CHALLENGES IN RESIDUAL SERVICE LIFE ASSESSMENT FOR REFURBISHMENT PROJECTS

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Abstract

A need for an efficient life care management of building portfolio is becoming increasingly due to increase in aging building infrastructure globally. Appropriate structural engineering practices along with facility management can assist in optimising the remaining life cycle costs for existing public building portfolio. A more precise decision to either demolish, refurbish, do nothing or rebuilt option for any typical building under investigation is needed. In order to achieve this, the status of health of the building needs to be assessed considering several aspects including economic and supply-demand considerations.

An investment decision for a refurbishment project competing with other capital works and/or refurbishment projects can be supported by emerging methodology *residual service life* assessment. This paper discusses challenges in refurbishment projects of public buildings and with a view towards development of *residual service life* assessment methodology.

Keywords: Refurbishment projects; Public buildings; Residual service life assessment, life care management

1. Rationale and Introduction

Significant growth in the construction of new buildings over the past 35-40 of years means that aged buildings are growing in number. Their utility has also changed due to various reasons including technological advancements, change in life style, increased commitment to sustainability and changes in legislations. All these advocate an opportunity for an efficient "re-life" rather than demolition and "new build".

In an infrastructure report for the condition of physical infrastructure for United State of America [1], "School Buildings" have been rated 'd-' (d minus), which is below 'poor'. In a similar report published for Australia [2], public buildings are not considered perhaps due to unavailability of sufficient data to reflect the status of health of public buildings.

Where there is a large stock of older buildings, more than half of all (construction) budgets is spent on maintenance and refurbishment. The International Organization for Standardization (ISO) 15686 [3] details typical maintenance costs in the USA and UK. For developing countries currently developing their building stock, the similar risk pertains if long-term performance is not taken into consideration at the initial planning stage. In developed economies, maintenance (including refurbishment) is recorded to be approximately 50% of spending on construction and up to 3% of the initial capital cost of the building is accounted for maintenance costs per annum. Various governments (including the UK and the USA) have now set targets promoting increased durability and flexibility for reduction of operating costs (including energy costs) and reduction in overall expensive maintenance [3].

Optimal maintenance per annum can be achieved when portfolio level maintenance requirements are well-documented. Accordingly appropriate asset management strategies can be developed and implemented. A robust prioritisation system of maintenance works would need to be in place based on criteria including occupational health and safety, code compliance, new regulations, environmental hazards, social important etc. Building condition needs to be maintained to appropriate standard in such a way that the proportion requiring maintenance in any future year is held at an optimum level. The information pertaining to the percentage of the portfolio requiring maintenance each year would be highly valuable for asset manager of public or private sector, managing large portfolio of buildings and other facilities.

The following figures as documented in ISO 15686 part 1 [3] taken from reports by Building Maintenance Information for the UK [3] and from an overview of US construction industry by Civil Engineering Research Foundation [3].

Nearly 50% of all construction output in the UK is spent on repair and maintenance (BMI Report 244, 199, Table 9). Total spending on building maintenance in the UK has increased by 66% in the last 10 years (BMI Report 253, 1996). It now represents over 5% of Gross Domestic Product, or £36000 Million (BMI Report 254, 1996). An average of 22% of occupancy costs in the UK is spent on building maintenance, including decoration, fabric and services (BMI Report 234, 1994, Table 1). In the UK, annual maintenance of building costs an average of about 2% of its initial capital cost (BMI Report, 244, 1995). Refurbishment costs between 54% (banks) and 82% (flats) of the initial capital cost (BMI Report 252, 1996, Table 1)

In the USA about 13% of Gross Domestic Product (as at 1996) is spent on construction, and about 40% of $342 billion of that is on maintenance and refurbishment. A 50% reduction in operation, maintenance and energy costs and a 50% increase in durability and flexibility have been set as industry targets [3]. Some building types (e.g. shops and offices) are refurbished every 10 years or so. Once improvements are taken in to account, work to existing building may cost 5% of the capital value of the national building stock every year [3]. The direct relevant figures for Australian scenario could not be traced; although from sustainability point of view, Maria [4] notes that buildings consume one third of the world's resources; they use 42% of Australia's energy; 12 % of water demand is consumed by buildings; up to 40% of waste going to landfill is from construction and deconstruction activities (majority being the churn of refurbishment); and 40% of Australia's air emissions are from buildings.

