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APPLYING SERVICE LIFE AND ASSET MANAGEMENT TECHNIQUES TO ROOFING SYSTEMS

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Abstract

The paper describes the need for information exchange related to service life issues among the research, standards and practitioner communities. The paper outlines the most significant research contributions in the area of service life prediction and durability research and describes existing guides and standards in this field. The paper also identifies the immediate need for a proactive approach to maintenance management and capital renewal. The authors discuss many opportunities that are available today to assist asset managers, including process re-engineering techniques and information technology tools. Techniques such as capital renewal/deferred maintenance planning, engineered management systems, level of investment studies and condition assessment surveys are described, as are tools such as computerized maintenance management systems, CD-ROM, the Internet, computer aided facilities management and mobile computing. The Building Envelope Life Cycle Asset Management (BELCAM) project is a research project employing these techniques and tools. The BELCAM project also incorporates the following enabling technologies: maintenance management, life cycle economics, service life prediction, user requirement modeling, risk analysis and product modeling. The project focuses on roofing, and more specifically low-slope roofing systems.

Keywords: Asset Management, Building Envelope, Durability, Information Technology, Life Cycle Economics, Maintenance Management, Risk Analysis, Service Life, Product Modeling.

Résumé

Ce document traite de la nécessité d'échanger les informations relatives aux questions de durée de vie entre les chercheurs, les organisations de normalisation et de praticiens. L'accent est mis sur les contributions majeures de la recherche dans le domaine de la prévision de la durée de vie et de la durabilité ainsi que sur les normes et directives existant dans ce domaine. Les auteurs soulignent le besoin immédiat d'une approche proactive de la gestion de la maintenance et du renouvellement du capital. Ils évoquent les différentes solutions possibles aujourd'hui pour aider les gestionnaires de biens, notamment les techniques de ré-ingénierie de procédés et les outils de technologie de l'information. Des techniques telles qu'une planification du renouvellement de capital/maintenance différée, des systèmes de gestion sophistiqués, des études du niveau d'investissement et des évaluations d'état sont décrites ainsi que des outils comme les systèmes de gestion de maintenance informatisés, les CD-ROM, Internet, la gestion des installations assistée par ordinateur et l'informatique mobile. Le projet de la gestion des biens au cours du cycle de vie de l'enveloppe des bâtiments (BELCAM) est un projet de recherche qui exploite ces techniques et outils. Ce projet comprend les technologies catalyses suivantes : gestion de la maintenance, économie du cycle de vie, prévisions de durée de vie, modélisation des exigences de l'utilisateur, analyse des risques et modélisation de produit. Le projet est particulièrement axé sur les systèmes de toiture, notamment ceux des toitures de faible pente.

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1. Introduction

Asset managers are faced with many difficult decisions regarding when and how to repair their building stock. The reasons for the difficulties relate directly to the lack of usable data, information and knowledge related to service life prediction, and the lack of tools to assist the asset manager in making a proper maintenance, repair or replacement choices (Lacasse and Vanier, 1996). Some of the most difficult decisions relate to the building envelope, which normally incurs the major portion of the initial cost of a building and it is the most significant system in terms of maintenance, repair and replacement (Dalgliesh and Brown, 1994).

The Institute for Research in Construction and the Real Property Services Branch (RPS) of PWGSC are proposing a major research project which will focus on building envelope service life prediction, in an effort to provide asset managers with a suite of tools to optimize the cost of asset management. The program goals of the Building Envelope Life Cycle Asset Management (BELCAM) research project are to develop methods to predict the service life of the building envelope and its elements and to assist asset managers in maintaining these building components (www.nrc.ca/irc/belcam). The initial field of investigation for BELCAM is the roofing domain. The tools and techniques developed in this initial domain will be modified and used for service life and asset management research of other building envelope systems.

The Building Envelope Program at the National Research Council Canada (NRCC) develops technologies for the design, construction and operation of durable, energy-efficient and cost-effective building envelope systems. Key to this program is the research required to predict the long-term performance of building envelope systems (www.nrc.ca/irc/programnotes/be.html). This is accomplished through the proper combination of:

- models of the heat, air and moisture transport mechanisms,
- facilities and techniques for laboratory and field evaluation,
- information structures to adequately model costs, performance and service life, and
- information technology tools to transfer technology to building practitioners.

