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Looking Back to See Forward: The Use of Historic Repair Records to Inform Preventive Conservation Planning

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Abstract
This thesis examines how historic records of repairs can inform service life estimations and preventive conservation planning for historic structures. After a discussion of service life and preventive conservation, this thesis extracted and analyzed historic mentions of repairs in the record books of the Concord School House in Germantown, Philadelphia, Pennsylvania, which span from 1775 to 1987. Repairs to the building’s masonry, carpentry, windows, finishes, and roof assemblies were chosen for investigation. Data collected included the length of time between repairs and the recorded prices of repairs. The prices of repairs were converted into 2013 dollars and used as an indicator of the size of repairs and a means of comparison between repairs in different time periods.

Ultimately, this thesis found that data from historic records of repairs was not specific enough to stand alone in estimating service lives of the building systems for use in preventive conservation planning. However, analysis of the historic records identified repair cycles which, when supplemented with conditions assessments, could be used to inform preventive conservation planning and the formation of building reinvestment plans. Investigation of historic repair records also revealed the importance of long-term, consistent care in preserving historic structures, and the need to conceptualize repair plans in terms of centuries rather than human lifespans.

Keywords
asset management, factoral method, probabilistic method, residual service life, building system

Disciplines
Historic Preservation and Conservation

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LOOKING BACK TO SEE FORWARD: THE USE OF HISTORIC REPAIR RECORDS TO INFORM PREVENTIVE CONSERVATION PLANNING

Meredith Alison Leep

A THESIS

In

Historic Preservation

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements of the Degree of

MASTER OF SCIENCE IN HISTORIC PRESERVATION

2015

____________________
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____________________
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Dedication

To my parents Daniel and Kathryn, for their support of all my endeavors.
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Finally, I would like to thank the generations of stewards who have cared for the Concord School House in Germantown, Philadelphia, Pennsylvania. For more than two-hundred years, since 1775, the dedication of countless individuals has preserved the school house and its historic documentation. Without their work, I would have no thesis.
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Chapter 1: Introduction

The following is an investigation of how analysis of historic repair records can inform long-term planning for preventive conservation for historic structures. It began as a quest to make specific estimations of the service lives of building components in order to plan for preventive conservation for a well-documented building, the Concord School House in Germantown, Philadelphia, Pennsylvania. However, upon examination of the records of the case study it was found that there was not sufficient specificity or reliability of information to determine accurate service life estimations. Instead, a closer look was taken as to what exactly the historic records were communicating: the patterns of repair cycles over time that would inform long-term planning for preventive conservation of the historic structure.

Key Concepts

The physical deterioration of structures is a given, and only a matter of time. The question is: how long can their functional lives be extended? Therefore, planning for preventive conservation is an important tool for stewards, or building caretakers, seeking to maximize the functional lives of their historic structures. For the purposes of this thesis, the term “preventive conservation” is used to encompass the proactive monitoring of building conditions and the deliberate planning and application of treatments (i.e., maintenance or replacement) before material degradation leads to the inability of building assemblies to perform at acceptable levels. While preventive conservation employs proactive monitoring, preventive maintenance involves planning for replacement of building components before they cease to function at appropriate...
levels, but does not use monitoring.¹ In contrast to both preventive conservation and preventive maintenance, which are planned and deliberate in nature, other approaches to maintenance include reactive maintenance, in which stewards address problems after they have occurred, rather than addressing them preventively. Reactive maintenance transitions into deferred maintenance when there is a backlog of needed repair work. The combination of deferred maintenance, periodic maintenance crises, and reactive maintenance can result in material degradation, invasive repair campaigns and preventable loss of historic fabric.

Preventive conservation strategically targets treatments to extend the lives of building components and assemblies. This thesis frequently uses the term “building systems” to refer to building assemblies. A building system is a configuration of building components that are interconnected to produce a larger whole.² Examples of building systems include roofs, which are assembled from components such as rafters, sheathing, flashing, shingles, etc.; windows, which are formed from components such as glass, wood, glazing putty and flashing; and timber framing beyond the roof structure, consisting of individual timber members joined together as a whole that supports structural loads. Building systems are interconnected with each other. For instance, a leak in a building’s roof can result in rot in its timber framing, shortening the service life

¹ Shah and Kumar, "Optimisation of Maintenance Expenditure for Buildings: Refurbish or Demolish?" In IABSE 2005 Conference (New Delhi: QUT, 2005), 3.
of the wood. Preventive conservation incorporates an understanding of how a building’s components and systems work together, and makes targeted interventions to extend the building’s functional life. This could take the form of repairing a leaky roof system before timber framing systems are damaged, or repointing the mortar of a masonry wall system composed of stone and mortar, to ensure that the stones stay together, water infiltration is minimized, and the wall as a whole remains intact.

Knowledge of the service life of a building’s systems or components can be used to plan for preventive conservation. “Service life” is an industry term referring to the period of that a material, component or system meets or exceeds its performance requirement.³ A “performance requirement” is the minimum level of a component’s acceptable performance, for example, the ability of a beam to support a structural load without breaking.⁴ Once a component or building system has been installed, its service life is referred to as its residual service life, or the time remaining after installation during which it will continue to meet its performance requirement.⁵ Service life estimation is a complicated endeavor. In fact, predicted service life is often a conservative estimate much lower than actual service life, or the actual period of time that a building material, component or system continues to meet its performance

⁴ “ISO 15686-1:2011.”
requirement. This is because actual service life depends on many factors, including environment, design, and periodic maintenance, and can therefore be difficult to predict accurately.

When stewards know the expected service lives of their buildings’ components or systems, they can better predict when those components or systems will require maintenance or replacement and plan accordingly. The ability to predict maintenance needs allows stewards to perform preventive conservation before minor problems become large and require greater intervention. It also allows stewards to plan for maintenance costs. This could take the form of a building reinvestment plan, in which stewards combine their knowledge of service lives or repair cycles, as well as maintenance and replacement costs, to budget accordingly. For example, the knowledge that a roof’s service life will expire in thirty years allows stewards to calculate the amount of money to put aside annually in order to afford the future replacement.

Building repairs often take place in repair cycles, which occur over time at a rhythm relatively specific to the individual building. Depending on the building system, these cycles can occur in terms of years, decades or even centuries. Though often less specific than service life estimations, knowledge of repair cycles can also aid stewards in planning for preventive conservation, by providing both a general idea of when to expect maintenance and a long-term perspective on a structure’s maintenance needs over time. However, repair cycles do not necessarily correspond with service lives, due
to practical matters such as budgeting, users’ needs, or availability of access to the building system for repairs.

Justification and Hypothesis

Preventive conservation is an important tool for the preservation of historic structures because it can maximize the preservation of historic fabric. To practice preventive conservation, stewards need information about the expected behavior of their building and its projected maintenance needs. Some historic structures have associated records of historic maintenance and repairs which, though currently untapped, may have the potential to provide stewards with such knowledge. This thesis hypothesizes that historic repair records can inform preventive conservation planning.

Service life information has considerable potential as a tool for stewards of historic structures to use in planning for preventive conservation, yet stewards face challenges in identifying the service life information they need. The majority of service life research has investigated modern materials. In cases where service life information may be available for the modern counterparts of historic materials, these modern counterpoints may have fundamentally different characteristics than the historic materials. For instance, old growth wood such as that used in historic structures is generally denser and more durable than new growth wood of the same species now available.6 Furthermore, long-term structural strain or weathering, over decades or even

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centuries, alters the performance of most materials. For example, a study of the mechanical characteristics of ancient hinoki wood in Japan revealed that compared with similar modern samples of the same species, it had increased brittleness perpendicular to its grain. This makes service life estimates for contemporary materials difficult to apply to historic materials, as such estimates are usually based on shorter-term studies. Additionally, building-specific factors such as design, climate, exposure to the elements, moisture infiltration, the presence or absence of biological life, the quality of materials and workmanship, and repair intervention type and frequency, can all lengthen or shorten the estimated service lives of various components. While some service life estimation models make efforts to take these case-specific aspects into account, such models generally require significant expertise to apply.

Although historic records of repairs may not provide the detailed data or sufficient sample size required to form service life estimates, they can offer an alternative: general information about repair cycles which still has value in informing preventive conservation planning. Hypothetically, records of repairs made to specific building systems, such as windows or masonry walls, could provide stewards with a better understanding of the long-term behavior of the systems of their historic structures. Centuries-old records of repairs can also provide stewards with insights into the expected maintenance regimes for historic materials over time, based on the

practices of historic caretakers who may have possessed greater familiarity with such materials. In its analysis of the application of historic documentation of repairs to plan for preventive conservation, this thesis offers insight to stewards in possession of historic maintenance records who wish to plan for the preventive conservation of their buildings.

Methodology

The building of this investigation’s case study is the Concord School House in Germantown, Philadelphia, Pennsylvania. It possesses a record of more than 200 years’ worth of repairs to its various systems, which spans from 1775 to 1987. The methodology of this thesis included the following four stages.

Stage 1: Built a foundation of knowledge. Researched concepts relating to service life and its estimation; preventive conservation; planning for preventive conservation; budgeting for building reinvestment; and conceptualizing cycles of building maintenance over long periods of time. Applied the concepts to a case study of the Concord School House.


Stage 3: Interpreted maintenance data from the Concord School House. Using Excel data, produced graphics representing repair cycles and expenditures, to aid in interpreting data. Analyzed data using basic statistics and graphics, looking for patterns
in maintenance and building reinvestment. Based on findings, identified common time intervals for repair cycles.

Stage 4: Placed findings in a wider context. Discussed the implications of findings from the case study for the use of historic records in planning for preventive conservation with other buildings.

