected to last physically, to when replacement or major rehabilitation is physically required (Woodward 1997), or: the period that no alternative exists with lower or at least equal exploitation costs (Hermans 1999).

2.1.3. Causality: the role of building period, location, dwelling/construction type and tenure

Though inevitable, the term average life span needs clarification. In fact, the length of lifespans are far from evenly distributed. Building period, dwelling type, construction type and tenure are of decisive importance (Thomsen and van der Flier 2009).
Although the building period correlates with the age and building standard, older does not mean nearer to demolition. In contrary, due to period bound differences in building quality and attractiveness of architecture and environment with associated degrees of earlier renovations and improvements, life spans can be completely different.
The same applies to some extent for dwelling and construction type, be it strongly depending on tenure. Demolition in the Netherlands – but also in most EU countries and outside – was mainly concentrated in the social rented sector, in particular due to large scale redevelopment of early post-war so called ‘run down’ areas with portico-type apartments and to a lesser extent gallery-type high-

rise apartments (Thomsen and Andeweg-van Battum 2005). On the other hand, demolition in the owner-occupied sector concerns practically exclusively detached houses, particularly in high demand areas where the value of the land as building site exceeds the value of the existing building (Thomsen and van der Flier 2007), whereas demolition of owner occupied semi-detached houses, terraced houses and apartments is a rare exception.

2.1.4. Statistics, data and availability

Apart from private sub-collections of housing associations and other large real estate companies, the collection and availability of housing stock data is a matter of national statistics. Though all EU countries provide statistical data of their building and housing stock, data on the average lifespan of dwellings are difficult to find, due to the long lifetime and the difficulty to find data that go back in time far enough (Sartori, Sandberg, and Brattebø 2016). The available data have a high uncertainty and cover generally just gross totals. Though highly decisive for the lifespan as explained above, subdivision in building period cohorts, dwelling types, construction types and tenure are largely missing.

Similar to population data, housing stock statistics are usually based on positive mutation by addition – subdivided in new construction and other additions (by splitting, conversion etc.) – and negative mutation by withdrawal – subdivided in demolition (planned or by disaster) or other withdrawal (by merging, change of use etc.).

3. Lifespan assessment, approaches, limitations and constraints

Life span assessment of buildings is mainly applied as a kind of forecasting. It has as such been studied in many ways, depending on the field op application, the research targets, the expertise and disciplinary background of the researchers and the way causality is handled. For example, from a technicians viewpoint the lifespan of buildings is primarily approached by the assessment of the physical performance and durability of the constituent building components, whereas property surveyors look at the economic performance and rate of return on the asset. On the other hand statisticians and actuary will look at the statistical probability of decay and mortality. More recently, the need for sustainable building stocks comes with an upsurge of new research e.g. EPISCOPE (TABULA/episcope 2016).

The applicable approaches can be divided in several ways: by the methodical approach: ex-ante or ex-post analysis or a combination of both and/or by the definition of lifespan (2.1.2) and the related targets and discipline of the applied expertise. The choice of approach also depends on the scale and composition of the research object, the kind and accuracy of the intended results and the applicable methodical limitations and constraints.

3.1. Ex-ante vs. ex-post

In short, ex-ante analysis refers to any prediction that is made prior to either before variables can be known or generally before an event occurs, whereas ex-post analysis uses historical data (Ledolter 2011). For example, demographic analyses are generally based on long term ex-post mortality statistics, whereas exchange rate or company returns or other forecasts about events where historic data are not available or not reliable are generally derived from ex-ante analyses.

Similar to human mortality, actuaries approach lifespan forecasts of buildings generally using ex-post mortality analyses, whereas technicians generally ex-ante forecasts based on ex-post derived lifespan data of the most relevant constituent building parts. As the latter illustrates, both methods are often combined.

3.2. Research approaches, constraints and opportunities

The overview below does not pretend to be complete nor fully representative. It represents the essential approaches in the available literature.