Typical major public buildings are generally designed for about 60-80 yrs. For any given consideration the remaining design life can be assessed by design documents. Varied usage, maintenance, environmental, natural (earthquake, floods) or intentionally made physical damages make structures deteriorate differently to the desired design time consideration. The complexity in achieving the currently used life (% of its original design life) and future economical service life need to be addressed.

By carefully implementing appropriate structural engineering practices with facility management, the whole of life cycle costs for public building assets can be optimised and considerable amount of public money can be saved and better utilised elsewhere. One of the various challenges of "re-life" in comparison to "new build"; is assessment of existing building and future performance estimation with varied repair, strengthening and maintenance options, i.e. the residual service life prediction.

An investment decision for a refurbishment project competing with other capital works and/or refurbishment projects can be supported by residual service life assessment methodology. This paper is part of a research project focusing on development of residual service life assessment/prediction methodology for refurbishment projects. The paper discusses challenges in refurbishment projects of public buildings with a view towards development of residual service life assessment methodology. The paper concludes with the authors' observations and research potential.

2. Understanding Residual Service Life (RSL) in Building Asset Management

Building asset management deals with demand requirements of the built assets versus supplied/available resources over the whole of life cycle of assets; including planning, procurement, ongoing support, rehabilitation, and disposal phases.

Figure 1 shows the position and importance of refurbishment projects and RSL methodology with context of building asset management in any organisation, through schematic diagram of typical asset life. Any typical asset life cycle consists of four basic phases. Advanced asset management system considers ongoing monitoring and performance evaluation stage as shown in the figure.

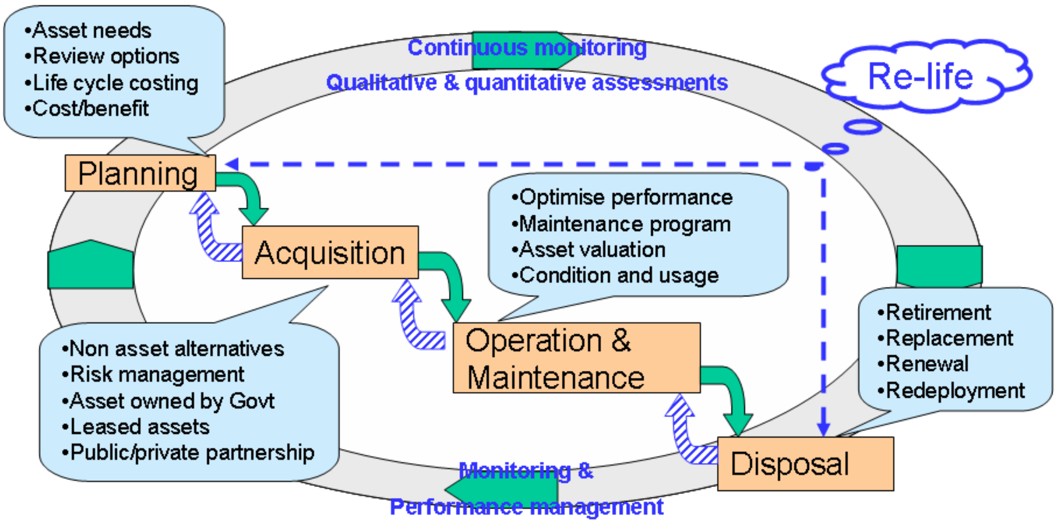

Figure 1: Asset Life Cycle

Planning phase consists of identification of asset needs and study of review options, life cycle costing and cost/benefit analysis. *Acquisition* phase consists of non-asset alternatives including feasibility of other assets owned by government or leasing options, public/ private partnership arrangement and risk management associated with above options singly or in combination. *Operation and Maintenance* phase consists of maintenance management program, asset valuation, condition, usage and performance. *Disposal* phase consists of retirement, replacement, renewal and redeployment options. Monitoring and performance evaluation is emerging stage of an advanced asset management system consists of continuous monitoring and qualitative and quantitative audits [6], [7].

