Re-Life of Buildings - Decision support tools for maximising project efficiency

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Summary.
This paper describes the process adopted in developing an integrated decision support framework for planning of office building refurbishment projects, with specific emphasize on optimising rentable floor space, structural strengthening, residual life and sustainability. Expert opinion on the issues to be considered in a tool is being captured through the DELPHI process, which is currently ongoing. The methodology for development of the integrated tool will be validated through decisions taken during a case study project: refurbishment of CH1 building of Melbourne City Council, which will be followed through to completion by the research team. Current status of the CH1 planning will be presented in the context of the research project.

Introduction
The significant growth in the construction of new commercial office buildings over the past 30 years has left a large stock of ageing buildings providing an opportunity for efficient re-life rather than demolition and new build. At the same time there is increased commitment to sustainability which encourages re-life options. A new project funded by the Cooperative research centre (CRC) for construction innovation entitled "Re-Life of Buildings" is aimed at integrating four major areas in relation to re-life projects: construction management issues, estimation of residual life, structural strengthening and floor space optimisation and waste minimisation and management. This paper will cover the methodologies developed in structural strengthening to optimise floor space and estimation of residual life of buildings to facilitate informed decision making by the stakeholders of building re-life projects.

A review of tools available for planning building re-life projects
A good retrofitting action plan will lead to the success of a re-life project. If a client makes inappropriate choices, the outcome may be a time and/or cost overrun and general dissatisfaction. Whilst there are a number of tools reported in literature, authors haven't been able to find a commercially available integrated decision support tool for assessing all the aspects of building re-life projects. Tools described in literature cover some of the aspects of re-life projects and are summarised below.

Brandt and Rasmussen (2002) report a tool entitled TOBUS, which has been developed to assess office building refurbishment projects based on an ongoing European research venture. The tool covers assessment of some functional aspects such as energy performance and indoor air quality and state of degradation of building components. It includes a common list of components for buildings (about 70 components identified) and a tool to assess degradation as well as the indoor air quality and energy consumption of the building. A structure for assessment of life cycle cost of office buildings has been proposed in a previous publication by Flourentzou et al (2000), which could be integrated with the TOBUS tools.

Bamforth and Alisa (2004) reports a log book approach for predicting life cycle costs and performance of buildings, which can be used to assess an existing building being considered for refurbishment. The methodology developed as part of a current research project in UK is presented, which covers assessment of economic factors using a net present value estimation and a qualitative approach for social and environmental factors.

Another European study (INVESTIMMO) (Brantz and Rasmussen 2002) has been aimed at evaluating housing maintenance and refurbishment options, which covers expectations of tenants, housing market, quality of building upgrading and environmental impacts in addition to the factors identified in TOBUS.

A number of international studies also report on selection of procurement methods for building refurbishment projects, which specifically addresses effective use of design and management contractors for retrofit projects (Cox, 2004, Reyers, 2001). De Silva et al (2000) reinforced the importance of using design built and operate contracts in a paper entitled improving maintainability of buildings. They have identified major factors which would improve maintainability of buildings by addressing these at the design stage. Minimisation of construction waste and recycling of existing materials is a topic which has recently attracted the interests of a number of international researchers. Publications in this area have addressed specifically strategies for minimising construction waste and improving sustainability of the built environment.

Requirements of an integrated framework for decision making in re-life of buildings
In considering the lifecycle of a building refurbishment project, following factors have been identified as important for the decision maker in selection of a refurbishment option. Some of these are economic factors whereas others are social and environmental issues.

