Ageing gracefully: how can a whole life support services framework enhance the life of the building services systems?

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ABSTRACT

Modern buildings are designed to enhance the match between environment, spaces and the people carrying out work, so that the well-being and the performance of the occupants are all in harmony. Building services are systems that facilitate a healthy working environment within which workers' productivity can be optimized in the buildings. However, the maintenance of these services is fraught with ageing problems that may contribute significantly to the total life cycle cost of the building. Maintenance support is one area which is not designed into the system.

At the University of Reading an integrated approach has been developed to assemble the multitude of aspects inherent in this field. The means records required and measured achievements for the benefit of both building owners and practitioners. This integrated approach can be represented in a Through Life Business Model (TLBM) format using the concept of Integrated Logistic Support (ILS). This TLBM approach facilitates the successful development of a databank that would be invaluable in capturing essential data (e.g. reliability, MTBF of components) for enhancing designs, life cycle costing and decision making by practitioners, in particular facilities managers in alleviating the ageing problems.

INDEX TERMS

Management; Maintenance; Commissioning and HVAC design

INTRODUCTION

Experience throughout the construction industry has shown that the increasing age of buildings and building services systems have the potential to cause deterioration of operability and maintainability of the building as well as its services. This is mainly due to the fact that major construction projects have traditionally been planned, designed, developed, built and delivered to the customer or user with very little consideration given to the aspects of maintenance, operation and support. This practice has been expensive because the cost of maintenance, operation and support constitutes a major portion of whole life cost. Over the lifespan of many types of buildings an owner will meet maintenance and repair costs equalling two or three times their initial capital costs. Long-term changes in building demand will oblige the building professions to shift their focus from new construction to maintenance and refurbishment of existing buildings.

Considering the age distribution of the building stock and resulting refurbishment needs, the demand for architectural practice and for engineers in general in the coming years will increasingly reside in the maintenance, refurbishment and adaptation of the building stock. These professions will have to develop new range of skills. It will, however, not be sufficient to have more appropriate design tools; practitioners also need more relevant contextual knowledge and new consistent value systems (Kohler and Hassler, 2002) that is honed towards solving the age related problems.

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The required knowledge can only be produced by multi-disciplinary scientific research and must be related back to professional practice. Many of the methods from research are not fully developed and will have to be designed by architects and engineers, who are familiar not only with the traditional skill and art of building, but also with the various scientific methods required (Kohler and Hassler, 2002) by the construction practitioners and facilities manager. The purpose of this paper is to identify, assess the importance of these methods and develop a consistent ageing management framework. The rest of the paper deals with the ageing problems, the solution in minimizing the ageing process and the framework within which this solution can be achieved and concludes by recommending more focus on the building stock ageing process and the benefits of managing and supporting the process.

THE AGEING PROCESS AND THE PRESENT ATTITUDE OF MAINTAINING BUILDING SERVICES

The deterioration and degradation problems of building services systems arise from two root causes, ageing and obsolescence, which have different characteristics, but are closely related. The need to address this problem is now becoming more pressing, because building services systems provide vital support for safe and economic operation of buildings and their functions must be sustained throughout so that workers productivity can be optimized and ensured.

The ageing process of building services includes the technical, administrative and legal aspects of operating the services as well as the maintenance and support requirements during the life of the services. The operation and maintenance regime of the service that was specified during the design phase will dictate to a greater extent what the support and maintenance regime will be to alleviate the ageing process of the service. However, most building services designers/installers do not have a well thought out life cycle procedure or approach for the maintenance regime and support of the services they designed. As such ageing occurs rapidly that can only be curtailed or controlled to a limited extent.

Ageing and obsolescence problems have been encountered and dealt with by most facilities management firms on a case-by-case basis, but not with a concerted effort across the industry. However, it is becoming clear that building services systems are potentially vulnerable to these phenomena and that a formal management strategy is needed to ensure that resources are targeted on priority cases to minimize the overall threat. Regulators and government agencies are also interested because a sudden degradation of building services components performance could place increasing demands on other systems with possible detriment to the environment and its population, for example, legionnaire diseases.