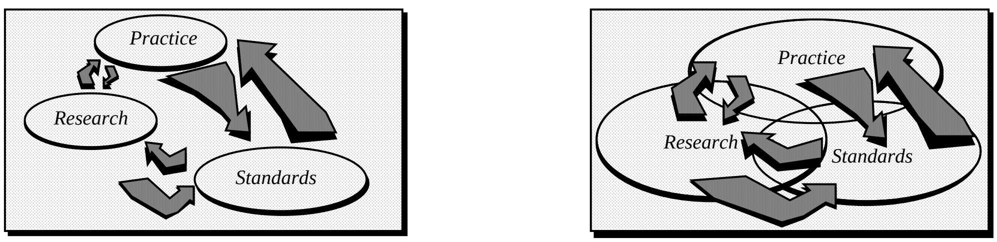
Public Works and Government Services Canada (PWGSC) is the principal landlord and contracting authority for the Canadian federal government; it is responsible for the planning, design, construction, commissioning and performance assessment, as well as, operations and maintenance of the wide range of physical assets in the federal government's portfolio. PWGSC has demonstrated expertise in building inventory management, preventive maintenance, collection of cost and field performance data, as well as having undertaken numerous demonstration projects to evaluate the effectiveness of various materials, products, processes and technologies (www.pwgsc.gc.ca).

This paper outlines the most significant contributions by NRCC, PWGSC and others in the area of service life prediction and related durability research, describes existing guides and standards in this field, identifies opportunities for research and development, describes the enabling technologies required to address service life prediction and outlines the research plan for the three (3) year BELCAM project. The author s identify tools and techniques from the area of service life and asset management that could assist the roofing industry; it is left to the readers to identify their own opportunities in the roofing domain.

In this paper, service life is defined as “the actual period of time during which the building or any of its components performs without unforeseen costs of disruption for maintenance and repair” (CSA, 1995). Durability is defined by the authors as "the rate of change of performance". An asset manager is "the individual responsible for the long-term strategic planning of a corporate real estate portfolio" and a property or facility manager is the person who deals with day-to-day maintenance issues.

2. Research, Standards and Practice

It is important to identify first the need for information exchange between various communities involved in service life and asset management in the construction industry. Unfortunately, researchers themselves can do little to increase the level of knowledge in the service life and asset management field. However, their research activities, in combination with their work on standards bodies, can significantly increase that knowledge level. In Figure 1 (a), the relative amounts of information exchange between research, standards and practice are indicated by the size of the arrows. Figure 1 (b) illustrates the desired information exchange where the amount of technology transfer is increased and where the three communities are working closer together.



(a) Existing Information Exchange (b) Desired Information Exchange

Figure 1 Relationships (Lacasse and Vanier, 1996)

In the following section the authors discuss service life and asset management activities in these three construction communities: the objective of this discussion is to stress the important functions of each community as they relate to service life prediction and asset management.

2.1. Service Life/Durability Research

2.1.1. Background

Service life and durability research has been part of the construction industry for almost 50 years. It was first identified as a research field as early as the 1950's and has spawned numerous research projects since that time. The technological importance of service life research is apparent from the number of conferences held in the past 20 years (Sereda and Litvan, 1978; Frohnsdorff and Horner, 1981; Sneck and Kaarresalo, 1984; Lee, 1987; Baker *et al,* 1990; Nagataki *et al*, 1993; Sjostrom, 1996), from the body of knowledge accumulated in these and other works (Grondin, 1993), and from activities of technical research committees, in particular those active in the International Council for Building Research Studies and Documentation (CIB) and the International Union of Testing and Research Laboratories for Materials and Structures (RILEM).

2.1.2. International Cooperation

International technical committees have also played an important part in the gathering and disseminating of information on durability and service life in roofing systems. Research has been reported in the Triennial CIB Congresses as well as the combined National Institute of Standards and

Technology and National Roofing Contractors Association (NIST/NRCA) conferences. A considerable amount of information has been also been contributed throughout the CIB technical committee W83/RILEM TC 120-MRS, “Membrane Roofing Systems”, the ASTM committee D08 on Roofing, and to a lesser extent, the CIB W80/RILEM-140 working commission.