*Limitations*

The greatest limitation to informing preventive conservation through analysis of historic repair records is the quality of data available. Stewards seeking to identify repair cycles are at the mercy of the recording and repair practices of their forebears. Missing records, or poorly documented repairs without explanations of their category, scale or location, can all limit sample sizes or the collection of detailed data. Finding records can also pose a challenge. Furthermore, identifying whether repair cycles are in fact representative of maintenance practices or simply anomalies can be an inexact process requiring discernment and critical thinking. For the case study in this thesis, at times, when the scale of work was not recorded in the historic documentation, the prices of the repairs were used as a proxy for scale. For comparison, historic prices were converted to 2013 dollars. Identifying modern costs from historic expenditures can be difficult due to changes in currency value and the cost of labor or materials. Therefore, findings of the expense of repairs in 2013 dollars should be read an indication of scale, rather than an exact comparison. Finally, the findings of this thesis are based on a case

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study of a single structure, and may not take into account variables applicable to other buildings.
Chapter 2: Literature Review and Background

The last few decades have seen an increase of interest in better understanding the service life of building materials and systems in order to manage reinvestment plans or maintenance for everything from institutional facilities,\(^9\) to transportation infrastructure,\(^10\) to individual buildings. Understanding the service life of building systems is crucial in allowing building stewards to budget for repairs and practice preventive conservation, rather than reactive maintenance. However, due to the complexity of building systems, where factors such as weathering or structural strain affect the long-term performance of individual components, as well as the inherent variability of factors such as the quality of workmanship between structures, identifying the service life of components or systems is complicated, challenging and often uncertain. A literature review has revealed that there are two approaches developed to predict service life: the factorial and the probabilistic methods.

The Factoral Method

An early discussion of the factorial method appears in *The English Edition of Principal Guide for Service Life Planning of Buildings*,\(^11\) published by the Architectural Institute of Japan and translated into English in 1993. The work was developed to


\(\text{\footnotesize 10 Statement No. 34 of the Governmental Accounting Standards Board: Basic Financial Statements—and Management’s Discussion and Analysis—for State and Local Governments, ed. Financial Accounting Foundation (Norwalk: 1999).}\)

address the challenges of designing and maintaining buildings and infrastructure to ensure the compatibility of their designed lives with the service lives of their individual components.

*The English Edition of Principal Guide for Service Life Planning of Buildings* addresses the inherent complexity of determining service life by calculating service lives based on considerations of many factors. These include factors inherent to a building: the performance of materials; quality of design; quality of construction work and the quality of maintenance and management. Factors also include “items relating to the environmental deterioration factor”: site and environmental conditions and the condition of the building.\(^{12}\) These factors are addressed for each building material, and each structural component. The factors are given weighted numerical values according to their assumed importance. These values are multiplied together to produce a figure that is evaluated in comparison to a scale indicating lesser to greater durability, with the number associated with a service life. The implementation of this technique appears to require substantial expertise in material properties, as well as dependence on standardized assumptions as to the importance of various factors. This inherently limits its accessibility to non-professionals. On the other hand, the work’s introduction of the means to quantify potentially qualitative factors such as the risk of biological deterioration, as well as the sheer ambition of its synthesis of a large number of factors relating to service life, provide a useful foundation on which to build.

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Like the *English Edition of Principal Guide for Service Life Planning of Buildings*,
the standard *ISO 15686-1:2011*, produced by the International Organization for
Standardization headquartered in Geneva, Switzerland, seeks to provide the means to
obtain the service life data required to design maintenance plans and ensure that the
designed service lives of buildings accurately take into account the service lives of their
components. The standard uses a factorial method for calculating service life similar to
that of the *Guide*, doing so by multiplying a reference service life, obtained through
comparative studies and testing, by a series of weighted “modifying factors” pertinent
to the specific conditions of the component in question. The possible factors are similar
to those of the *Guide*, including quality of components; design level; work execution
level; indoor environment; outdoor environment; in-use conditions and maintenance
level. The greatest difference between the two sources is a greater specificity on the
part of *ISO 15686-1:2011* regarding the factors for calculating service life. For instance,
when evaluating the factor of work execution level, the standard specifies that its users
should consider details such as site management, level of workmanship and climatic
conditions during the execution of work, which is more specific than the *Guide*.

According to B. Marteinsson, in his article *Durability and the Factor Method of
ISO 15686-1*,\(^\text{13}\) in actual application, *ISO 15686-1:2011* requires a great deal of expertise
to use accurately, though with the necessary expertise it provides a valuable
methodology for estimating service lives. Marteinsson determined this through a study

\(^{13}\) B. Marteinsson, "Durability and the Factor Method of ISO 15686-1," *Building
detailed in his article, which applied the standard’s service life prediction method to estimate the residual service life of rural Icelandic wooden windows. Like the English Edition of Principal Guide for Service Life Planning of Buildings, the most valuable aspect of the standard is its presentation of a methodology for calculating service life that takes into account the diverse factors that influence service life.

**The Probabilistic Method**

The probabilistic method of calculating service life is a broad category that encompasses the statistical analysis of data from various sources to estimate the probable service life of a material. Methods for obtaining service life data are detailed at length in *Part I: Service Life and Durability Research* of the standard on *Prediction of Service Life of Building Materials and Components* published by CIB W080/RILEM TC140.14 Long-term studies are considered ideal, as well as laboratory testing, comparison surveys, in-situ testing and field exposure of components, supplemented by conditions assessments. Many actual studies follow such recommendations in their data selections. For example, as F. Flourentzou et al. explain in “MEDIC-a Method for Predicting Residual Service Life and Refurbishment Investment Budgets,” the MEDIC program bases its calculations on “a large number of previous investigations/refurbishments and the current state of the object under study.”15

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Similarly, in the article *Durability Assessment of Building Systems,* authors J. Lair et al. gather data from laboratory tests, field studies, studies on material properties, and reliability studies.  

A material’s probable durability or length of service life is expressed in various ways using probabilistic methodology. For instance, using the MEDIC program, Flourentzou et al. categorize the possible condition of a material into four states, from worst to best, then calculate the probability that under a certain length of time the material will transition from one state to another. Other authors, including Lair et al., attempt to address the acknowledged complexity of possible influences on a material’s service life by combining several probability models in various steps, ultimately synthesizing the data to produce a probable range of service life values. Limitations of such statistical models include their complexity, and the resulting high level of expertise and amount of data they require to execute effectively. As a result, use of complex models is often limited to entities with access to a high level of resources, such as large academic institutions in possession of a large number of structures, or even governments in possession of infrastructure systems. However, other probabilistic models attempt to offer a simplified methodology.

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K. Moser, in the article "Towards the Practical Evaluation of Service Life - Illustrative Application of the Probabilistic Approach," offers one such model, which combines the factorial method promoted by ISO 15686-1 with a statistical approach. Probable service life is obtained and estimated by various means, by a density curve providing the probable distribution of service lives, derived either from manufacturer’s data, or from consultations with experts via the Delphi method. In the Delphi method, experts are provided with information on the service life factors explained in ISO 15686-1, and provide initial service life predictions. Experts then discuss and analyze the assumptions of their first predictions, and based on their discussion and analysis, produce a second, more accurate, set of service life predictions. According to Moser, the Delphi method “has proved to give extraordinary good results in fields with lack of sufficient statistical data” such as risk engineering.18 Furthermore, the approach suggested by Moser is applicable to individual buildings, while approaches requiring larger amounts of data are not.

As is evident, accurate data collection is key to effective service life prediction, especially for probabilistic approaches. Sources of data and data collection methodologies are therefore objects of discussion in a number of articles and standards. In “The Importance of Quality Sampling in Service Life Prediction,” M.M. Galbusera et al. discuss techniques to ensure that data taken for service life analyses is representative.19

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18 Moser, "Towards the Practical Evaluation of Service Life,” 1323.
In sampling the condition of ceramic tile facades in Lisbon through visual survey, Galbusera et al. recommend recording two data sets from the same facade, four years apart. After collecting data, they weighted degradation factors to produce a standard percentage of degradation, which they graphed versus age, excluding non-representative samples that failed to follow the shape of the degradation curves.\textsuperscript{20} Notably, the purpose of the study by Galbusera et al. was to determine the service lives of facades experiencing representative degradation, and the authors excluded data from facades exhibiting degradation due to factors such as poor design or structural decay. As a result, the study provides an overall idea of the material service lives of facades under average conditions. It does not provide information on how to calculate the service lives of facades in outlying circumstances, which is also necessary for use in maintenance and reinvestment planning.

