Optimisation of Maintenance Expenditure for Buildings: Refurbish or Demolish??

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Summary

With an increase in growing number of aging public building infrastructure globally, there is an opportunity for an efficient life care management rather then mere demolition and rebuild. By carefully implementing appropriate structural engineering practices with facility management, the whole of life cycle costs for public building assets can be optimised and public money can be saved and better utilised elsewhere. A need of decision support tool/methodology which can assist asset manager make better decision among demolish, refurbish, do nothing or rebuilt option for any typical building under consideration is growing in order to optimise maintenance funds.

The paper is part of research project focusing on development of such methodology known as *residual service life prediction*. The paper is mainly focusing on following three major aspects of public building infrastructure; first, issues and challenges in optimisation of maintenance funds, second, *residual service life* prediction methodology and issues and challenges in the development of such methodology. The paper concludes with the authors' observations and further research potentials.

Keywords: Residual service life prediction, Building asset management, Optimisation of maintenance funds, Public buildings

1. Introduction

In any economy, large amount of public funding is being spent annually managing and maintaining public built assets. These assets make up the social and economic infrastructure, which facilitate the essential services to public and business. Significant growth in the construction of new buildings over the past 35-40 of years means that aged buildings are growing in number. The demand on their utility has changed due to various reasons including technological advancements, change in life style, increased commitment to sustainability and change in legislations. All of these advocate the opportunity for an efficient "re-life" rather than demolition and "new build".

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.

This information will assist in the asset management of buildings and will provide input to:

- deal with aging of the assets and asset renewal issues;
- optimise the resources for managing these assets; and
- respond effectively to possible asset failures.

This paper represents initial stage of the research project. The objective of the project is to develop *residual service life* prediction methodology in order to assist optimisation of maintenance funds for existing buildings during the maintenance and operation phase of Building Asset Management (BAM). In other words, the project aims at development of *residual service life* methodology to assist optimising the maintenance funds for large portfolio (at portfolio level) or for a single building (at project level). The depth of analysis at portfolio level and project level would certainly be different. Such methodology once well developed and implemented has great potential to save public funds for maintenance of public buildings which can better be utilized elsewhere towards reduction of poverty.

The paper explores issues and challenges in the optimisation of maintenance funds and development of *residual service life* prediction methodology. The paper concludes with observations from authors and further research potentials.

2. Residual Service Life Prediction

2.1 Building Asset Management (BAM)

Public buildings consist of several different types of structures. Major public buildings can be categorised into public health facilities, public office buildings, public housing, public heritage, recreational and tourism facilities including town halls, public education buildings including schools, libraries and universities and other public buildings. BAM is a complex process, fundamentally involving several stages. It should deal with competitive prioritization of investment choices with due consideration of social, economical, environmental and political factors associated. It should also match with Government or organizations' strategies and legislation.

BAM should address integration of demand requirements of the built assets with resources availability over the whole of life cycle of assets; including planning, procurement, ongoing support, rehabilitation and disposal phases. Detailed classification of building functionality, its location (historic or otherwise) and design, construction, fit-up, operational and maintenance data would be required to mange building portfolio efficiently. The systems and serviceability of an individual building must be adequately described and preferably in user friendly format to best assist in matching the users' requirements to the capabilities of the building portfolio [1,2].

2.2 Understanding *Residual Service Life* (RSL) in BAM

Position and importance of RSL methodology within building asset management, through schematic diagram of typical asset life is shown in Figure 1.

Any typical asset life cycle consists of basic four phases and may be ongoing monitoring and performance evaluation stage as shown in the figure.

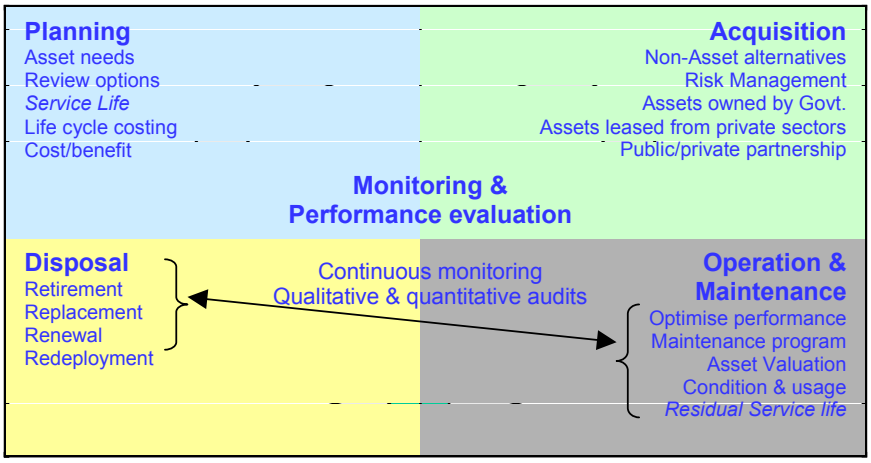

Fig 1: Asset Life Cycle [3,4]

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 [5,6].