A typical public building consists of several components such as structure, outer finish (façade), inner finish, building services and others. In order to optimise maintenance expenditure for a typical refurbishment projects, correct balance among 'corrective', 'preventive' and 'condition based' maintenance types needs to be achieved together with assessment of existing condition and future performance estimation with varied repair, strengthen and maintenance options needed to be analysed for these components.

Development of *Residual service life* prediction methodology is emerging with an aim to assist in meeting above also referenced in [3] [8] [9]. ISO 15686 [3] defines "*Service Life*" as "*period of time after installation* *during which a building or its parts meets or exceeds the performance requirements*" and "*Residual Service Life*" has been defined as "*service life remaining at certain period of consideration*".

Residual service life prediction of building is an estimation of the remaining period of time during which a building or its parts meet or exceed the performance requirements at any given time. In simple terms, in order to estimate the residual service life of building; knowledge of its existing condition, its past/future deterioration trend and minimum acceptable performance levels for each of the components would be required.

Correct balance of technical life time analysis versus economic life time analysis in an asset management paradigm is required [10]. "Technical life time"- can be achieved by assessing technical performance versus investments with criteria to sustain minimum acceptable performance (more towards structural, facility management issue). "Economic life time"- can be achieved by assessing the revenues and expenditure for particular or group of assets with criteria of managing the assets as long as revenues are higher then expenditure (more towards real estate issue).

3. Conceptual Model: Residual Service Life Assessment

For a typical aged/existing building, residual service life prediction/planning is a process which seeks to ensure, as far as possible, that remaining *service life* of building will equal or exceeds performance requirements, while taking into account *sustainability* and (preferably optimising) the remaining life cycle costs of the building. Sustainability has been considered as an implicit performance requirement rather than additional criteria.

Figure 2 below shows a typical deterioration trend of a typical element (say structure) of a building. After X years of building life, major rehabilitation/repairs works or routine maintenance works can be undertaken. A strategy is needed to analyse different options with a view to optimise return on investment.

In the hypothetical example shown in figure 2, there are various choices available after building age of 'X' years; from demolition to refurbishment. This concept model would give near optimum economic solution for the said building considering whole of life costing and other environmental issues.

Different scenarios for prediction of service life and building performance with range of repair options (extensive to minor) as shown in Figure 2 under 'B' can be achieved. This can be done through condition assessment data, deterioration trend, reliability based analysis, aging test and non-destructive testing and others (factor method/ probabilistic/engineering method (ISO 15686 & parts) [3] [8] [9]. These may be applied singly or in combination.