One aspect of determining material service lives that appears to have garnered little attention in pure discussions of approaches to service life calculation is the context in which service lives should be evaluated—at the level of individual components, or at the level of building systems or subsystems. Some sources, such as \textit{The English Edition of Principal Guide for Service Life Planning of Buildings}\textsuperscript{21} and ISO 15686-1\textsuperscript{22} advocate evaluating the service life of each individual component in a building. Others, such as Lair et al., suggest analyzing the service life of buildings by the service lives of systems

\textsuperscript{20} Ibid., 23, 28.
\textsuperscript{21} Principal Guide for Service Life Planning of Buildings, 4.
\textsuperscript{22} ISO 15686-1, 6.
and subsystems, in order to better predict subsystem interactions and deterioration patterns. P.D. Mayer and P. Wornell, in their article “Assessing the Remaining Service Life of Existing Building Components for Insurance,” also analyze the residual service life of buildings by subsystems, and apply this approach to the practical use of making insurance estimates. Considering the complexity of the problem of estimating service life, it seems as though approaching a building’s service life through its multitude of pieces rather than more organized systems or subsystems would simply add to the difficulty of the task, though admittedly analyzing service life by system could require the synthesis of a daunting amount of factors influencing the system. It seems strange that no standard has been established by the ISO, ASTM or by the joint CIB W080/RILEM committees for how to present service life data in a systematic way grouped by building system. Although literature with a specific focus on the methods of estimating service life may not focus on identifying the service life of building systems, it is perhaps not surprising that literature discussing the practical application of material service life estimations for planning maintenance tends to approach structures from a systems perspective. For instance, in “A Planning Support System for Management of Components Maintenance,” M. De Grassi and B. Naticchia attempt to predict the

\[\text{References}\]

interrelated behavior of different building system components in order to identify maintenance priorities within a building system.\textsuperscript{25}

Preventive Conservation

Material service life estimations can be used as the foundation for forming maintenance plans and planning for building reinvestment. One fundamental objective of these plans is to optimize maintenance expenditures, and one method for doing so is the use of preventive conservation, a concept also described by various terms such as proactive maintenance and asset management planning. In her graduate thesis from 2008, “Implementing Preventive Architectural Conservation: Do Historic Property Stewards in the United States Possess the Tools to Meet the Challenge?” Alice Louise Finke explains that preventive, routine care of buildings is an ideal way to preserve historic fabric, though unfortunately, her survey with 60 respondents from heritage organizations revealed that few historic property stewards seem to have the staff or funding to practice preventive conservation. In “Optimizing Facility Component Maintenance, Repair, and Restoration Investment Strategies Using Financial ROI Metrics and Consequence Analysis,” Grussing et. al contrast preventive conservation, which they term proactive maintenance, with reactive maintenance, where structural problems are addressed only after they have become evident, have escalated or have resulted in

significant deterioration.\textsuperscript{26} Reactive maintenance is frequently less cost-effective than preventing problems in the first place.

Preventive conservation is not a new concept. The philosophy of taking deliberate, preventive measures to protect objects or buildings from factors that would hasten their decay, in order to extend their service lives, dates back millennia. For example, in the first century B.C.E., in his \textit{Ten Books of Architecture}, Vitruvius outlined the means by which residents could make deliberate architectural design choices to produce favorable environments, which could protect objects from damaging factors such as temperature, moisture, and sunlight.\textsuperscript{27} For more than a millennium, the Japanese have used protective storehouses called kura to shield their cultural treasures from humidity, light, fire, earthquakes, and vermin—clearly identifying and neutralizing threats to deterioration.\textsuperscript{28} In his nineteenth-century work \textit{The Seven Lamps of Architecture}, famed Victorian art critic John Ruskin clearly stated the importance of routine care in preventing the deterioration of historic structures, appealing to his readers to “Take proper care of your monuments, and you will not need to restore them. A few sheets of lead put in time upon the roof, a few dead leaves and sticks swept

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in time out of a water-course, will save both roof and walls from ruin.”²⁹ In 1877, William Morris, co-founder of the Society for the Protection of Ancient Buildings explained that buildings should be cared for preventively rather than have their historic fabric altered radically. He wrote that “It is for all these buildings, therefore, of all times and styles, that we plead and call upon those who have to deal with them, to put Protection in the place of Restoration, to stave off decay by daily care, to prop a perilous wall or mend a leaky roof by such means as are obviously meant for support or covering, and show no pretense of other art, and otherwise to resist all tampering with either the fabric or ornament of the building as it stands...”³⁰ Morris’ statement reveals an understanding of the power of “daily care” to preserve the fabric of a historic building, and also demonstrates an awareness of the importance of preserving the integrity of historic fabric. Clearly, forms of preventive conservation have been used in many times and places.

In addition to its use to preserve rare treasures and its discussion by intellectual elite, preventive conservation has also been practiced in the vernacular sense. Eighteenth century writings for housekeepers explained such concepts as the importance of keeping moisture away from the foundations of buildings.³¹ Furthermore,

modern expressions such as “nip the problem in the bud” and “a stitch in time saves nine” reflect a common understanding of the importance of addressing problems before they escalate, and preventing the need for extensive repairs by acting quickly to address maintenance needs.

Residual Service Life

One asset in controlling buildings’ service lives, for both preventive conservation and other purposes, is the use of residual service life knowledge to plan for maintenance. In their article, “Optimization of Maintenance Expenditure Plans for Buildings: Refurbish or Demolish,” Ashish Shah and Arun Kumar make use of residual service life knowledge to design targeted maintenance plans to achieve the building service lives desired by building managers. As their maintenance plans work from the premise that the structures in question will eventually be demolished and are not necessarily of historic value, Shah and Kumar do not solely advocate or even use the term preventive conservation. However, they explain that targeted maintenance informed by knowledge of residual service lives has the potential to lengthen building service lives.32 Daniel Hallberg, in his 2005 licentiate thesis, Development and Adaptation of a Life Cycle Management System for Constructed Works, also explains the importance of residual service life knowledge in informing predictive maintenance plans. According to Hallberg, a knowledge of residual service life is key to forming

“Maintenance, Repair and Refurbishment” plans based on long-term predictions and planning of maintenance needs.\textsuperscript{33}

To identify residual service life, or the time remaining during which an installed building component or system will continue to meet performance requirements, stewards require a combination of knowledge of its predicted service life, its age and/or its current condition, and its location within the building, which together inform estimations of the length of time remaining to its functionality. Mayer and Wornell, in their work “Assessing the Remaining Service Life of Existing Building Components for Insurance,” recommend estimating residual service life by evaluating current condition, age of the component and its context in the building system.\textsuperscript{34}

Conditions Surveys

Knowledge of current material conditions is best obtained through repeated and repeatable conditions surveys. Repeated conditions surveys also allow stewards to monitor changes to the condition of their buildings over time. Without sufficient care, however, the data gathered by conditions surveys can be inconsistent and therefore of limited use. M. R. Johnson and D. P. Wyatt, in their article “Preparation and Prioritization of Maintenance Programmes,” explain that while conditions surveys are a powerful tool for building maintenance planning, they can “lose credibility if they lack accuracy or flexibility,” and that to prove useful in the long-term, they must be easy to


\textsuperscript{34} P. D. Mayer and P. Wornell, “Assessing the Remaining Service Life of Existing Building Components for Insurance,” 1616.
use, must be repeated and repeatable, must be capable of revision and, ideally, focus not just on individual conditions but how they relate to the structure as a whole. Published the same year as the Johnson and Wyatt article, *Statement Number 34 of the Government Accounting Standards Board, Basic Financial Statements—and Management’s Discussion and Analysis—for State and Local Governments*, also emphasizes the importance of repeatability and clear methodology when it comes to implementing conditions assessments. The work notes that to be of use, conditions surveys must be repeatable by the means of following clear measurement methods that others beyond the initial surveyor can follow as well. One method for standardizing conditions surveys is the use of a Condition Index, which evaluates a defined asset such as a building, building system, or component, on a scale from 1-100, placing it in one of seven established conditions brackets, from poor to good. According to M.N Grussing et al., acceptable condition scores can be specified, providing stewards with a standard for comparison. When describing techniques to use during conditions surveys, Mayer and Wornell recommend visual surveys, as well as more invasive methods such as hands-on probing and opening up systems as necessary to evaluate structural components. They also note the potential utility of compiling an illustrated compendium of reference.

36 *Statement No. 34 of the Governmental Accounting Standards Board*, 30.
conditions for each component, “showing stages of deterioration, for differing modes of failure, from new to failed.” Surveyors could compare illustrations in this compendium to components in the field in order to produce conditions assessments evaluated by the same standard. The authors acknowledge that such a compendium would necessarily be large and difficult to use in the field. Nevertheless, it would aid in standardizing evaluations between surveyors and increase the likelihood that results will be repeatable over time. Indeed, the use of photography, be it in the form of reference images in a compendium, or the regular photographic documentation of the condition of components over time, can be an important tool for standardizing conditions assessments between surveyors and ensuring comparable survey results over time. Implementing and funding a scheduled program of conditions surveys is considered an important step in producing effective maintenance plans, according to both Nes and Hovde and GASB.

Planning for Maintenance: Considerations

The information obtained through conditions surveys and residual service life estimations is important in maintenance prioritization, which is a vital aspect of preventive conservation plans. However, additional variables must be considered when forming a prioritized maintenance plan, for instance, the interrelated functioning of building components in a system. An understanding of the functioning of a system

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39 Ibid.
allows stewards to better predict the consequences of various repair interventions. In some cases, a repair may have unexpected negative outcomes. For example, changing an HVAC system can alter a structure’s relative humidity, which can encourage moisture or drying damage. M. De Grassi and B. Naticchia, in their article “A Planning Support System for Management of Components Maintenance,” attempt to address the problem of understanding the implications of repair changes to a building’s systems and show how this can optimize repair interventions. They propose the use of a Bayesian network to model the probable interrelationship of various components, and the implications of changing them. Although their approach allows for the integration of many variables, one drawback is its complexity, which decreases its ease of use, and potentially makes it inaccessible to non-experts. Nevertheless, De Grassi and Naticchia point out the necessity of approaching maintenance plans with an understanding of structures as a whole, not just individual components. Planning for maintenance with building systems in mind can prevent inadvertent negative consequences to repairs. Significantly, it can also allow stewards to target their maintenance efforts at repairs that will have the greatest benefit to the building.