1. Functional obsolescence of the building
2. Current state of degradation/performance
3. Strategies for optimising floor space for the proposed use
4. Strategies for structural strengthening to satisfy other objectives.
5. Residual life of the building at its current state
6. Life cycle cost of the proposed refurbishment scheme
7. Best construction management schemes to minimise risk
8. Functional performance after refurbishment
9. Minimising waste to achieve sustainability objectives
10. Criterion for integrating the above conflicting requirements
11. In-service performance after refurbishment

From the review of literature it was clear that there have been studies which addressed as many as four of the above issues simultaneously in an integrated manner, however, there

haven't been any reported work where all the eleven factors have been integrated in a decision support framework. The Re-Life of buildings project funded by the CRC for construction innovation has provided an excellent platform for combining expertise in four major areas to achieve the above objective. Above factors are encapsulated in four major strands as:

1. Floor space optimisation – Lead by RMIT University
2. Estimation of residual life and – Lead by RMIT University
3. Construction management – Lead by Queensland University of technology
4. Waste minimisation – Lead by University of Western Sydney

Whilst this paper discusses the methodologies of the first two strands lead by the authors, the overall picture is presented for the integrated framework in figure 1.

Proposed integrated decision support framework for Re-life of buildings

The need for refurbishment usually arises out of a high maintenance cost, functional obsolescence and/or a need for change of user needs. In some occasions, a developer will identify the potential for increasing rental revenue and will explore a business case. These will be compiled for the design team as "Clients' requirements". Subsequently a matrix of potential solutions will be developed in response to these requirements. These may be significantly influenced by the seven parameters listed as optimising usable floor space, structural concepts, residual service life of the existing building as well as the refurbished building, life cycle cost, procurement risks, functional assessment and recycling potential of the existing building materials/components (Figure 1). Once potential solutions are identified, a criterion is required to facilitate decision making for project efficiency. Most common criteria currently adopted are initial cost combined with user comfort. Occasionally, use of life cycle costing is reported in assessment of refurbishment projects (Aye et al 2000). A major aim of the current research project is developing simple criteria for inclusion of other factors in the decision making process to improve the efficiency of the project as well as optimise outcomes.

Once a solution is approved by the stakeholders, a detailed procurement plan will be made considering key project risks, which can be high in a refurbishment project. Proposed process diagram has been developed integrating the expected outcomes of all the four strands of the re-life project. A most important attribute of the framework is the facility for feedback which will enable the user to collect information as feedback and modify the tools for each of the specific areas being addressed, which has proven to be successful by Bamforth (2004).

Overall Methodology adopted in the Research Project

The research project is being conducted using data and observations from three current building refurbishment projects: Council House 1 of Melbourne City Council (CH1) at Little Collins St. Melbourne, 63, George St., Brisbane and Sydney Law Courts building (to be confirmed). Upon completion of the review of literature, the four research teams have identified the major issues pertaining to each strand of the re-life project and developed a DELPHI questionnaire to seek opinion of experts in the field. The DELPHI method can be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals as a whole to deal with complex problems Chan et al (2001). The process comprises a series of questionnaires sent either by mail or via