2.1.3. Application of Service Life and Durability Research to Practice

There is considerable depth and breadth to service life prediction, but there is little that can be readily used by building practitioners. This is primarily because much of the information has been derived for research consumption, without systematic organization to promote access by practitioners. Although there have been considerable efforts made to develop standard methods of service life prediction for materials and, to a lesser extent, components, there is still substantial work needed to relate these studies to the service life of building assemblies and indeed, the asset management of buildings.

2.2. Codes, Standards and Guides

Codes, standards and guides, whether voluntary or mandatory, provide instructions and guidance for construction practitioners. These documents therefore should play a vital role in service life specification and prediction.

2.2.1. Existing Building Codes, Material and Component Standards and Practice Guides

Building codes in North America generally do not address durability or service life explicitly. Many of the prescriptive requirements, referenced material and component standards implicitly provide some durability provisions but, for the most part, the actual degree of durability that will be provided in a particular service environment is unknown.

Various sectors of the construction industry have, over the years, produced a number of very valuable publications describing the design and construction of building envelope elements. Again, while adhering to these guides generally ensures some acceptable level of durability, information is not provided on service life related to the actual service conditions.

2.2.2. National Guides

A number of guideline documents have been produced in the recent past including:

1. Japan, The English Edition of: Principle Guide for Service Life Planning of Buildings, Architectural Institute of Japan (AIJ, 1993);
2. Britain, Guide to Durability of Buildings and Building Elements, Products and Components, British Standards Institution (BSI, 1992);
3. Canada, S478-1995: Guideline on Durability in Buildings, Canadian Standards Association (CSA, 1995).

The Japanese guide was developed under the direction of a committee that was established to systematize the concept of durability (AIJ, 1993; Shirayama 1985). This committee first defined the terminology related to the field of durability. Thereafter, a sub-committee proceeded to prepare principles for the process of planning for durability and to develop a procedure for predicting the service life of dwellings and their elements. Although first published in Japan in 1989, the guide was only made available in English in 1993. Efforts in Japan are continuing along the same vein, and a guide for the repair and maintenance for buildings is also being produced (Shirayama and Nireki, 1993). The minimum planned service life for a facility is listed as 15 to 40 years or more, the required service life for a roof is 23 to 32 years depending on the type of building.

The Guide to Durability of Buildings produced by BSI gives guidance on the durability required and the predicted service and design life of buildings and their elements (BSI, 1992). It applies primarily to new construction rather than alterations, and only partially applies to other civil engineering works (e.g. roads, buildings and dams) and emphasizes communication among the various parties involved in building design and construction. Although much of the service life information in this guide applies to the roofing domain, there is nothing specifically referenced.

The CSA "Guideline on Durability in Buildings" (CSA, 1995; Chown *et al*, 1996) had as its initial model the BSI guide but developed to have significantly more depth of information and breadth of scope. It provides a set of recommendations to assist designers, builders and owners to create and maintain durable buildings and a framework within which durability targets can be set, assessed and verified. It also describes approaches for specifying the durability performance of buildings and their elements. It contains generic information on factors, such as environmental loads, that impact on the durability of the materials in a building and it also identifies the need for designers to consider costs, maintenance and replaceability in the selection of materials. The guideline makes it quite apparent that durability is affected by service life requirements and design choices. Although much of the service life information in this guide applies to the roofing domain, the only roofing references appear as examples in the appendices. Appendix A provides examples of decisions and records and Appendix F predicts a service life of 20 years for a built-up roof with regular inspection and maintenance.

2.3. Practice and Technical Information Exchange

Statistics Canada has estimated that over 40 billion dollars is spent each year to maintain Canada's 2 trillion dollars worth of building stock (Statistics Canada, 1993). Roofing membranes and systems account for approximately 30 percent of these costs. In the United States of America the numbers can be conservatively estimated at ten times higher (NRC, 1990). Therefore, asset managers are responsible for managing a substantial amount of construction and maintenance work. In many instances, the initial design and construction costs are small compared to the asset maintenance costs throughout the building's life: this makes the asset manager a major player in the construction game.