Interestingly, though service life is an important component in making maintenance prioritization decisions, it is not necessarily the deciding factor in allocating resources. An effective maintenance plan must coordinate both the needs of the

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structure and the needs of its stewards. Ideally, in the case of preventive conservation, items will be repaired and their residual service lives extended. However, as M. R. Johnson and D. P. Wyatt explain in their article “Preparation and Prioritization of Maintenance Programmes,” when initiating a preventive conservation maintenance plan, a structure may have components that are nearing the end of their residual service lives and operating suboptimally. In the event that those components are not critical to the stability of a building, and providing that they are not preventing the building from serving its function, stewards may justifiably make the decision not to replace the components immediately should financial resources be limited and other items of repair take priority. At other times, it can be most practical for stewards to group repairs, for instance, to take advantage of expensive constructed scaffolding and/or minimize disruptive maintenance episodes for building tenants. In such a situation, according to Johnson and Wyatt, components may be repaired before the expiration of their residual service life requires it. At other times, stewards may need to schedule or even delay repairs to avoid events such as the tourist season, in the case of museums. A well-designed preventive conservation plan should account for such issues, and service life may not ultimately be the deciding factor in the timing of maintenance plans.

Looking Over the Horizon: the Challenge of Historic Buildings

While the details of service life data, conditions surveys and practical considerations are all useful in planning for preventive conservation, stewards must also look at the long-term context of their preventive conservation efforts. In his book *How Buildings Learn: What Happens to Buildings After They’re Built*, Stewart Brand investigates “what happens . . . in buildings over time.”\(^43\) According to Brand, “buildings loom over us and persist beyond us.”\(^44\) This is especially the case for historic structures, many of which have existed long before their stewards, and are intended to continue long after their current caretakers are gone. Stewards can see their preventive conservation efforts as part of a larger whole, a moment in the cycling of maintenance interventions. Brand writes that in caring for their buildings, stewards are “participating physically in a deep, long life.”\(^45\) Seeing buildings in their long-term contexts allows stewards to plan for preventive conservation in terms of centuries rather than decades, and identify the factors important to ensuring the continued existence of a structure, such as reliable care. For example, in his work “Capital Renewal and Deferred Maintenance Programs,” Harvey Kaiser discusses planning for renewal of various building systems with hundred-year cycles, such as building foundations and structural


\(^{44}\) Ibid, chapter 1, loc 216.

support. Such extended planning is key for historic structures that are intended to endure.

Chapter 3: Maintenance Considerations for Structures with Extended Service Lives and the Role of Service Life Knowledge in Planning for Preventive Conservation

Stewards of buildings employ many approaches to maintenance, some more deliberate than others. Shah and Kumar describe a number of such approaches. They describe “corrective maintenance,” (also known as reactive maintenance), which involves the implementation of repairs after failure has occurred, without regular inspection. Shah and Kumar consider this approach acceptable when failure will not have a large impact, and inspections are costly. Another approach, which Shah and Kumar term preventive maintenance, involves replacing components before they no longer meet their performance requirements, based on a knowledge of service life rather than information from regular inspections. They consider this a reasonable option when the cost of failure is high and failure can be predicted. The authors also describe the practice of “conditions based maintenance,” where regularly-planned inspections are carried out to identify when components require repair in order to function at acceptable levels.47

The specific needs of historic structures make certain maintenance practices inappropriate choices for their care. Many maintenance practices are designed with a “cradle to grave” approach to building stewardship in mind. In this model, buildings have a designed service life, and maintenance is planned according to that projected service life, where the end of the building is expected and accepted. In contrast to

47 Shah and Kumar, "Optimisation of Maintenance Expenditure for Buildings: Refurbish or Demolish?" 3.
buildings with a set expiration date, many stewards of historic buildings want their structures to last indefinitely, and intend to delay “the grave” as long as possible. Many historic structures have already outlived their original service life expectancy at both the material and system levels, and stewards are often working to continue to extend the existence of historic structures beyond their originally intended functional life. As a result, maintenance practices such as deferred or reactive maintenance, which permit the extensive decay of building components, are not advisable because they hasten the decline of the building. Furthermore, a common goal of stewardship of historic structures in the West is to preserve as much historic fabric as possible. Reactive maintenance is therefore problematic, due to the high cost of extensive deterioration in a historic building. If a component reaches the end of its residual service life through deterioration, other interrelated components may also do so as a result. This will likely result in significant repairs or even complete replacements to restore deteriorated components to functionality. The resulting loss of historic fabric is not compatible with historic stewardship goals.

In contrast to deferred or reactive maintenance, which can shorten buildings’ service lives, preventive conservation can be used to extend buildings’ service lives for as long as possible. Preventive conservation proactively monitors building conditions and provides treatments (i.e., maintenance or replacement) before material deterioration leads to the deterioration of building systems. This results in extended

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residual service lives of systems and a greater preservation of historic fabric.  

Maintenance strategically targets systems, or components of systems, which have a wide impact on the well-being of the building as a whole. For instance, stewards practicing preventive conservation may target repairs to windows or roofs to keep moisture out of the building system and thereby stave off deterioration.  

Preventive conservation requires proactive and intentional planning for repairs. To perform this planning, stewards require knowledge of the repair cycles or service lives of their buildings’ systems. For buildings that are already constructed, including historic structures, stewards must know the residual service lives of buildings’ systems. Residual service life may be calculated by subtracting the age of a system from its estimated service life to identify the time remaining to it. At times, a system’s age can be obtained from maintenance records, though in some cases it may be unknown and require estimation. Residual service life estimates can be confirmed in the field with regular conditions inspections.  

Once service life estimations are established, from historic records or other sources, they can inform preventive conservation plans. Knowledge of the service lives and residual service lives of systems or materials allows stewards to anticipate and plan for their repair or replacement. Planning for preventive conservation has both logistical and financial components. Logistically, stewards can coordinate repairs together to take advantage of erected scaffolding and minimize disruption. Financially, stewards can

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49 Brand, How Buildings Learn, chapter 8, loc 2802.
50 Ibid., chapter 8, loc 2799.
estimate the cost of the repairs and when the expenditures will take place, and save the necessary funds over time to implement them with minimal financial strain.

Financial planning for preventive maintenance can take the form of a building reinvestment plan. The principle behind a building reinvestment plan is that after initial construction, buildings require regular reinvestment (or maintenance) in order to continue to meet their performance requirements in the long-term. A building reinvestment plan identifies when a structure will require maintenance or replacement of its systems, often through the use of service life estimations, or potentially through knowledge of predicted repair cycles combined with conditions assessments. Using this knowledge of when maintenance will be needed, as well as the projected cost of the maintenance, the reinvestment plan budgets the amount of capital needed in order to afford the maintenance at the expected time.\textsuperscript{51}

Stewards of historic structures face challenges in obtaining reliable service life data for use in preventive conservation planning. Service life estimates are based on specific factors, which may or may not be applicable to a steward’s particular building. For instance, in calculating the service life of finishes, M.A. Garrido et al. explore the effects of southern exposure, finishes composition, finishes texture, substrate conditions and climate.\textsuperscript{52} These estimations may not be applicable to stewards if their buildings possess factors not taken into account, such as a climate different from that

\textsuperscript{51} Kaiser, "Capital Renewal and Deferred Maintenance Programs," 12.
used in the calculations. Furthermore, many service life estimations cover a wide range of possible service life lengths. For instance, in their article “Life Cycle of Window Materials: A Comparative Assessment,” M. Asif et al. report on a survey of 22 specialists throughout the United Kingdom, which found that timber windows had a median service life of 35 years, with an inter-quartile range of 16.3 years. Such a range is large enough that planning for preventive conservation based on such an estimation would leave considerable uncertainty about when maintenance would be needed. Additionally, since historic buildings are already assembled, preventive conservation plans would need to take their residual service lives into account, which are specific to each building and require additional calculations to obtain.

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Chapter 4: Estimating Service Life from Historic Repair Records: A Case Study

The hypothesis behind this investigation is that records of repairs have the potential to identify valuable and accessible service life information for stewards. Repair records, when consistent, often provide information about when repairs occurred and at what intervals. Working from the logic that repairs occurred when components or systems neared or were at the end of their residual service lives, one could hypothetically use the length of time between repairs to estimate the length of service life. Service life estimations derived from a structure’s own maintenance records might have an added benefit in being building-specific. Because they are based on actual responses to disrepair caused by the many factors influencing building conditions, they should already encompass the confounding variables that make estimating service life so challenging and complicated, such as the quality of workmanship, design flaws or strengths, and environmental conditions, to name a few examples.

The Concord School House

The Concord School House was built as a single story structure in 1775. Its footprint expanded in 1788, and a second story was added in 1818. It is constructed of random Wissahickon schist rubble with white oak framing, a wooden shingle roof and wooden windows. The first floor of the school house served as a school room continuously until the advent of public schools in the 1840s, at which time it was periodically rented out to private school teachers. Since its construction in 1818, the second floor was rented out, providing additional income to support the school house’s upkeep. Tenants of the second floor included the Free Masons, the nativist Junior Order
of United American Mechanics, and the Charter Oak Library, a gentleman’s social club. In the 1940s, it was converted into an apartment for caretakers.

From 1775 through the 20th century, the structure was owned and operated by the Trustees of the School House, a private group responsible for the structure’s construction and upkeep. The Trustees were also responsible for obtaining subscriptions to the school and finding tenants. For the 18th and 19th centuries, the Trustees generally came from generations of the same families, such as the Johnsons and the Kaisers. Other individuals joined the Trustees in the 20th century, including women, as well as individuals interested in the history of the school house. Today the school house is run by the Board of Directors of the Concord Schoolhouse and Upper Burying Ground, the organizational descendent of the Trustees. The second story is still occupied by a caretaker, and the first floor is routinely open to the public as a museum. From 1775 through 1987, the Trustees recorded nearly annual reports of events, expenses, and repairs to the school house. This thesis investigates these records for information regarding repair cycles and service life.