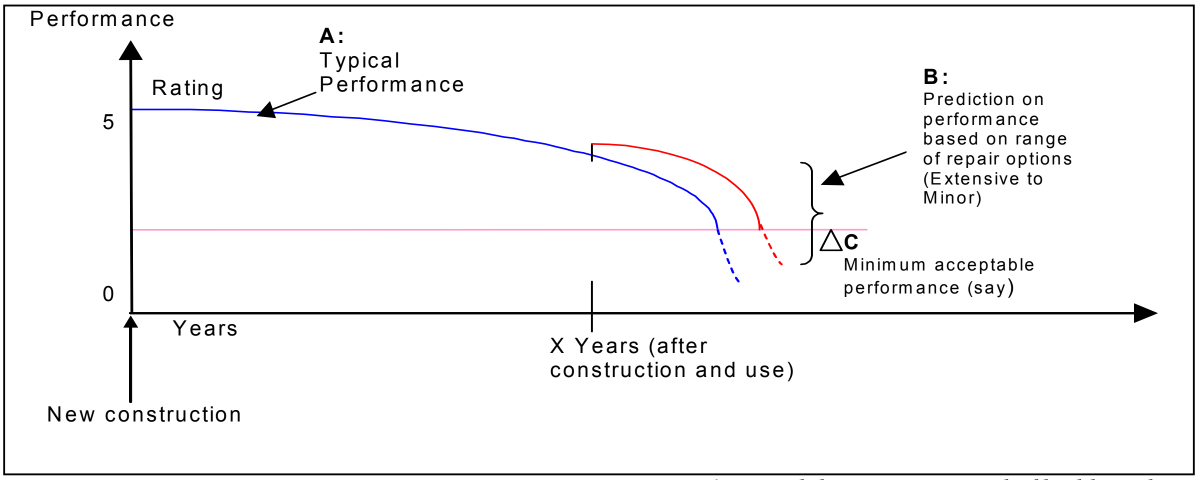

Figure 2 Typical deterioration trend of building element

This analysis may be applied to different elements (such as structure, outer finish, inner finish & others) of the building. Number of moderately aged public buildings are likely be used as a case study. Identification & development of Part A, B and C in the above figure no 2 will be a significant part of the project. Its worthwhile pointing out that, for developing and under developed countries different threshold limits of minimum performance requirements but similar criteria for assessment would be required. The methodology needs to be carefully refined to suit local conditions and economy.

For major refurbishment projects where the building is to be extensively stripped back to the structural frame the major question is to understand the structural characteristics of the frame, its potential remaining useful life, and opportunities for re-loading the structure with the refurbished components. A critical issue includes the interaction between the structure and the non-structural components of the refurbished building, especially where these differ from the existing building.

Phases of RSL (ISO 15686 framework)

Any typical prediction process should involve analysis of current problem by, refining it by gathering all the relevant data, information and knowledge supported by testing and interpretation of results.

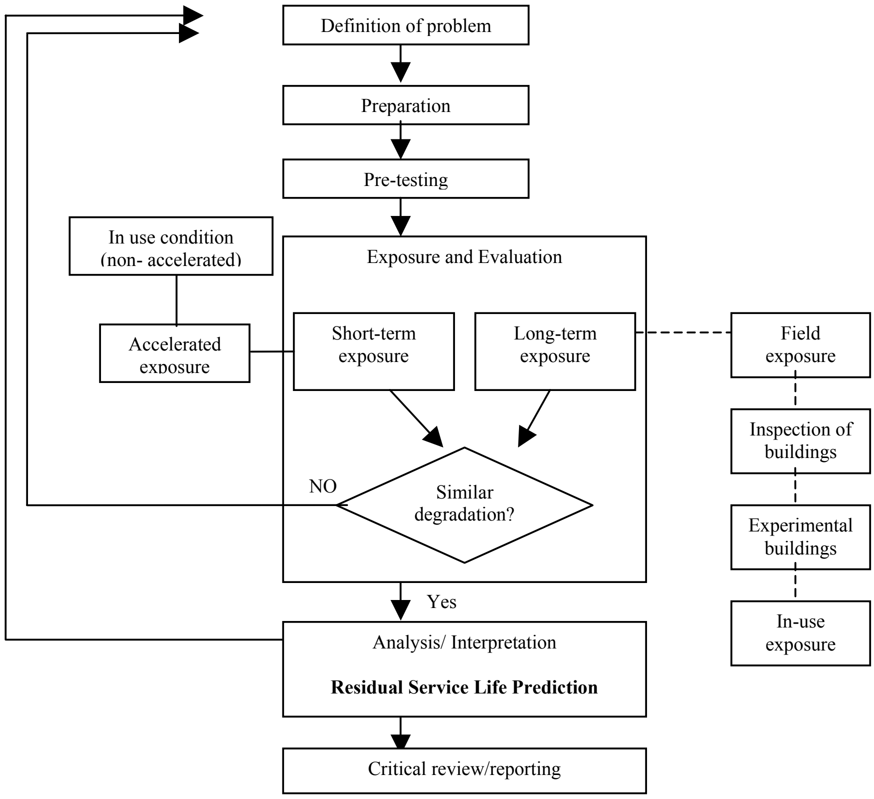

Figure 3: Schematic diagram of methodology for residual service life prediction (from ISO 15686 part 1)

The chart above slightly modified (from ISO 15686 part 1) [3] suggest the systematic methodology for residual service life prediction for building components.