Asset managers are faced with many difficult decisions regarding when and how to maintain and repair their constructed facilities. The reasons behind these difficult decisions are the growing fiscal constraints, an increasing maintenance deficit and a substantial repair backlog. In addition, asset managers resources are being challenged from all sides: they are also being asked to cut cost, to privatize operations, to outsource responsibilities, to reduce maintenance and to increase efficiency. These problems are exacerbated by the lack of usable data, information and knowledge related to maintenance and repair, and the lack of tools to assist the asset manager to make proper inspection, maintenance and repair choices.

The Office of the Auditor General of Canada has already commented on the poor state of Canadian government assets: "The consequences of not carrying out adequate building maintenance and repairs are loss of asset value, poor quality of working space, potential health and safety problems, the probability of higher repair costs in the future, and increasing reliance on more costly leased accommodation. ... Without proper maintenance, facilities will deteriorate to the point that extensive investment is required to restore or replace them. The result, ultimately, will be increased federal costs” (OAG, 1994).

It is estimated that there is over $ 1.7 billion in deferred maintenance in the Canadian Department of National Defence alone, which equals approximately 13 percent of its plant replacement value: “The Department [of National Defence] should introduce life cycle management for major individual elements of infrastructure to determine the most appropriate balances between capital and maintenance spending, monitor the amount of deferred maintenance of those individual elements as well as in total, and use the information in infrastructure planning” (OAG, 1994).

The OAG recommendations include:

- be certain that it has appropriate management information on asset condition, building costs and performance, and the consolidated requirements for repairs and maintenance;
- ensure that appropriate maintenance standards are in place and consistently applied in each region;

The OAG (OAG, 1994) also identified traits of strong and weak real estate management; specific traits relating to service life and asset management are listed in Table 1.

Table 1: Real Estate Management

Strong	**Weak**
Appropriate management information systems for real estate operations. Property-by-property accounting methods. Availability of information and methods for evaluating real estate performance and use. Performance of real estate assets in comparison with overall corporate assets.	Failure to maintain adequate information systems on real estate assets. Management attitudes: “we do not manage our real estate in a business like manner”. Operational concerns unduly influencing decision making. Failure to take property costs into account in making program decisions.

It is clearly evident from the information in Table 1 that proper data collection, information management and performance evaluations are key to success in asset management.

Many of these problems would be solved if there were more information exchange in the construction industry regarding service life and asset management. However, the roofing industry is no different from the rest of the construction sector: money is tight, maintenance backlogs are increasing and information is scarce. That was the bad news, the good news is that opportunities abound in these troubled times.

3. Opportunities

Many organizations have recognized the service life and asset management problems identified in the previous section (NACUBO, 1990; NRC, 1990; CERF, 1996); they have also identified opportunities to address these problems. These opportunities lay in two areas: Process Re-engineering and Information Technology. There is, however, a little blurring between the two because much of the process re-engineering naturally involves information technology.

3.1. Process Re-engineering

"Re-engineering is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed" (MacIntosh and Francis, 1996). Three examples of this innovative thinking can be used in the roofing domain, namely capital renewal/deferred maintenance planning, level of maintenance investment studies, engineered management systems and condition assessment surveys.

The National Association of College and University Business Officers (NACUBO, 1990) has proposed a detailed process to gain control of the escalating maintenance costs of colleges and universities. Basically, its process consists of separating repair work that is capital renewal from that which is deferred maintenance. In this process, the asset manager identifies maintenance that has been postponed, phased or deferred, and then attempts to provide an estimate of the cost for that deferred maintenance (DM). The second portion of the NACUBO process is capital renewal (CR) analysis. NACUBO suggests that the asset manager catalogue the replacements that will be required at the end of the service life of various parts, components or systems. In the CR process the asset manager also includes the estimates of the renewal costs (*e.g.* roofs, boilers, air-conditioning systems, windows). The cataloguing includes the estimates of these costs in five year lumps, and spreads these costs equally over each year. In this way, costs for CR for each asset can be calculated well into the future, and can be brought forward to a present value or calculated as an annuity expense. This process can readily applied to the roofing industry.