In the maintenance management program of building assets, typically three types of maintenance exist as outlined in [7], first the corrective maintenance, in which no inspection is carried out and repair is done after failure has occurred and notified. Corrective maintenance should generally be applied if the cost of failure is relatively low or inspection costs are relatively high. Second the preventive maintenance in also which no inspection is carried out but replacement or maintenance at a time that no failure has occurred. Preventive maintenance will generally be applied when the failure costs are high and the time of failure can be predicted in advance. Third the condition based maintenance in which, inspections are planned in advance and when measured parameters no longer meet the prescribed criteria; repair or replacement must be carried out. Inspections intervals may be either fixed (based on long term plan) or may depend on the measure condition at the previous inspection.

A typical public building consists of several components such as structure, outer finish (façade), inner finish, building services and others. Different type of maintenance type would be applicable for such components of building assets. In order to optimise maintenance expenditure, correct balance among the above 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. The first stage of the research project accentuate structural component of building system.

Development of *Residual service life* prediction methodology is emerging with aim to assist meeting above also found in [8]. "*Service Life*" has been defined 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*" [8].

Residual service life prediction of building is estimation of remaining period of time during which a building or its parts meets or exceeds 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.

3. ISSUES & CHALLENGES:

3.1 National and Portfolio Level

In a Infrastructure report published for United State of America [9], "School Buildings" have been rated 'd-' (d minus), which is below 'poor'. In a similar report published for Australia, public buildings are not considered perhaps due to unavailability of sufficient data to reflect the status of health of public buildings [10]. The methodology behind the ranking system can be put in the simple terms as comparison of asset components with standard minimum set of performance requirements.

For developing countries facing severe financial restriction in comparison to developed countries, perhaps different threshold limits of minimum performance requirements but similar criteria for assessment can be applied. Such rankings of public infrastructure can help government plan robust infrastructure management and development strategies for overall of development & betterment of economy and hence achieve considerable amount of reduction in poverty. Such arrangement would certainly assist to optimise the maintenance and/or capital expenditure for public buildings. There is a strong need to have national level guidelines and/or legislation to identify and report the status of major public buildings. It would accordingly assist organisations manage and utilise their assets more effectively. It would also need to be revised at certain period (say 5 yrs) and/or after major economic change.

Buildings 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 the percentage of the portfolio require maintenance each year would be highly valuable for asset manager of public or private sector, managing large portfolio of buildings and other

facilities.

Optimal maintenance per annum can be achieved when portfolio level maintenance requirements are well documented and 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 safety, occupational health and safety, code compliance, new regulations, environmental hazards and social important etc.

Typical major public buildings are designed for about 60-80 yrs or more. For any given consideration the remaining design life can be known by design documents. Due to varied usage, maintenance, environmental, natural (earthquake, floods) or intentionally made physical damages make structure 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.

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 very difficult to deal with. However failures due to inappropriate maintenance care and ignorance should be taken care. The safety and security of the occupants of the building should be well taken care of by studying the status of health of the building at certain repetitive point of time during its lifetime (say every 5 yrs).

3.2 Conceptual Model

As discussed, 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 implicit performance requirement at some extend rather then additional criteria.

In a hypothetical example shown in figure 2, there will be various choices available after a building aged say ‘X’years; from demolition to refurbishment; on economic aspects abiding building regulations. The proposed model would give near optimum economic solution for the said building considering whole of life costing and other environmental issues.

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.

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 [8,11,12]. These may be applied singly or in combination.

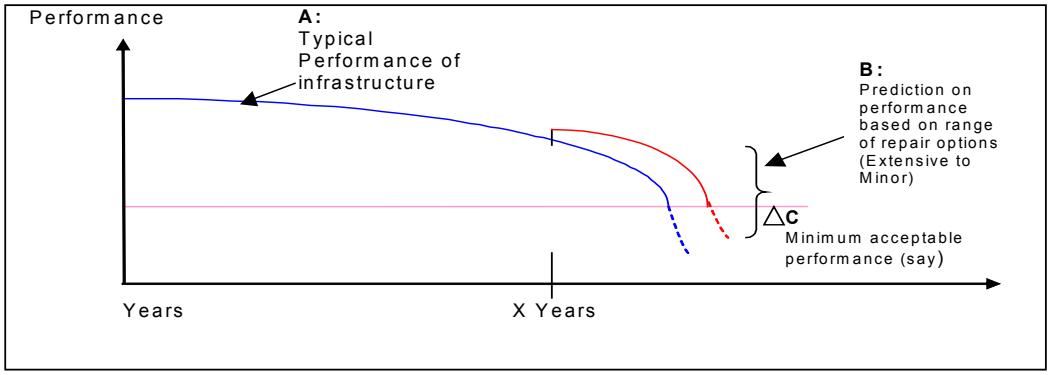

Figure 2 Typical deterioration trend of typical building element

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 case study. Identification & development of Part A, B and C in the above figure no 2 will be 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.