How different businesses react to their building and its services maintenance is still not very clear. However, it is a general perception among facilities managers that when a business is not functioning properly or is in the red, one of the first departmental budgets to be cut is the maintenance. Reasons for the budget shortfall is that facilities managers do not have any tangible evidence to argue their case why their budget should not be maintained at the required level and it is not a common practice for facilities manager to be in the higher decision making positions within firms to influence such practice. Such top-level decisions have a knock-on effect on the way the services are maintained leading to ageing and degradation.

Various maintenance strategies are available, ranging from scheduled maintenance, through condition-based maintenance to ‘run to failure’. The relative advantages and disadvantages of these alternative approaches are discussed in the CIBSE’s *Guide to Ownership, Operation and Maintenance of Building Services* (CIBSE, 2000). These maintenance strategies do not give all the answers required to facilities management and corporate management about the ageing of equipment. The ageing problem needs more thought and how best to make informed decisions about solving the ageing problems.

TOWARDS A RECOVERY: AN AGEING MANAGEMENT APPROACH

In the same way that there is human life-cycle of birth, growth and development, old-age, and eventual death, so there is a 'life-cycle' for mechanical equipment of design and prototype development, maintenance, obsolescence, withdrawal from service and eventual recycling or disposal. Put simply, it is 'the long view'; the recognition that the whole life cycle approach is important and that gives the full story. There are no identified standards on management of ageing of building services systems that are consistent in the industry. However, the prerequisite to gradual ageing should be thorough and efficient commissioning. Teething problems of operating equipment starts with inadequate commissioning. Ageing of building services and its components can then be managed within the following means:

1. replacement of the equipment;
2. maintenance routines and optimal testing;
3. control of environmental conditions;
4. corporate commitment.

The initial requirements to managing the ageing process include:

- *Identifying the need*
  A key factor in identifying the need is discussion with the facilities managers group operating these systems, and sometimes environmental health departments. Collaboration with FM authorities from the outset in the design is essential to the care and repair process that would be encountered downstream during the operation of the systems.
- *Establishing a scheme (identifying the scale and scope of the service)*
  A client will first need to determine its objectives, both in terms of the services required and the workforce operations. Discussion with the strategic management and other key senior personnel would help identify whether a practical maintenance strategy should be made on a small scale, contained or cover a holistic approach.
- *Technical aspects*
  This is dealt with under the main ageing sections.
- *Assessing costs and establishing financial procedures*
  The key factor determining the initial viability of the maintenance scheme adopted will be the availability of funding for setting up a tailored maintenance scheme.
- *Staffing and employment issues*
  Where the required skills cannot all be necessary by recruitment, appropriate training will be necessary; on the job if necessary or through courses and study.
- *Other useful sources of information*
  Information from manufacturers and suppliers, such as the reliability of their systems and components is essential for effective and efficient planning and management of the ageing process. Effective *post-occupancy evaluation* (POE) data is important in a constant feedback loop about the equipment through its life cycle for future designs.

Replacement of Equipment

Only a few scientifically performed equipment life studies have been published in the open literature. Some manufacturers perform such studies on components of their equipment based on in-warranty claims, but rarely are results of such studies made public. One finds when performing real-life studies, that many factors impact replacement decisions, and often equipment is fully operational when replaced (Hiller, 2000). Some of the reasons for equipment replacement decisions are:

- *Equipment failure* often is not the reason for replacing equipment. Rather, replacement decisions often are made on the basis of anticipated failures.

- *Physical appearance* of equipment is often a strong factor influencing replacement decisions.
- *Obsolescence* is often a factor in replacement decisions, especially when capacity, speed, or capability of equipment is no longer acceptable.
- *Dissatisfaction* with equipment performance is sometimes a factor in replacement decisions. Noise level, safety, and maintenance requirements are factors which concern customers.
- *Efficiency level or operating cost* of new equipment compared to older equipment is an issue in some replacement decisions.

Equipment service life information is useful for many purposes, to both consumers and manufacturers (Hiller, 2000), particular when considering the ageing problems of equipment.