Methodology for Data Collection and Organization

Data were collected through a careful reading of Concord School House of Upper Germantown Trustee Records54 dating from 1775 to 1987, as well as The Treasurers’

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54 Concord School House of Upper Germantown Trustee Records 1775-1945, Pennsylvania Historical Society and Board of Directors of the Concord Schoolhouse and Upper Burying Ground.
Records of the Concord School House,55 recorded separately from 1877 to 1945. The following data were collected from the mentions of repairs: the date, the repair and the listed price of the repair. Once collected, the data were organized by the building system repaired. Systems included in data organization were masonry, carpentry, metal work, windows, finishes, roof, cupola, sewer, heating method, landscaping, and electrical. Ultimately, repairs to the masonry, carpentry, windows, finishes, and roof systems were chosen for investigation.

The above systems were selected deliberately. For instance, they had the largest number of listed repairs spanning the entire existence of the school house, the volume of which would assist in estimating repair cycles. Furthermore, the masonry, carpentry, windows, finishes and roof systems were identified as the most significant to the structure. The Concord School House is a masonry structure with timber framing, thus the importance of information on repairs to the building’s masonry and wood systems. The windows serve as a key interface between the exterior and interior environments, and as a result have a major role in determining the interior environment of the school house. Additionally, the school house has traditional wooden windows, which possess different maintenance requirements than modern windows, and stewards could benefit from information on their repair cycles and the traditional rhythm of repairs. The finishes of the school house have implications for protecting the structure from the elements, and also require good maintenance due to the aesthetic implications they

have on the interpretation of the structure as a historic site. Finally, the roof is a vital component in keeping the structure standing and in good repair, and is also a major expense when its replacement is required, making information as to its expected service life a useful tool to enable stewards to plan financially for its maintenance and replacement.

Although systems such as heating methods and the electrical system are also significant, they were not included in the study. The heating methods of the school house have changed numerous times, from wood stoves, to coal burning, to gas heat, to electric space heaters. Investigating the repair cycles of obsolete heating methods, though potentially of historic interest, has little practical use. A system such as the electrical wiring of the building, though very important for the structure’s users, has only appeared in the structure in the last sixty years, and then only on the second floor of the structure. It was therefore excluded from research due to its limited presence in the history of the school house.

Type of Repairs and Implications for Interpreting Records

The work on the systems selected for study can be divided into two general categories: periodic complete replacement, and maintenance occurring in situ. In the case of the school house roofing system, the structure’s roof was replaced four times between 1775 and 1987. Because the roofs themselves may have varied in quality and materials used, this poses a challenge in interpreting the repair data. Should it be analyzed in the context of the roof to which it is specific? Or should the repairs be examined as a whole, with the assumption that each roof was similar in quality? A
similar conundrum appears in the case of the windows, which were replaced two times between 1775 and 1987. For the purpose of this analysis, replacement is considered a “repair,” as like smaller changes to the system, it too is an action taken to keep the system functional and in good condition.

Limitations in Data

Although specific systems may have long intervals between recorded repairs, an investigation of the frequency of repair recording overall suggests that recording practices were fairly fine-grained and consistent over the years. A graph of the years between mentions of repairs to all systems included in data collection (masonry, carpentry, metal work, windows, finishes, roof, cupola, sewer, heating method, landscaping, and electrical), revealed that the longest interval between mentioning a repair of any sort was thirteen years, immediately after the building was built, a period that also included the Revolutionary War. The average time between repair recordings was 1.8 years (see figure B.15).

The consistency of the repair record also suggests that the record is relatively intact. However, it is possible that some parts of documents are missing, such as pages from the Treasurers’ Records. Previous to this thesis, a historian of the Concord School House, Mrs. Doris Ritzinger, compiled a record of all repairs to the building. Her record included mentions of repairs in the 1850s and 1860s that were not included in the versions of the Trustee Records and Treasurers’ Records currently available in the Pennsylvania Historical Society. Other than the additional records of repairs, her findings matched those of this study. It seems likely that when she wrote in the 1970s, she had
access to pages of the *Treasurer’s Records* that have since been misplaced. Fortunately, Mrs. Ritzinger’s work fills known lacunae in the data, though there may be others that remain unidentified.

Despite the overall frequency of repair recording, the maintenance records for some systems have long hiatuses. Based on the apparent consistency of repair recordings, it seems likely that gaps in maintenance records of specific systems were the result of lacks of maintenance. Gaps could also be the result of the grouping of maintenance tasks into a generic category such as “repairs” or “sundries,” or the direct payment of repair expenses to individuals who were tradesmen, but not identified in the records by their trade or by the repair they completed.

A further limitation in the use of historic data to determine repair cycles is that the historic mentions of repairs, while they may have mentioned the general system repaired, rarely specified where on the building the repair took place, or the scope of the repair. Entries such as “carpentry work,” or “painting” are common. Fortunately, the price of many repairs was mentioned, and was used as a proxy to indicate the scale of the repair. However, the low specificity as to repair locations would pose a challenge for stewards looking to form fine-grained maintenance plans with high levels of certainty about what should be preventively conserved and when.

*The Use of Relative Values to Compare Scale of Repairs over Time*

In order to compare the cost and scale of work over time, it is necessary to convert the prices to correct for inflation and economic changes. As explained on the
Measuring Worth website, measuring cost over time presents challenges, and the method for measuring worth must be selected carefully depending on what is being measured. For the US, between 1774 and 2013, Measuring Worth provides six measures of worth: the consumer price index; the GDP deflator; unskilled wage; production workers’ compensation; nominal GDP per capita; and relative share of GDP. Calculations with these indicators produce highly variable values. For instance, $9 spent in 1819 is valued at $170 according to the consumer price index, but $208,000 according to the relative share of GDP. For projects, such as “the construction of canals or the installation of a cable network,” Measuring Worth recommends the use of labor prices to indicate the worth of US dollars. Because the maintenance of the school house seems best categorized as a project, as it involved labor and construction, labor prices were used to indicate cost. Production workers’ compensation was chosen for use as the indicator. It is a way “to determine the relative cost of something in terms of the amount of work by . . . manufacturing production workers, which would include blue-collar workers, hourly rated workers, or non-office workers.” Production workers’ compensation was chosen for use as the indicator. It is a way “to determine the relative cost of something in terms of the amount of work by . . . manufacturing production workers, which would include blue-collar workers, hourly rated workers, or non-office workers.”

56 Measuring Worth, www.measuringworth.com/uscompare/. The Measuring Worth website was only selected for use after careful investigation determined that it was reputable and academically sound. Although it is independent of any institution, its founders are published academics: Laurence H. Officer, Professor of Economics at University of Illinois at Chicago, and Samuel H. Williamson, Research Professor of Economics at University of Illinois at Chicago and Professor of Economics, Emeritus, from Miami University. Its board of advisors includes representatives from Harvard University and the London School of Economics, among other institutions.


58 Ibid.
compensation was chosen because it uses skilled labor prices as the basis for its calculation, such as that of the skilled tradesmen hired by the trustees, including carpenters, masons, and roofers. Conveniently, it is based on data reported annually from 1800 to the present day, and therefore covers the entire period during which the dollar was used for the payment of expenses. In contrast, the other labor price indicator available, the unskilled wage, appears less applicable as it is not based on skilled labor.

A further challenge was faced in deciphering the relative cost of repairs prior to 1811, when the pound was still in use for payment. While one could easily assume that the currency used was the British pound, the American colonies used their own pounds, which were less valuable than the British. To further complicate matters, the value of pounds from individual colonies was distinct. Built in Germantown, Pennsylvania, the Concord School House was almost certainly paid for with Pennsylvania pounds. Unfortunately but perhaps not surprisingly, the Measuring Worth website does not provide values for that currency. This problem was addressed in the following manner. The exchange rate between Pennsylvanian pounds and British pounds in October 1775, the month the school house was completed, was obtained from the definitive work by John J. McCusker, Money and Exchange in Europe and America, 1600-1775. Because later exchange rates between British and Pennsylvanian pounds were not available, but the exchange rate had remained relatively stable since around 1740, the 1775 exchange rate was used to calculate the price of expenses incurred between 1775 and 1811.

1775 British pounds. Then, using the website *Measuring Worth*, the price in British pounds was used to calculate the value in 2013 pounds based on the average earnings index. The average earnings index is the recommended measurement for determining the relative value of historic prices in pounds for projects such as construction, much like the production workers’ compensation index for American dollars. Finally, the 2013 value in British pounds was converted to 2013 American dollars, based on the 2013 exchange rate, provided by *Measuring Worth*. Despite the complexity of the process used to arrive at comparable values for the Pennsylvania pound, based on comparison between the converted prices of whitewashing during the Pennsylvania pound and dollar periods, the results seem promising. In 1839, the converted 2013 value of whitewashing was $1350, and between 1775 and 1811 the converted 2013 value was approximately $1000-$1900 dollars, within a several-hundred dollar range of the 1839 price. Given possible variability in the scope of the whitewashing task, which would result in pricing differences, as well as the inexact nature of identifying converted values, these results seem sufficiently proportional to use as a basis for comparison.

Repair Cycle Findings for the Concord School House

Due to the lack of specificity in repair records, as well as the sometimes wide variability in the intervals between repairs, identification of specific service life estimations with high levels of certainty was infeasible. Instead, analysis of data revealed general information about repair cycles: how frequently and what scale of

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repairs could be expected by stewards, based on the building’s repair history. Analysis of the data also provided a wide perspective as to the long-term nature of the planning required for the successful preventive conservation of historic structures.

General Repair Trends

In general, reinvestment in the traditional systems of the school house decreased after the 1910s, with the exception of finishes applications, which continued at regular intervals and at a similar scale. Perhaps significantly, of all the studied systems, maintenance to the masonry and timber structural systems of the school house decreased the most during the 20th century. It appears that much of the maintenance efforts of the trustees during this time were focused on maintenance of the second floor apartment, which was installed in 1949, ensuring its habitability through investment in electrical and heating systems.