computerized systems, to a preselected group of experts Gordon (1994). These questionnaires are designed to elicit and develop individual responses to the problems posed and to enable the experts to refine their views as the group's work progresses in accordance with the assigned task. Each strand of the project then developed a framework for the decision support tool, which would be validated using application on the case study projects. During the validation process, further parameters which may be considered by the design teams of each of the projects will be added to the parameters considered.
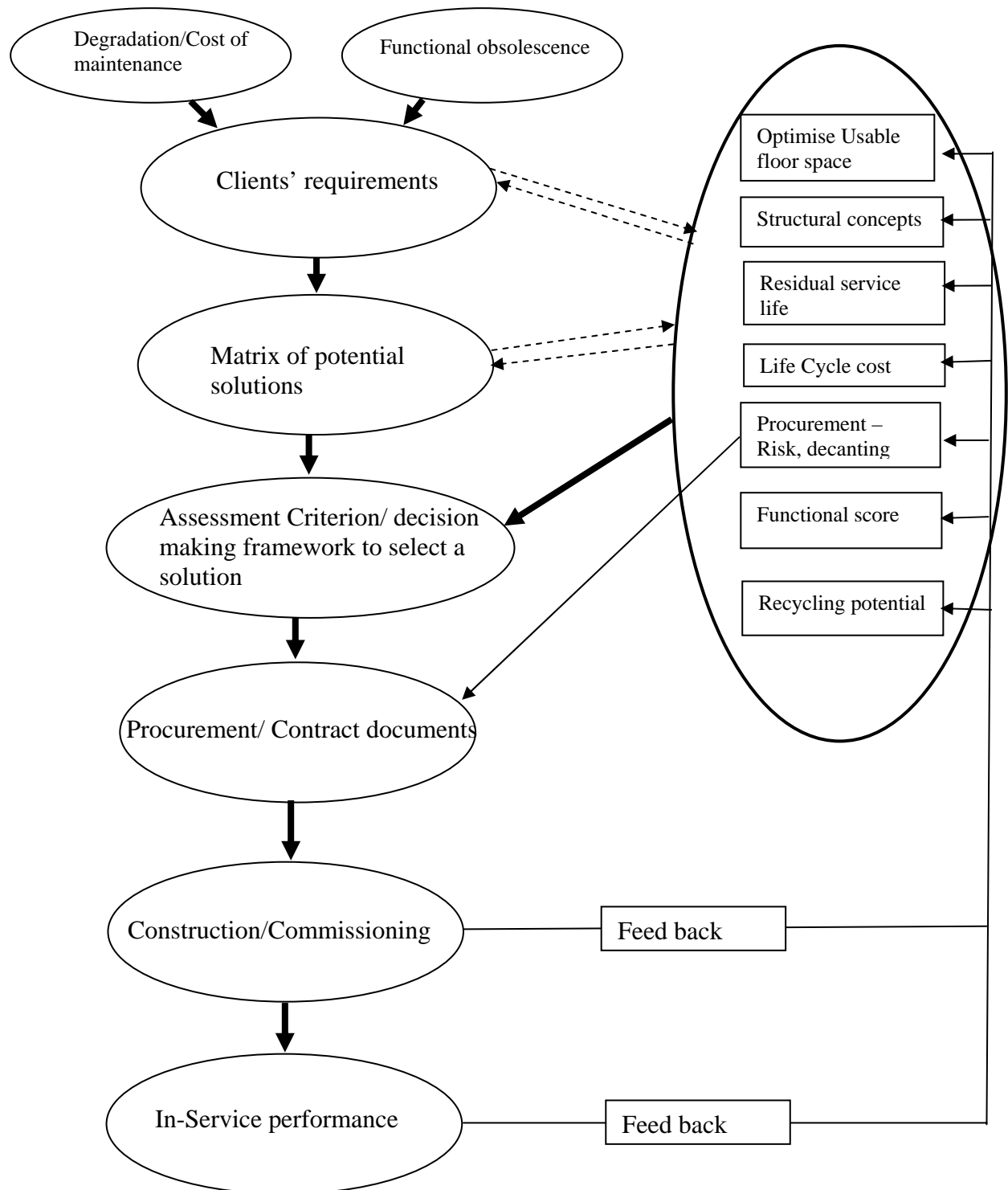

Figure 1: Integrated framework for project planning in re-life of buildings

Specific research methodology adopted in optimisation of floor space and structural strengthening

From the review of literature, the research team compiled a set of solutions for structural strengthening of buildings. The specific flow chart for this strand is given in figure 2. In addition to those identified through the review of literature, following issues were identified as important by the experts engaged in research/practise in the field of building refurbishment.