Level of investment (LOI) studies (NRC, 1990; CERF, 1996) have indicated that maintenance expenditures should be between two and four percent of the capital replacement value (CRV) of a facility. Although it is difficult to establish what constitutes maintenance, and how to calculate the CRV, these percentage figures are generally accepted in the industry as good engineering practice. It can be assumed that there is still some variation in these figures, as it is difficult in most instances to differentiate maintenance from capital renewal, and determine whether or not CRV should be based on the purchase price plus an appreciation factor; a current cost to replace the asset, or the cost to replace the functional portion of the asset with current construction technology. In any case, LOI provides tools for asset managers to determine the level of investment necessary to properly serve their users, while maximizing the value of their assets. Research on small samples of roof areas show that aggressive maintenance can provide savings of $0.15 per square foot over moderate inspection; where aggressive means semi-annual inspection with an annual moisture survey and conventional means a walk-around annual inspection (Marvin, 1996)

The Construction Engineering Research Laboratory (CERL) has pioneered the use of engineered management systems in many construction sectors including roofing, paving and rail networks (Shahin *et al*, 1987; Bailey, 1989). Engineered management systems (EMS) attempt to establish a condition index (CI) of an asset based on a number of factors including the number of defects, physical condition and quality of materials or workmanship. Research studies have estimated the potential degradation of the CI based on loads on the system or external agents acting on materials. With all these data in hand, it is therefore possible to estimate the CI well into the future, given degradation curves and the effect of remedial action. ROOFER deals with a number of CI including the Flashing Condition Index, Insulation Condition Index, and Membrane Condition Index..

A condition assessment survey (CAS) establishes the existing condition of the asset, and hence is a benchmark for comparison not only between different assets but also for the same asset at different times. "Using CAS, a maintenance manager can formalize the assembly of basic planning elements such as deficiency-based repair, replacement costs, projected remaining life and planned future use." (Coullahan and Siegfried, 1996). CAS provides asset managers with the data necessary to quantify the current state of their assets. CAS records the deficiencies in a system or component, the extent of the defect, as well as the urgency of the repair work. “Management, as a result of the data generated by CAS, is better able to develop optimal plans for maintenance and repair of their buildings” (Coullahan and Siegfried, 1996). This type of systematic inspection would also help eliminate a large portion of standard roofing problems.

3.2. Information Technology

Information technology (IT) such as maintenance management systems, CD-ROM, Internet, computer aided facilities management and mobile computing provide an information infrastructure to manage the vast and diverse data collected in the re-engineered asset management.

Many commercial systems now exist to help asset managers gain control of their day-to-day “paperwork”. Many of these computerized maintenance management systems (CMMS) are relational database applications that have been developed to meet the data handling needs of asset managers. For example, any number of database applications can manage work orders, trouble calls, equipment cribs, stores inventory, and preventive maintenance schedules, and many include features such as time recording, inventory control and invoicing. A number of commercial packages existing in the roofing domain, MicroROOFER is one example.

CD-ROMs are available from major product manufacturers and this media can provide a cornucopia of information on products, including colour images, product specifications, CAD detail drawings and installation videos. CD-ROMs also provide quick access to many of the codes, standards and specifications required by asset managers.

The Internet is fast becoming the search tool of choice in the Information Age; good roofing examples include NRCC’s Roofing Resources (www.nrc.ca/irc/roofing) and the Roofing Information Support System (www.usacpw.belvoir.army.mil/RISS/RISS/RISS.HTM). The Internet’s user-friendliness, low cost, quick response time and graphical interface all contribute to its recent and continuing popularity. At one time, only librarians had access to electronic literature search; now it can be on everyone’s desktop. For example, a simple search using the AltaVista search engine (www.altavista.digital.com) and the search strategy “roof*” and “service life” produced 82 documents, the large majority directly relating to the topic at hand and some providing extra information for this paper. As a comparison, Megasearch (www.megasearch.com) provided an additional 40 related hits. The Internet is an excellent tool for finding information about new publications, innovative companies and products or computer software, but fails miserably when looking for older documents.

Computer aided facilities management (CAFM) is the graphical side of the maintenance management. Initially used by the facility designers as a computer aided design and drafting tool, CAFM now provides the opportunity to integrate the design information to some of the facilities management data. This graphical type interface is invaluable for roofing inspection and maintenance.

Mobile computing is opening up many new possibilities for asset management. Portable computers and personal digital assistants (PDAs) provide the input and output required for asset managers who are on-site or in-the-field. These devices can tie directly to the CMMS and CAFM systems, permit the operator to upload or download data in the field, and increase both the accuracy and the speed of data collection. Other related technology includes Global Positioning Systems or GPS. Opportunities abound for rapid and accurate data collection using GPS: precise building locations can be identified, roof areas can be calculated, building height can be estimated, and the physical location of identified defects and potential problems can be easily, clearly and unambiguously documented.