3.2.1. Technical/physical: targeted at the physical durability

This is the classic (ex-ante) approach used for forecasting of planned maintenance and major repairs, based on the (ex-post) physical lifespan of the constituent building parts and materials. Lately this approach is commonly used to provide the essential lifespan data for LCA (Life Cycle Assessment) analyses underlying sustainable building strategies, and for LCC (Life Cycle Costing or whole life costing) and overall comparing alternatives for the purpose of which research methods have been further developed (Factor method) and underpinned with ISO standards (ISO 2000)(Straub, 2015).
The main limitation of this approach lies in the focus on the physical lifespan. In the Netherlands for instance, physical durability turned out to be the least decisive reason for the end-of-life of social rented as well as private dwellings (Thomsen and Andeweg-van Battum 2005 , Thomsen and van der Flier 2007) and there is no reason to assume that this is different elsewhere. On the other hand, this approach enables the analyses of buildings of all kind and quantities, from a single dwelling up to housing stocks, be it not for factual lifespan predictions.

3.2.2. Economic: targeted at the economic lifespan

Regarding economic life span assessment, two different approaches should be distinguished: starting from initial deprecation, and starting from actual performance.
The first approach dates from the early post-war reconstruction period, where everything was dominated by the unsurpassed mass new construction assignment and the question how to finance that task. For example the precalculated depreciation of Dutch post-war residential stock was officially set on 50 years for the building and 75 years for the land. Though outdated, this kind of rules is still in the mindset of housing professionals and in use for e.g. asset- and market value assessment. .
The latter approach is the classic (ex-ante) approach for professional building stock management from an economic viewpoint, based on (ex-post) case and cohort studies, focussed on economic lifespan and risk management (Miles, Berens, and Weiss 2007, Grover and Grover 2015). Since the main limitation of this approach lies inherently in the fact that the economic lifespan is again all but decisive for the factual lifespan, it may be practical for the timing of asset management and performance improvement but not for factual lifespan predictions. Also, the economic life span and environmental requirements can be on bad terms: replacement for economic reasons may not be very sustainable, unless the environmental impact of replacement is translated into costs and included in the price of the alternative.(Hermans 1999). Nevertheless this approach enables the analysis of economic survival for different building types and stocks as long as these limitation are taken in account.
In view of these limitations and looking upon the importance of institutional regimes for the long-term management of stocks, Kohler and Yang developed a more sophisticated recourse economic framework based on modelling their composition and dynamics as flows and/or as capitals (Kohler and Yang 2007). But to what extent this approach can be used for more differentiated factual lifespan assessment is not clear.

3.2.3. Functional/social: targeted at the service life

As noted above, specific lifespan analyses using this kind of approach are hardly reported. Since the available sources define service life not principally different from economic lifespan, the above also applies to this.
A particular method to assess the service life is by means of collective guess e.g. the Delphi method. Van Nunen found in this way for buildings in the Netherlands an average lifespan of 120 years (van Nunen 2010).

3.2.4. Actuarial: targeted at mortality of buildings

This is the classic (ex-post) approach for actuarial analyses, based on ex-post mortality statistics and analyses, targeted mainly at insurance risks of real estate property. This approach was first reported by (Gleeson 1985) and since by a range of authors (Hunt and Blake 2015). Though ex-post mortality analysis are based on factual lifespans, the long lifetime poses a serious constraint for future lifespan prediction. As the majority of the dwelling stock in most EU countries has been built only recently, the average lifetime of the stock is so young that ex-post based forecasting of their life span is actually impossible.
Lately a similar methodology is also applied for building stock modelling (Sartori et al. 2008, Brattebø et al. 2009, Sandberg et al. 2017), using methods that are in principal applicable to cohorts of various building age, type and tenure. As the limitations of the foregoing limitations apply thus to a lesser extent, this approach looks most promising for factual lifespan forecasting. Nevertheless, the above stated constraint is also relevant.