Despite the longer intervals between maintenance events between 1915-1987, the cost of repairs did not generally increase, suggesting that not only were repairs delayed, they were not as thorough as they had been in earlier decades. A number of the repairs were made only after several years of recommendations in the Trustee Records, and sometimes the need for repairs were mentioned, but no repairs recorded, suggesting a reactive rather than preventive conservation cycle through much of the 20th century.
Repair Cycle Findings by System

Roof System (see figures B.1 to B.2)

The roof was replaced four times between 1775 and 1987, at the ages of 43, 57, 31 and 44 years respectively. The mean age of the roof at replacement was 44 years of age. Unknown variables about each roof include the quality of their original workmanship and materials, and their degree of damage when replaced. The reason for the 26-year difference in replacement times between the oldest and youngest roof is unclear. It is possible that the 57-year-old roof was of superior quality, experienced unrecorded maintenance, or was simply neglected. It is also possible that the 31-year-old roof was replaced before serious issues had arisen, or was already of poor quality and required early replacement.

Data are limited, as there are only four examples of replacement, and those with a wide range of years. However, based on the records, one could make the conservative estimate that a roof made of traditional materials such as that of the Concord School House would have a replacement cycle of 30 to 45 years, depending on maintenance and quality of workmanship.

Carpentry System (see figures B.3 to B.5)

Carpentry repairs are generally recorded as payments for wood materials or to carpenters, rather than mentions of what was specifically repaired. Of the twenty-five wood repairs listed, thirteen occurred at 0 to 4 year intervals, indicating that small, regular repairs were common. All but 1 repair took place at intervals between 0 to 19 years. Of the 22 carpentry repairs with recorded prices, 18 were below $7000 in 2013.
dollars. When significant building campaigns are excluded, longer intervals between repairs were not correlated with an increase in the price of repairs. This could be an indication of inadequate or deferred maintenance, especially in the 20th century, which saw a decrease in the frequency and size of expenditures on carpentry. For instance, one 39-year interval without mentioned maintenance from 1902 to 1941 was broken with a $187 repair to a joist, likely a small repair, as the average recorded price of repairs, excluding the building additions mentioned above, was $5218.85 in 2013 dollars. Because deferred maintenance can skew the length of identified repair cycles, it must be taken into account when attempting to identify ideal repair cycle lengths. For this reason, graphics such as histograms are important tools in understanding the distribution of repairs over time. For preventive conservation purposes, regular small repairs are to be preferred to deferred maintenance, or even to large repairs after long intervals. For the Concord School House, stewards or hired professionals are recommended to inspect the wood components regularly, perhaps annually, for rot, insect infestation and loss of paint where existing, and should expect to make small repairs in 0 to 5 year cycles. Conditions recording should be duplicable and could include annual photographs of identified problem locations.

Masonry System (see figures B.6 to B.8)

Like carpentry repairs, masonry repairs are generally recorded as payments for mason work, rather than mentions of what was specifically repaired. Compared to the other systems studied, the masonry system appeared to have a wider range of durations between repairs, with three repairs recorded at 0 to 4 year intervals, one at a 5 to 9 year
interval, four at 10 to 14 year intervals, and three at 15 to 19 year intervals. Interestingly, while the carpentry system had a larger number of repairs at short intervals between 0 to 4 years, the largest number of masonry repairs occurred at the 10 to 14 year interval range. With the exclusion of financial outliers due to the construction of building additions, the interval between repairs does not appear to be correlated with greater expense in repairs. It appears that maintenance of the masonry stopped nearly completely for much of the 20\textsuperscript{th} century, as after a repair in 1913, no repairs were paid for through 1987, when records end, despite mentions of the need for masonry repairs. Based on the distribution of repair times indicated in the record, it is recommended that stewards plan to maintain the masonry system at least every 10 to 14 years, perhaps with repointing, though annual inspections should be used to determine if maintenance is needed sooner.

Windows System (see figures B.9 to B.11)

All windows of the school house were replaced completely in 1870 at the age of 95, and at least partially in 1947, at the age of 77. Windows have remained wooden. The most notable aspect of the windows is their frequency of maintenance. Out of 25 mentioned repairs between 1775 and 1987, 12 occurred at 0 to 4 year intervals. The majority of repairs were small, glazing and replacing lights. In fact, of the 18 repairs with available cost data, 16 were valued under $7000 in 2013 dollars, 10 of those costing less than $1000. By far the greatest expense was the full replacement of the windows, in 1870, which cost $62,200 in 2013 dollars. This historic record of frequent minor repairs stands in marked contrast with the approach commonly taken in modern times of
leaving wooden windows in place with minimal interventions until they fail and require replacement. To ensure the longest possible residual service life for wooden windows, historic records suggest that it is both necessary and cost effective to regularly inspect them, perhaps annually, and complete small repairs as needed.

Finishes System (see figures B.12 to B.14)

An examination of the intervals of finishes applications revealed that applying new finishes was both the most affordable and most frequent repair type throughout the entire history of the Concord School House. The average interval between finish applications was 6.7 years. Interestingly, the cost of finish applications appears to distinguish between the less expensive whitewashing, which may have been applied to the exterior (last mentioned in 1859), and the application of paint. Of the 19 finish applications with recorded prices, the average expense was $3447. Of the 19 finish applications with associated cost data, 18 are below $8000 in 2013 dollars in cost, with a single outlier in 1848 costing $15,550 in 2013 dollars. This suggests that the finish applications may have been similar in scale. One notable aspect of finishes repairs is that unlike repairs to the majority of other systems, they continued regularly throughout the 20th century. As finishes can conceal a multitude of pathologies, one wonders if in the 20th century the Trustees used finish applications to cover up problems with wood or masonry, which they maintained less frequently than in the 18th and 19th centuries. Several factors present a challenge in estimating the repair cycles of finishes for the Concord School House. Though the finish applications were applied regularly, they were likely applied to various parts of the building, some parts with greater
frequency than others. Many finish applications incorporated historic finishes materials such as oil, which may have a different length of repair cycle than modern finishes, such as those containing latex. Nevertheless, the regularity of the finish application intervals suggests that stewards of the school house should anticipate frequent finish application campaigns and touch-ups, perhaps every 6 years or so as necessary. Interior and exterior parts of the building would require applications at either shorter or longer intervals, depending on their degree of exposure to the elements and the quality of finishes used.

Conclusions

The investigation of the Concord School House records sought to identify specific service life estimates for use in informing a preventive conservation plan. Ultimately, the data available in the repair records lacked the specificity required to form service life estimates sufficiently precise to stand alone for use in preventive conservation planning, because records do not include the motivations or locations of repairs. It did however offer insight into repair practices by providing information about the general repair cycles stewards could expect over time, and by offering a long-term perspective about the maintenance required to sustain a structure for centuries, all of which can be used to inform preventive conservation planning for historic structures.
Chapter 5: Application to Other Buildings

The process of gathering repair cycle information from historic records of repairs to inform preventive conservation planning is applicable to other structures in addition to the Concord School House, especially as the findings need not be extremely specific to prove useful. For instance, in the case of the Concord School House, findings from maintenance records are not necessarily exact enough to be used as the sole guide for planning preventive conservation. That said, they can provide insight into appropriate intervals for conditions surveys, and a general guide for when repairs may be expected. Provided with a general estimate of when to expect repairs, stewards can plan financially, confirm the projected declines in performance in the field with conditions surveys, and practice preventive conservation accordingly. Furthermore, analysis of records provides a long-term perspective to preventive conservation planning, and insight into the conditions necessary for the successful preservation of a historic structure, such as planned, consistent maintenance. The following is necessary to extract sufficient information about repair cycles to inform planning:

1) Records with regularly recorded and detailed mentions of specific repairs or need for repairs over time, as well as information regarding the scale, price or location of repairs.

2) Critical thinking in interpretation of data.

Historic Recording of Repairs—Information Needed and Where to Obtain It

Although in the case of the Concord School House, the mentions of repairs took the form of trustee and treasurer’s documents, with creativity, data could likely be
derived from a variety of sources, providing that they meet the basic requirement of regularly recording repairs and repair details over time. For instance, the historic diaries of detail-oriented individuals have the potential to provide records of repairs. Other sources could include correspondences or estate expense books. A single, continuous source is not necessarily required. Stewards are encouraged to combine records of repairs from various sources, which can be assembled to fill lacunae or confirm each other. When combining mentions from various sources, careful citations are recommended to ensure that data collection can be checked and replicated if necessary.

Based on findings from the Concord School House records, the longer, more continuous and more detailed the maintenance record, the more representative the data for repair cycles is likely to be. Long-spanning records of repairs provide a “big picture” view of data, and help inoculate findings against distortion from short-term maintenance trends. For instance, maintenance of the studied systems of the school house from 1775 to around 1905 occurred with greater frequency than during the period between 1906 and 1987. Fortunately, as the data spans from 1775 through 1987, the trend is identifiable and can be taken into account when interpreting data. Furthermore, the outlying long intervals between repairs did not skew data interpretation, as the mode of repair intervals rather than the mean was used to estimate representative repair cycles. However, if only the data from 1906 to 1987 were available, estimates of the length of representative repair cycles would be longer and possibly skewed by lack of repairs because of deferred maintenance.
The specificity of recording should at least mention the general category of the repair performed, for instance “carpenter’s work,” or “glazing.” This will allow the repairs to be organized by building system. At times, the Concord School House recorded “sundry” or miscellaneous repairs. These are unable to be categorized or attributed to specific systems, and are therefore gaps in the data. If stewards possess records that do not appear to name specific repairs, they may still be able to unlock the information with additional research. Mrs. Doris Ritzinger, a historian of the Concord School House in the 1970s, looked up the names of individuals paid in the treasurer’s accounts to reveal their professions, and therefore the category of repairs for which they were responsible. Her work revealed that an individual named H. H. Busby who was paid regularly in the late 19th and early 20th centuries was in fact a carpenter, which was verified with the U.S. Census records for this thesis. Investigation into U.S. Census records or trade union membership lists can reveal individuals’ professions and therefore indicate generally how to categorize their repair work.