3.3. Synopsis of Opportunities

Unfortunately, the opportunities listed in this section are only partial solutions to many of the problems in asset management, and more specifically to the problems in roofing asset management. There is still need for research in this field: (1) what data should be collected, (2) what are the life cycle costs of maintenance, (3) what data are required for service life prediction, (4) what is the essential maintenance and what can be deferred, (5) how to deal with risk and the consequences of asset failure, repair and renewal, and finally, (6) how to integrate all these new data and information.

The NRCC and PWGSC are addressing these questions with the BELCAM Project. The BELCAM project will attempt to build on the existing service life and asset management information discussed above, will endeavour to provide a clearinghouse for service life and asset management research for roofing systems, and will provide tools and techniques for building practitioners.

4. BELCAM Research Plan

4.1. Service Life/Asset Management Enabling Technologies

The BELCAM project (Lacasse and Vanier, 1996; Vanier and Lacasse, 1996) has identified the six enabling technologies illustrated in Figure 2 that can help asset managers predict the service life of building envelope components:

- Maintenance Management to record and monitor the current condition of building elements and systems (PWGSC, 1993a, 1996);
- Life Cycle Economics to model the construction as well as operation and maintenance costs from cradle to grave;
- Service Life Prediction to collect the necessary laboratory and field data for the development of building component performance curves (Kyle, 1993; PWGSC, 1993b; Kyle, 1996; Lacasse and Vanier, 1996);
- User Requirement Models to quantify the desired building performance levels and to establish criteria for assessment (IRC, 1994; PWGSC, 1995; Vanier *et al*, 1996);
- Risk Analysis to determine the probability and consequences of repair and rehabilitation decisions (Cheung and Kyle, 1992, 1996);
- Product Modeling to manage and integrate data and information related to service life prediction and asset management (Vanier *et al*, 1996).

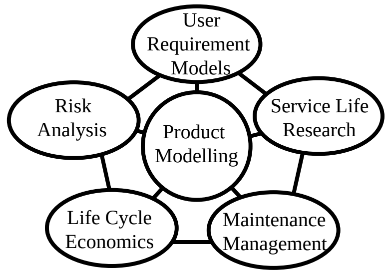


Figure 2: BELCAM Integrated Models

In essence, the six enabling technologies address many of the problems identified in the previous sections, as well as, many of the objectives for sustainable roofing identified for this workshop. That is, the integrated model shown in Figure 2 identifies the need for close ties between maintenance management, life cycle economics, and user requirement models; these are all components of a sustainable roof system. Product modeling is seen as the integrator for these well-established research areas.

4.2. BELCAM Approach

The overall goals of this NRCC/PWGSC joint initiative are:

1. Predict the service life of building components.
2. Assist asset managers to maximize the effectiveness of their maintenance dollars.

The objective of this initiative is to develop models, methods and tools to achieve these goals. This joint NRCC/PWGSC initiative should be considered as the large picture on service life and asset management research; however, to meet the goals and objectives there is need for focused research and development in specific construction sectors. NRCC and PWGSC have agreed to participate in a pilot project dealing with near-flat roofing systems.

The planned deliverables in this three year project include: roofing maintenance checklists, a standards database, computerized maintenance management software evaluations, Internet technical information, inspection manuals, roofing surveys and reports, roofing databases and roofing guidelines.

5. Summary

In summary, asset managers face many difficult tasks to maintain their building stock in the existing economic times; but fortunately, there are many opportunities to assist them with their problems. However, to take advantage of these opportunities requires a concerted effort from the following three construction communities: research, standards and practice. In essence, without standards there is marginal service life information exchange to practitioners and without research there is limited information and data for the standards.

Techniques described in this paper such as capital renewal/deferred maintenance, condition assessment surveys and level of investment studies provide systematic ways of dealing with rapidly-increasing maintenance backlog. Tools such as information technology provide accurate, standardized and rapid ways to collect service life and asset management data.

The solutions to the problems of deferred maintenance and expensive capital renewal are neither imminent nor obvious. However, the problem is not intractable, at least not yet. The BELCAM project addresses such problems in roofing asset management.

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