3.2.5. Logical probability: targeted at the minimal necessary stock

To counter the afore going limitations and constraints, an alternative ex-ante approach can be found in the confrontation of the factual stock development – addition by new construction minus decrease by demolition – with the minimal necessary stock to fulfil the housing need, resulting in the minimal necessary lifespan of the average building c.q. dwelling (Thomsen and van der Flier 2009). For example, if the annual net addition is 1% of the existing stock, the average minimal lifespan of dwellings, starting from a constant quantitative housing requirement, is 100 years. As the average annual addition in most EU countries is far below 1%, the required average minimal lifespan is a multitude of this, varying from roughly 300 years (Austria, Netherlands) trough over 1000 years (UK). Though this is of course also a reasoned guess, it indicates that the future real lifespan of the existing EU housing stock may, instead of the often mentioned 50 years, be better measured in centuries.

3.3. Constraints

Overlooking the literature, lifespan assessment is in general not intended for the prediction of the factual final end-of-life of buildings, but to be applied for the aforementioned LCA and LCC methods. Combined with the aforementioned limitations, factual lifespan data are scarce. As far as available they consist either of national or state/region averages, derived from housing stock statistics without breakdowns to decisive building characteristics as building period, building type, tenure and market conditions, or of more differentiated small scale specific case studies that are hardly generalizable. As noted before in 2.1.3 these characteristics are highly decisive for the service life and the end-of-life of dwellings. The same applies for non-residential buildings as for instance office buildings and shopping malls.
Compared to physical variables, behaviour factors as e.g. the proprietor’s management and decision making and the market position and conditions turn out to be far more decisive for the factual lifespan, but also far more difficult to predict, being most probably the reason why most approaches are based on physical durability.
Last but not least, the life of buildings does not consist of just one period of consistent performance decline. Though most life span approaches lean upon this idea, this misunderstanding dating from the post-war mass production era has never been true. In contrary, building life spans consist of long chains of periodical changes in ownership, users, use and circumstances and accordingly interventions, ranging from panting maintenance trough refurbishment, additions, renovations and transformations till the final end-of-life. For real lifespan assessment, knowledge of these chains and dynamics is indispensable, but up to now insufficiently available (Thomsen, Schultmann, and Kohler 2011).

4. Conclusions and discussion: What is the average lifespan of residential buildings?

Overseeing the foregoing, none of the approaches is sufficiently suited to answer the problem definition's main question about the average lifespan of residential buildings, not even with respect to aggregated averages of common parts of the housing stock. Not surprisingly, most life span approaches do up to now not start from this perspective but look at the physical durability to be applied for design and management directed LCA and LCC methods.

Due to the growing importance of not only physical durability but also the physical, economical and social sustainability of our environment, lifespan expectancy of dwellings will more and more gain importance.

Important constraints to be cleared in this direction are:

- The very long life span of buildings and the wide variety of different buildings, types, age, functions and tenures;
- The complexity and dynamics of the life course of buildings and the role of (deep) renovations and transformations, as well as changes in ownership and management;
- And in relation to that, the unpredictable behaviour of markets and stakeholders.

To counteract these constraints, better insight and knowledge in the life course of buildings and the underlying cause-effect processes is indispensable, as are better and more extended statistics with distinction to different building types, building periods and tenures including essential interventions as renovations, transformations and change of ownership. Regarding research methods and approaches, recent research shows that apart from that a more differentiated sequence analysis is possible and promising (Bradley 2017).

But even then, the prediction of lifespans will most probably stay questionable. Because finally again, buildings are man-made artefacts whose distinct is just as little predictable as the question of how long we live ourselves.

References

Awano, Hirohisa. 2006. *Towards Sustainable Use of the Building Stock*. Edited by OECD/IEA, Urban Policy Development Workshop. Paris: OECD.

Bradley, Patrick Erik. 2017. "Methodology for the sequence analysis of building stocks." *Building Research and Information* no. 2017:1-15.

Bradley, Patrick Erik, and Niklaus Kohler. 2007. "Methodology for the survival analysis of urban building stocks." *Building Research & Information* no. 35 (5):14.

Brattebø, Helge, Håvard Bergsdal, Nina Holck Sandberg, and Daniel B. Müller. 2009. "Exploring built environment stock metabolism and sustainability by systems analysis approaches." *Building Research & Information* no. 37 (5-6):14.