The level of regularity and detail of records provides insight into the dependability of past recording practices. The more frequent and detailed the records, the greater chance that caretakers were recording a high percentage of repairs, and the greater likelihood that the records will provide reliable data. When evaluating records for regularity, one can look to mentions of any repairs or alterations to a property as indicators that repairs were being recorded, even if repairs to the systems of interest go through years-long intervals without mention. For instance, between 1822 and 1837, if one were to look at the Concord School House records for repairs solely to the
carpentry, masonry, finishes, roof or windows systems, it would appear that only two repairs were made in a 15 year interval, which could suggest a lacunae in in the record. However, when looking at the records in terms of any and all repairs recorded, it becomes apparent that 5 repairs took place during the 15-year interval, indicating that maintenance was taking place and being recorded, simply not to the systems of interest. When evaluating records for their level of detail, the smaller the recorded repairs, and the greater the consistency of their mention over time, the greater the confidence one can have of a more complete record. For instance, multiple generations of stewards of the Concord School House have recorded expenses as detailed as the replacement of a single pane of window glass, suggesting a high level of conscientiousness in recording repairs.

Knowing simply that repairs occurred does not necessarily provide sufficient information to interpret the significance of repair cycles. Knowledge of the extent of the repairs is also needed in order to provide a better understanding of the cycles of repairs. In some cases, where the scope of work is not described verbally, price can serve as a proxy indicator of scale. This was the case for the Concord School House records, which rarely if ever provided written descriptions of scope. For instance, in 1863 and 1883, school house Trustees made entries reading “mason work.” No further description was provided to explain the extent of the “mason work.” An investigation of the relative value of the repairs revealed that they cost $582 and $7,350 in 2013 dollars respectively, and were therefore very different in extent, despite identical written descriptions. Of course, descriptions of the location of repairs would be ideal, though
they are not always available. One of the weaknesses of the data of the Concord School House is their lack of specificity as to where on the building repairs occurred. This prevents specificity in the repair cycle estimations derivable from the data, limiting them to the system, rather than building component level.

How Complete Must Data Be?

The question of how much data are needed to provide useful repair cycle information is difficult to answer due to the variability between buildings, systems, and the context of recording practices. Stewards using records to inform repair cycle predictions are subject to the whims of the recording and maintenance practices of the people before them. In general, the larger the data set, the more confidence can be placed in it. The bare minimum of data required for systems with complete replacement such as roofs is two repairs, or one repair cycle, because the scope and location of the repair is relatively clear. For systems that persist in situ, like masonry, the data from repair intervals can be more ambiguous, as it can be difficult to determine exactly what part of the system was repaired and when. For these systems, a larger sample size of repair intervals is recommended, along with data indicating the size of the repairs, such as expense records.

*The Critical Interpretation of Data*

Addressing Gaps in Data

At times, records may have years’ long periods without mention of repairs, may go years between entries, or may be clearly missing. Long periods between repairs in data are challenging to interpret, as they could indicate that no repairs occurred, or that
repairs occurred but were not recorded. In rarer instances, the cause of the gap may be obvious—for instance in the unlikely event of torn out pages and an entry starting in mid-sentence, one could infer that the data was simply lost. Historical context can also give some insight to possible causes for gaps between repair or recording intervals. For instance, the longest interval without record repairs for the Concord School House spans from 1775—1788, and may be the result of the upheaval of the American Revolution. In the case of obviously physically missing data, one can exclude the lacunae and restart calculating repair intervals from where the record resumes. Where data are not physically missing, one can include all intervals in repair cycle calculations. Analyzing the repair intervals using graphic histograms will contextualize the long periods and determine if they are representative of data overall.

Using Qualitative Data to Identify Trends

In addition to recording numerical-based intervals between repairs and expenditures, stewards can augment their data by gathering qualitative information from their sources. In the case of the Concord School House, careful reading of comments in the records uncovers indicators of deferred maintenance in the 20th century, a finding which is supported by the longer intervals between repair cycles. The records mention decisions to defer roof replacement specifically because of the expense. In 1943, a special meeting was called to respond to a newspaper article titled “Historic School Forgotten,” indicating that the school house had reached levels of disrepair noticeable by the public. In 1967, the historian of the school house mentioned that the cellar and attic of the school house had not been cleaned in “a long, long time,”
and described the need to keep the school house “in better order,” suggesting unmet maintenance needs. Furthermore, the records mention instances such as the disrepair of the structure’s stucco, but do not record repairs to it. Qualitative information provided in such records can both support and confirm trends such as deferred maintenance. Identifying such trends aids stewards in the interpretation of repair cycle findings during these intervals. For instance, the repair intervals during times of deferred maintenance may not be the best source for identifying representative repair cycles.

In periods during which deferred maintenance was practiced, repair cycle intervals can potentially still be obtained through mentions of disrepair or the need for repairs, even if the repairs were not performed. Such mentions indicate the expiration of a system’s residual service life and can be used to estimate a repair cycle. However, given a data set with clear periods of both regular and deferred or nonexistent maintenance, repairs that actually occurred can be given preference during analysis. This can take the form of excluding mentions of the need for repairs from the data.

Contextualizing Data

Once data are collected from records, they should be analyzed thoughtfully to avoid misleading interpretations. For instance, in the case of the Concord School House, examination of repair records in the 20th century revealed a pattern of lower expenditures and deferred maintenance. Repairs performed during periods of deferred maintenance are most likely not the best source for identifying representative repair cycles, as maintenance was likely minimal and reactive. Trends such as deferred
maintenance should be taken into account when forming repair cycle estimations. Other earlier records of the school house reveal large, one-time expenditures, the result of building campaigns. Taken alone, these large, one-time expenditures could be interpreted as representative. But when viewed as part of a pattern, they can be contextualized and read as unusual events rather than indicators of the expected size of repairs. These factors need to be taken into account when interpreting the significance of expenses and intervals between repairs to gather repair cycle information.

Graphic Tools for Interpreting Data

In addition to basic statistics, graphic displays of data are highly recommended for use in analysis. Graphics used in the analysis of the Concord School House records include histograms of the distribution of the intervals between repair cycles (see figures B.2, B.4, B.7, B.10 and B.13), as well as timelines of repairs and mentions of the need for repairs (see figures B.1, B.3, B.6, B.9 and B.12), and scatter plots illustrating a general lack of correlation between the length of time between repair cycles and the expense of repairs (see figures B.5, B.8, B.11 and B.14). The histograms of the distribution of time between repair cycles illustrate the most frequently-occurring intervals between cycles, and prove a useful visualization of outlying repair cycles such as those occurring in the 20th century during the period of deferred maintenance. This provides insight into when repairs occurred most regularly. Repair cycle data from periods of regular maintenance, as opposed to deferred maintenance, is most likely to provide representative information. The timelines of repairs and mentions of repairs, using the year on the x axis and the expense of the repair on the y axis, provide a general visualization of trends.
in repairs, and also highlight large expenditures such as roof or window replacements or additions to the building. By using the same scale and units through all timelines, displaying all systems together provides a “big picture” insight as to when repairs to multiple systems were occurring at the same time, and the scale of the repairs.

Additional Avenues of Investigation: Extracting Data with Greater Specificity

*The Incorporation of Additional Historic Records*

Written records can be a wealth of data that may not be initially apparent but can be unlocked through consultation with additional sources. As mentioned earlier, in cases where individuals are paid in the records, and their full names are recorded, their professions can be investigated through US Census data to determine whether the payment indicates a repair or maintenance. Additionally, the repair records from historic buildings contemporary to that under investigation can be consulted in order to gain greater insight into historic prices, and therefore the scale, of repairs. Further understanding of historic repair pricing and scale could potentially be obtained from historic trade journals or trade catalogues selling materials.

*Supplementing Repair Cycle Data from Historic Records with Building Archaeology*

Identifying the time period of building components and alterations by applying knowledge of historic building technology may allow stewards to link specific repair entries to specific components. This could provide insight into which components were repaired when, and even the approximate intervals between repairs, depending on the level of physical integrity of the fabric. This information would allow stewards to estimate the repair cycles of the specific components, which might not be possible
through repair records alone. The success of this technique would depend on the presence of largely intact historic fabric with evidence of repairs, and the possession of expertise in identifying the periods of historic repairs based on that fabric.

*Consultations with Experts in the Traditional Building Trades to Inform Repair Cycle Estimations*

An important source of knowledge about traditional building materials is master craftspeople working in the traditional building trades, who specialize in historic building construction and repair techniques. These individuals include master masons, window sash makers, timber framers, carpenters, and roofers using slate or wooden shingles, among others. Many master craftspeople have both personal expertise working with traditional materials and building techniques, and expertise acquired through apprenticeships with other masters as part of a centuries-long tradition. In fact, many are the intellectual descendants of 18th and 19th century craftsmen, the same people who built and maintained structures such as the Concord School House. Such experts in the traditional trades are likely to possess general knowledge of the service lives of historic materials.