Definition of problem phase should identify user needs, building context and range of agents, performance requirements, materials characterisation, change in functionality/legislation/use and heritage preservation. *Preparation* phase should cover identification of degradation agents, mechanisms and effects, choice of performance characteristics and evaluation techniques, feedback from other studies. *Pre-testing* phase should cover checking mechanisms and loads, and verifying choice of characteristics and techniques by short-term exposure. *Exposure and evaluation* phase should evaluate short-term exposure by using accelerated exposure and in-use condition exposure and long-term exposure should by field exposure, inspection of buildings, experimental buildings and in-use exposure. *Analysis/Interpretation* phase should process performance over time or dose-response functions to establish prediction models which would result into residual service life prediction. C*ritical review/reporting* phase should take care of quality assurance and validity of the results. It should be transparent and consistent to inform intended users.

4. Observations

Building elements should be classified with respect to their importance in overall maintenance expenditure and overall criticality to functionality. Only those requiring attention can be further explored, else all can be neglected for detailed analysis. Even when comparing the overall maintenance and repair costs, we need to neglect the regular service maintenance costs, as they are not necessary.

In any predictions certain unsystematic risks, which involves pervasive factors that affect all assets, those are unavoidable uncontrollable risks, e.g. Inflation, interest rates, market cycles, political events, etc. Availability of cheap alternative materials / technology /labor versus the one suggested for future maintenance works is a huge risk/assumption. Structured risks (such as location, tenancy risk, financial risk, liquidity of asset etc.) would be difficult to quantify but might be controlled/managed. Those would require appropriate risk management policies in place.

Availability of base data and suitable experimental buildings for case study is the main concern in assumption of success of such research project. The change in the functionality/legislation/use drives the most of the refurbishment projects. The user needs seems to be ambiguous in most cases. Identification of agents and performance requirements has to be aligned with relevant building codes or standard and the user's expectation. After identification of possible degradation agents for the local condition from visual inspection has been carried out, possible effect of such agents and their evaluation would be generally chosen from other available studies, which may be difficult to obtain for the similar local condition.

Typically, condition assessment of buildings is done merely by visual inspection; detailed analysis (structural inspection) is only done when several cracks are visible. Any prediction outcome will certainly depend upon the quality of input data and condition assessments, so robust methodology for those phases would be required. Development of dose-response curves/ performance over time would need number of case studies to be analysed and historical data of performance would be difficult to find.

In the case where there is no user/legislation requirement for refurbishment, is there any need to do such assessment and if, what is the best time for the assessment? In Australia, as per '*financial reporting by local government (AAS 27)*' [11] organisations need to report the depreciation value every two years, is it based on technical assessment? Should users wait until there is any visible notification for refurbishment? Is there any possibility of floor plate increase and potential of added return on such investment? When to refurbish?? Wait until it is getting too deteriorated?? Or know the status of the health of portfolio and plan accordingly? As they say prevention is better than cure? One step ahead is to know, plan and act to prevent the problem is much better and safer or know, plan and act to prevent the problem is much better and safer than experiencing the problem!!!!

Asset renewal issues can be tackled considering sustainability, heritage, social and economical aspects using cost-benefit analysis. For example, by analysing maintenance expenses vs. performance improvement for that asset under consideration by post maintenance evaluations/condition assessment may be after several years of usage with varied options. Condition assessment of the existing building will be a background stage to deal with activity. All the challenges and issues related to building condition assessment and access to major repair and maintenance data will apply. Original configuration details with plan, structural drawing and method of construction during the period of building erected would be required. Knowledge and research of the construction practices during that period will be very useful while assessing the condition but may not be easily available. A classification of building under consideration needed to be specified in the scope of the works.

Accidental failures (due to unavoidable circumstances such as earthquake beyond design code expectation, storms or floods) are difficult to deal with. However, failures due to inappropriate maintenance care and ignorance should be taken care of. The safety and security of the occupants of the building should be taken care of by studying the status of health at certain repetitive point of time during its lifetime (say every 5 yrs).

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