Maintenance Routines and Optimal Testing

Maintenance is a design parameter and the maintainability process is a formal method to incorporate maintenance knowledge and experience into the project delivery process including specific tools to facilitate implementation. A maintainability programme is a structured process fortified with corporate resources and support to standardize and increase the predictability of planning and designing for maintainability (Moua and Russell, 2001). Some key ingredients needed for the development of a maintenance strategy for ageing equipment are:

- *Failure histories*: purpose is to rank components according to detected failures followed by detailed analyses to provide failure modes and description of effects. Overall the number of failures may be very low limiting the benefit of the analysis.
- *Maintenance information*: to identify maintenance costs and current maintenance strategy, review the current maintenance testing. This method requires the existence of maintenance databases with information on maintenance operation, type of maintenance (preventive/corrective), and costs of plant, personnel or external companies, spare parts, etc.
- *Effect on system availability*: to identify the cost of failures. Some information can usually be obtained from the failure records.
- *Safety related systems*: provide information on component safety.

Control of Environmental Conditions

At the level of individual materials and components, durability is often defined as a resistance to one or many exposures, including weather (normal and severe), chemicals, dirt, grease, cleaning agents, abrasives, impacts, temperature changes, pollution, light, water, air, and vandalism. For example, the quality of the water play a role in the degradation of the ducts, or the air quality also has an effect of the air handling units. These environmental agents need monitoring to allow for the equipment to be managed for ageing gracefully. Cleaning regimes are also very important.

Corporate Commitment

The corporate value of an organization is defined by the organizations mission and values. The corporate value is therefore the mind set of the senior management and the chief executive, and there are measured goals to achieve their mission and visions (Moua and Russell, 2001) at minimum cost.

THROUGH LIFE BUSINESS MODEL APPROACH

Efficient information management is the key to better decision making for infrastructure. When reliable data and effective decision-support tools are in place, the costs for maintenance

repair and renewal will be reduced and services will be timely and less disruptions. A Through Life Business Model ensures no factors are left out.

At the University of Reading an integrated approach has been developed to assemble the multitude of aspects inherent in this field. This integrated approach can be represented in a Through Life Business Model (TLBM) format using the concept of Integrated Logistic Support (ILS). The TLBM model was reported in the paper presented at CIBSE 2002 on *Enhancing the Design of Building Services System* (John *et al.*, 2002). This TLBM approach facilitates the successful development of a databank that is invaluable in capturing essential data (e.g. reliability of components) for enhancing future building services designs, life cycle costing and decision making by practitioners, in particular facilities managers. When used for assessing the ageing process and its desired solution, the process represented in the operations and maintenance of the facility as shown in Figure 1 is essential in identifying all the related ageing issues that had been discussed in this article. Although the same diagram in Figure 1 can be used when designing the system, it is also invaluable in determining what sought of management strategy to adopt in a structured approach and solution to the ageing problems.