Consultations with master craftspeople via the Delphi method could provide useful repair cycle knowledge, potentially detailed enough to serve as service life estimations. As discussed in Chapter 2, Moser explains in his article “Towards the Practical Evaluation of Service Life—Illustrative Application of the Probabilistic Approach,” that the recursive Delphi method has been used successfully to identify
unknown values in fields such as risk engineering. With their experiential knowledge of the behavior of traditional building materials, master craftspeople could provide valuable estimations of the service lives of such materials. These estimations could be used to confirm, refute, or supplement the repair cycle estimations derived from historic records.

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Chapter 6: Applying Repair Cycle Findings from Historic Records to Plan for Long-Term Preventive Conservation

A Wider Perspective

A significant benefit to studying historic records of repairs to develop repair cycle estimates is the perspective it provides on the measurement of time, which can effectively inform planning for preventive conservation. Because human lives span decades rather than centuries, individuals frequently judge the passage of time in small increments, years instead of decades, decades instead of centuries. Yet the truth of the matter is that ideally, the lifespan of a steward is but a blink of an eye compared to that of a historic structure. In the case of the Concord School House, the Trustee Records annually listed the names of trustees. Frequently, a name would appear for 30 or more years, until the time when mention was made in the yearly minutes of that individual’s death, often accompanied by a brief acknowledgement of thanks for their service to the school house. Another trustee would then take his or her place, generation after generation. Stewards of a historic structure must remember that the building has outlived its predecessors, will outlive them, and if all goes well, will outlive future stewards too. Planning for preventive conservation using short-term time scaled to human lives is the equivalent to staring at one’s feet when walking, rather than looking ahead to anticipate the best path.

To cogently plan for long-term preventive conservation, stewards must do so from the perspective of building-time rather than people-time. They must take into account the rhythm of their structure, the cycling renewal and expiration of its systems.
over time. Preventive conservation plans should plan in terms of centuries, rather than decades. Hallberg writes that for a constructed work with an estimated service life of 50 years, maintenance schedules should plan for at least 30 years. Logically, historic structures intended to last for centuries require planning for repairs on a longer-term schedule, because unlike modern buildings with short designed service lives, these structures are intended to endure. Knowledge gained from historic repair records of past repair cycles provides stewards with the means to generally predict and plan for future long-term maintenance based on historic patterns.

Although probably not sufficiently detailed to stand alone as a source for specific service life estimations, when supplemented by methods such as professional estimates and conditions assessments, repair cycle information from historic repair records still has a role in informing preventive conservation. Many structures lack the level of documentation of the Concord School House, and even its extremely well-documented records have limits to the specificity of their repair cycle information due to a lack of recording of the location or scale of repairs. Records from other buildings are likely to have data with similar, if not greater, limitations. Nevertheless, analysis of historic repair records can provide an overall picture of the most common times between repair cycles. This information can be applied to planning to predict, in general terms, when repairs may be needed. Predictions can be confirmed in the field through regular conditions

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assessments, and potentially through consultations with experts who can supplement the predictions with their own service life estimates.

A Reality Check

Repair cycle findings from historic records can also provide a baseline measure that stewards can use to judge whether their current maintenance budgeting and scheduling are sufficient to meet the likely needs of their building. For instance, if the average historic maintenance or replacement cycle for a roof is 44 years, are stewards saving for eventual roof replacement? Or if windows have historically been maintained most often in cycles of 0 to 4 years, does this match stewards’ current practice of maintenance? If not, stewards may benefit from re-evaluating whether their maintenance scheduling is frequent enough to keep their building systems in optimum repair. Using historic repair cycles as a yardstick to evaluate current practices can aid stewards in identifying unsustainable maintenance practices such as deferred or reactive maintenance, and has the potential to provide the impetus necessary to form an action plan to adapt more sustainable practices such as preventive conservation.

Another insight provided by investigations of historic repair records is a recognition of the importance of consistent and stable stewardship in maintaining a building. Historic structures are the product of generations of effort expended to keep buildings standing and hopefully in good repair. Continuity of ownership is not so important as continuity of care, but care may be most reliable when it takes the form of an organization maintaining the building over time rather than the piecemeal efforts of individuals. Ideally, an organization has the potential longevity needed to plan for and
maintain a building for generations, and a greater access to the financial and organizational resources needed to do so. In order to succeed at the long-term physical conservation of its structures, an organization must be functional enough to administer consistent maintenance over time. Thus, stewards looking to practice preventive conservation in the broadest sense must work towards ensuring the sustainability and longevity of their own organizations. Stewards must honestly evaluate the current strength of their organizations, and if possible, seek to strengthen their weaknesses to ensure they will be capable of administering the long-term maintenance required by historic structures.

Conclusion

Preventive conservation is a key tool in ensuring the long-term survival of buildings. Practicing it prevents building deterioration and maximizes the preservation of historic fabric. When available, historic records of repairs can give stewards a starting point in planning for their structure’s preventive conservation. Looking back at past repair cycles provides stewards with general information about the expected maintenance needs of their buildings. It also provides stewards with a clearer understanding of the long-term nature of preserving historic structures, which is the work of generations rather than a single human lifetime. This wide view of stewardship allows stewards to look ahead when planning for preventive conservation by anticipating structures’ maintenance needs and ensuring their preservation far into the future.
Bibliography


Appendix A: Glossary

**Actual service life** is the actual period of time when a building material, component or system continues to meet its performance requirement. It may differ from predicted service life because actual service life depends on many factors, including environment and design, and can therefore be difficult to predict accurately.

**Building reinvestment plan** is a plan where stewards combine their knowledge of service lives or repair cycles, as well as maintenance and replacement costs to budget accordingly. For example, the knowledge that a roof’s service life will expire in thirty years allows stewards to calculate the amount of money to put aside annually in order to afford the future replacement.

A **Building system** is a configuration of building components that are interconnected to produce a larger whole. Examples of building systems include roofs, which are assembled from components such as rafters, sheathing, flashing, shingles, etc.; windows, which are formed from components such as glass, wood and glazing putty; and timber framing, where individual timber members are joined together as a whole that supports structural loads. Building systems are interconnected with each other. For instance, a leak in a building’s roofing can result in rot in its timber framing beneath, shortening its residual service life.

**Deferred maintenance** occurs when there is a backlog of needed repair work.

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Repair cycles occur over time at a rhythm relatively specific to an individual building. Depending on the building system, these cycles can occur in terms of years, decades or even centuries. Though often less specific than service life estimations, knowledge of maintenance or repair cycles can also aid stewards in planning for preventive conservation by providing both a general idea of when to expect maintenance and a long-term perspective on a structure’s maintenance needs over time. However, repair cycles do not necessarily correspond with service lives, due to practical matters such as budgeting, users’ needs, or access to the building system for repairs.

Performance requirement is the minimum level of a component’s acceptable performance, for example, the ability of a beam to support a structural load without breaking.64

Predicted service life is the predicted amount of time during which a material, component or system will meet its performance requirement.

Preventive conservation is the proactive monitoring of building conditions and the deliberate planning and application of treatments (i.e., maintenance or replacement) before material deterioration leads to the deterioration of building assemblies. It is planned and deliberate in nature.

Reactive maintenance is maintenance that addresses problems after they have occurred, rather than addressing them preventively.

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64 “ISO 15686-1:2011.”
**Residual service life** is the time remaining after installation that a material, component or system continues to meet its performance requirement.⁶⁵

**Service life** can be defined as the period of time that a material, component or system meets or exceeds its *performance requirement*.⁶⁶

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Appendix B: Repairs by System with Corresponding Graphics

B.1: Roof Expenses in 2013 Dollars by Year
Missing Prices Listed as "?"

B.2: Distribution of Time Intervals Between Recorded Roof Replacements
B.6: Masonry Expenses in 2013 Dollars by Year

B.7: Distribution of Time Intervals Between Recorded Masonry Repairs

B.8: Duration Between Masonry Repairs vs. Price

Mean and Median Annotated; Repairs without Prices Excluded

NOTE: no repairs occurring after 1915
B.9: Window Expenses in 2013 Dollars by Year

B.10: Distribution of Time Intervals Between Recorded Window Repairs

B.11: Duration Between Masonry Repairs vs. Price

Mean and Median Annotated; Repairs without Prices Excluded
NOTE: no repairs occurring after 1915
B.15: Years Between Recorded Repairs to Any System (Including Masonry, Carpentry, Metal work, Windows, Finishes, Roof, Cupola, Sewer, Heating, Landscaping, and Electrical Systems)

Average: 1.8 years
Appendix C: the Concord School House, Germantown, Philadelphia PA

C.1: Concord School House in the 1850s, earliest known photograph
Photograph courtesy of the Germantown Historical Society

C.2: Concord School House in 2015 from the Same Perspective as the 1850s Photograph
Photograph by Meredith Leep
C.3: Concord School House Mid-20th Century
Photograph by Helen M. Bauhof, courtesy of the Germantown Historical Society

C.4: Concord School House 2015 from the Same Perspective as the Mid-20th Century Photograph
Photograph by Meredith Leep
C.5: Interior of the Concord School House, First Floor, Facing Germantown Avenue, 2000s
Currently converted into school house museum
Photographed by Andrea Gottschalk, University of Pennsylvania Libraries

C.6: Interior of the Concord School House, First Floor, Facing Germantown Avenue, 1910s
Original home of the Site and Relic Society (now the Germantown Historical Society)
Photograph courtesy of the Germantown Historical Society
C.8: 1935 Historic American Building Survey Drawing of Concord School House Elevations
Original as well as Subsequent
Proceedings
of the order and management of
the School and
Building the Concord
School house
at the upper end of Germantown
1775

C.9 (far left) and C.10
(left):
Pages from the
Concord School
House of Upper
Germantown Trustee
Records
Courtesy of the
Pennsylvania
Historical Society
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