Gleeson, Michael E. 1985. "Estimating Housing Mortality from Loss Records." *Environment and Planning A* no. 17 (5):13.

Grover, Richard, and Christine Grover. 2015. "Obsolescence - a cause for cencern?" *Journal of Property Investment & Finance* no. 33 (3):16.

Hermans, Marleen H. 1999. "Building performance starts at hand-over; the importance of life span information." In *Durability of Building Materials and Components 8*., edited by Michael A. Lacasse and Vanier Dana J., 1867-1873. Ottawa: National Research Council Canada.

Hunt, Andrew, and David Blake. 2015. "A General Procedure for Constructing Mortality Models." *Pension Institute Discussion Papers* (PI-1301):52.

ISO. 2000. ISO 15686-1. *Building and Constructed Assets - Service life and Planning, Part 1. General principles*. Geneva: ISO.

IVSC. 2014. *RICS Valuation – Professional Standards ('Red Book')*. Edited by RICS. Vol. 2014. London: RICS.

Kelly, D.J. 2007. *Design life of buildings; A scoping study* Livingston (GB): Scottish Building Standards Agency.

Kohler, Niklaus, and Wei Yang. 2007. "Long-term management of building stocks." *Building Research & Information* no. 35 (4):12.

Ledolter, Johannes. 2011. "Prediction and Forecasting." In *Encyclopedia of Statistical Sciences*, edited by S. et.al. Kotz. Wiley & Sons.

Mansfield, John R., and James A. Pinder. 2008. "“Economic” and “functional” obsolescence: Their characteristics and impacts on valuation practice." *Property Management* no. 26 (3):16.

Miles, Mike E., Gayle L. Berens, and Marc A. Weiss. 2007. *Real Estate Development: Principles and Process*. Edited by Urban Land Institute. 3 ed. Washington, DC: Urban Land Institute.

Sandberg, Nina Holck, Igor Sartori, Magnus I. Vestrum, and Helge Brattebø. 2017. "Using a segmented dynamic dwelling stock model for scenario analysis of future energy demand: The dwelling stock of Norway 2016–2050." *Environment and Planning A* no. 2017 (146):13.

Sartori, Igor, Håvard Bergsdal, Daniel B. Müller, and Helge Brattebø. 2008. "Towards modelling of construction, renovation and demolition activities: Norway's dwelling stock, 1900-2100." *Building Research & Information* no. 36 (5):14.

Sartori, Igor, Nina Holck Sandberg, and Helge Brattebø. 2016. "Dynamic building stock modelling: General algorithm and exemplification for Norway." *Energy and Buildings* no. 132:13-25.

TABULA/episcope. 2016. *Monitor Progress Towards Climate Targets in European Housing Stocks; Main Results of the EPISCOPE Project* Edited by Britta Stein, Tobias Loga and Nikolaus Diefenbach. Darmstadt: IWU - Institut Wohnen und Umwelt.

Thomsen, André , and K. van der Flier. 2009. "Replacement or renovation of dwellings: the relevance of a more sustainable approach." *Building Research & Information* no. 37 (5-6):649-659.

Thomsen, André, and Marie-Thérèse Andeweg-van Battum. 2005 "Demolition of Social Dwellings in the Netherlands; Volume, Plans and Motives." *International Journal for Housing Science and Its Applications* no. 29 (3):213-223.

Thomsen, André, Niklaus Schultmann, and Niklaus Kohler. 2011. "Deconstruction, demolition and destruction." *Building Research & Information* no. 39 (4):6.

Thomsen, André, and Kees van der Flier. 2007. Demolition of Private Housing Stock in the Netherlands, Volume and Motives. In *Sustainable Urban Areas*. Rotterdam: OTB/ENHR.

van Nunen, Haico. 2010. *Assessment of the Sustainability of Flexible building* Boxtel NL: Aeneas.

Woodward, David G. . 1997. "Life cycle costing; Theory, information acquisition and application " *International Journal of Project Management* no. 15 (6):9.