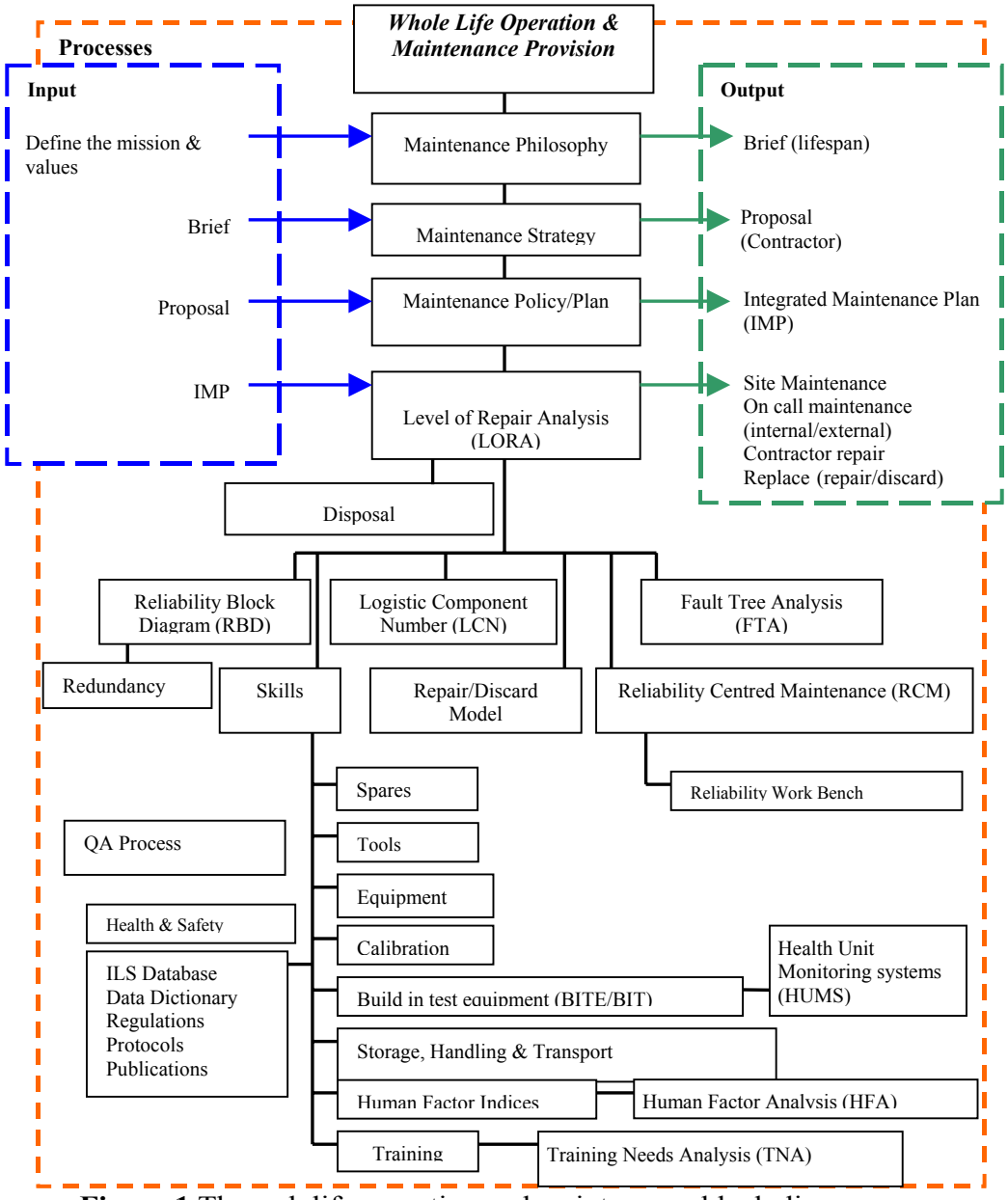

Figure 1 Through life operation and maintenance block diagram.

DISCUSSION AND CONCLUSIONS

This paper is concerned with the *ageing management* of building services systems. It draws upon various researches that have been carried out in maintenance techniques in the industry and also from other industries that are ahead in the management of their ageing components. The information is distilled into an ageing management strategy and several practical steps are suggested. Using the TLBM, a structured approach within the operations and maintenance framework developed is presented to manage the required information. Part of the information that is accumulated on component failures is used to identify possible problem areas and effects of ageing by analyses of the failure histories. More detailed analyses can be done e.g. by applying failure modes and effects analyses (FMEA) methodology on operating experience. Because of the sparse or missing information in failure reports the realization of this approach would be evident in the long term.

Monitoring the temperature, humidity and other environmental conditions to which building services are exposed is one way for life extension and ageing management. BMS can be used to get the data which is fed into the TLBM database. The useful life of equipment is typically specified by manufacturers based on the expected conditions to which the equipment may be exposed during normal operations. Depending on the intensity of the environment, whether, mild or harsh, its expected lifetime is typically shorter or longer than that specified by the manufacturer. However, for the ageing management to succeed a corporate commitment of management to the ageing process of the building and its services is very important. A well planned ageing management system within the context of the TLBM would reduce cost and take all the alternatives into consideration, do a trade-off, before any informed decisions about the scheme can be made in an holistic manner.

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