3.3 Phases of RSL

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.

The following chat below slightly modified (from ISO 15686 parts) [8,11,12]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.

'Critical review/reporting' phase should take care of quality assurance and validity of the results. It should be transparent and consistent to inform intended users.

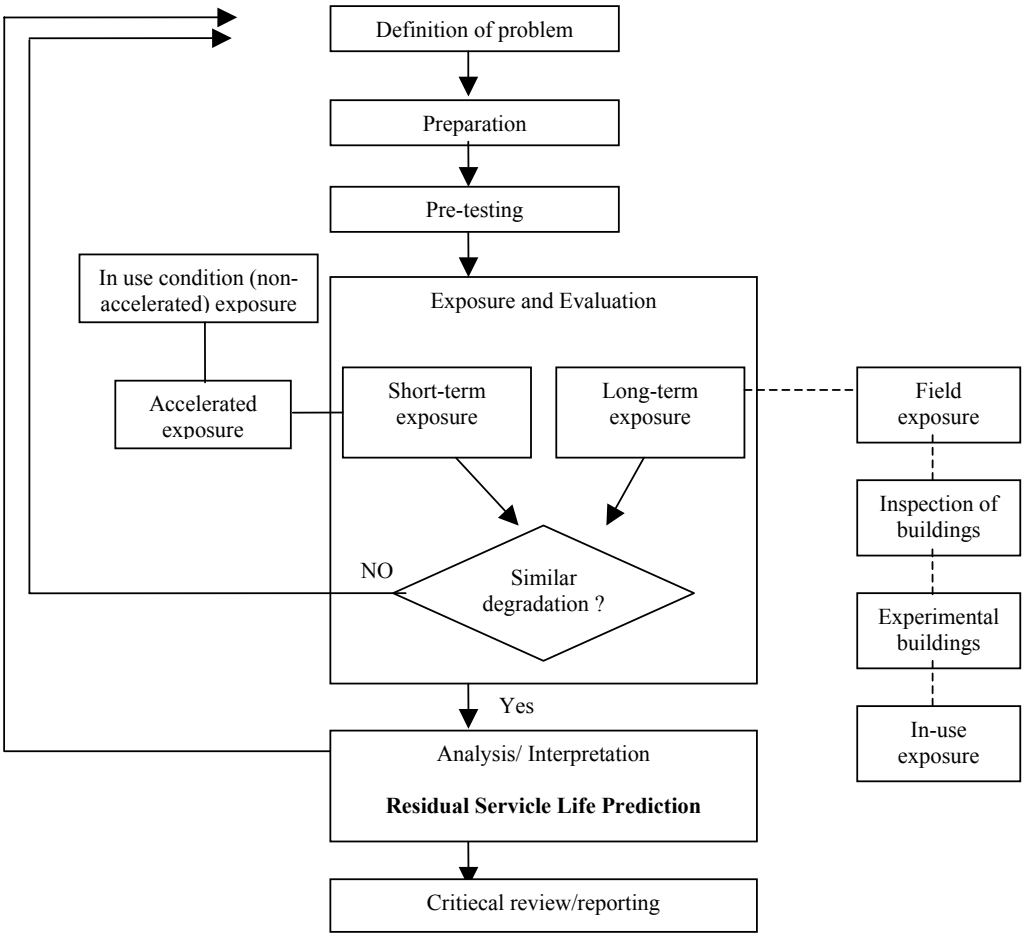

Figure 3: Schematic diagram of methodology for residual service life prediction (from ISO 15686 part 1)

4. Observations and recommendations

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 the 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 inspections, detailed analysis (structural inspection) 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 no. 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? As per '*financial reporting by local government (AAS 27)'* [13] organisations need to report the depreciation value every two years, is it based on technical assessment? Should the user wait until there is any visible notification for such need? Is there any possibility of floor plate increase and potential of added return on such investment?

The next phase of research would touch on various conditions assessment practices being used and endeavour to gain current and past condition data for some buildings. In order to do get appreciation of minimum performance requirements for building focus groups of asset manager/ building users and other field experts are planned. Review of code requirements for minimum performance requirements would also be conducted.

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