1. Change of use of floors
2. Cutting openings in floors and extending floors
3. Relocate/renew services
4. Structural appraisal prior to refurbishment
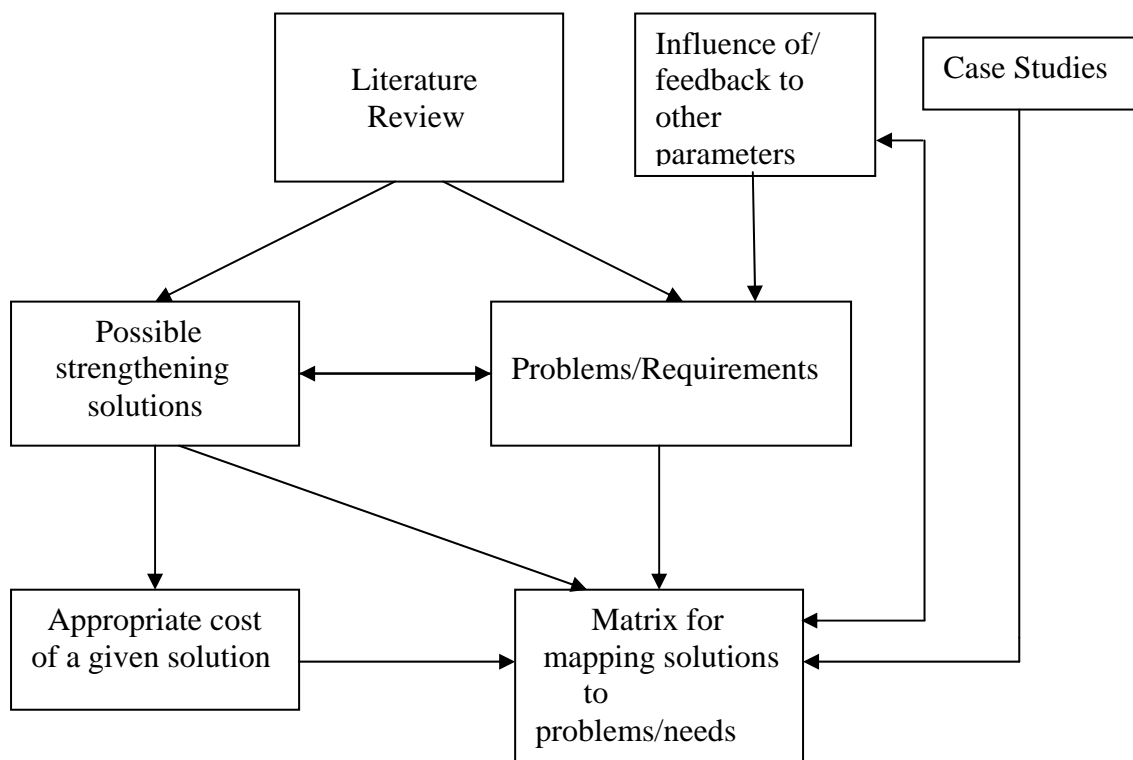5. Safety reliability issues in structural strengthening

Figure 2: Research flow chart for the floor space optimisation strand

Specific research methodology adopted in estimation of residual life of buildings

Research team has compiled the methodology for estimation of residual life and the process is depicted in figure 3. Research team has completed the stage 1 of the process and is currently working on stage 2. At this stage, the application of the methodology to the Melbourne case study: CH1 building is in progress. Through the DELPHI study, following four issues have been identified as significant in evaluating performance of existing buildings:

1. Functional defects
2. Structural defects
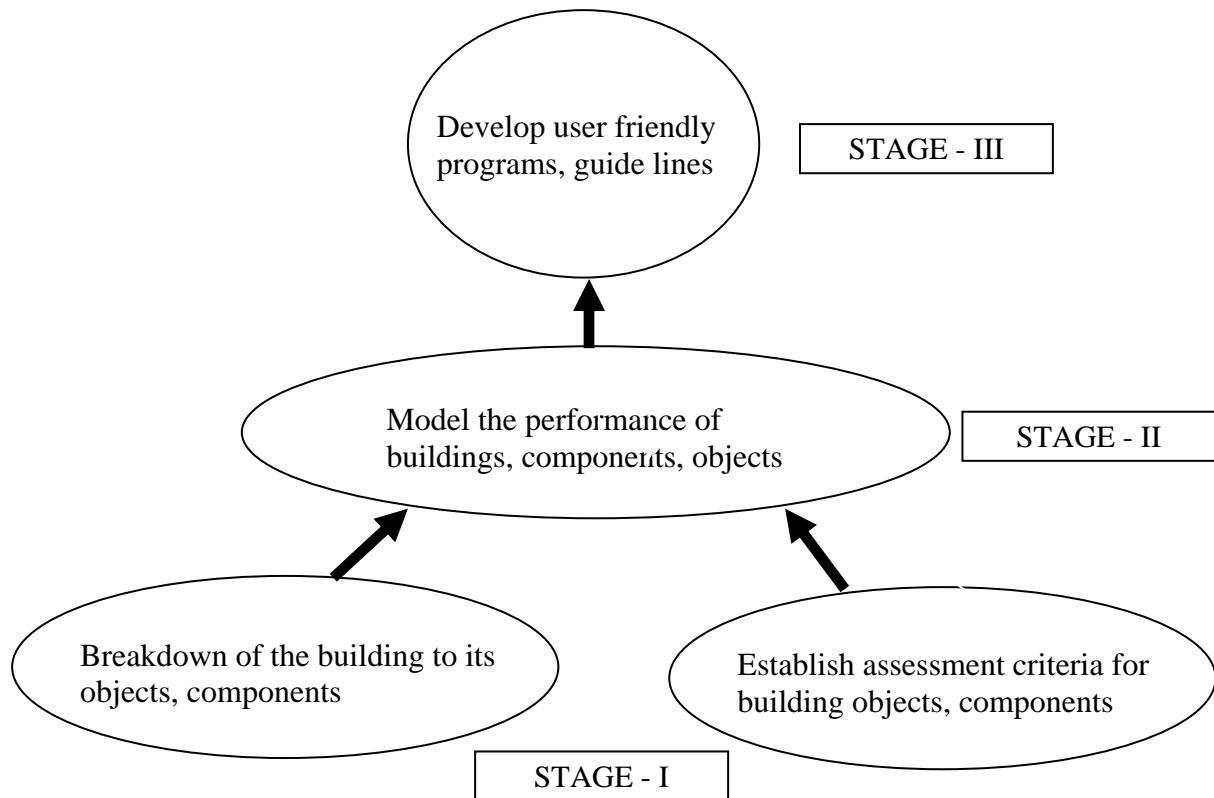3. Appearance
4. Status of structural health

Figure 3: Evaluation of residual life of an existing building

Case Study: Council house 1 (CH1) building in Melbourne
This is a nine storey office building approximately 35 years old**.** There are seven levels occupied by offices and 4 levels of car parks, two of which are underground. The structure of lower levels occupied by car parks comprises of reinforced concrete slab supported on secondary and primary beams and concrete encased steel columns. Seven levels occupied by offices have a reinforced concrete flat slab supported on concrete encased steel columns with steel edge beams on the perimeter. The options considered by the design team of Melbourne City Council are summarised below:
Design Option 1
Replace the present four off street vehicular accesses with one from Russel place up to all four car-parking levels, level 7 changed to a childcare centre, a new stretcher / service lift to be provided to serve all floors.

Design Option 2
Similar to the option 1 except level 7 and, 8 were changed to a childcare centre

Design Option 3
In addition to the items considered in options 1 and 2, following items are also included.
Retrofit of CH1 with systems which are complementary to CH2. CH2 is the new building being constructed by the Melbourne City Council, with state of the art technology in sustainable design of buildings. Three atriums will be provided. Suspended ceiling will be replaced with open grid system

During the process of finalising of design options, structural changes to the building were considered to satisfy the functional needs in improving user comfort and sustainability of the design, even at an additional cost. Change of use of floors did not require any additional changes to the building structure. Expected service life of reinforced concrete facades, affected by carbonation of concrete were considered in deciding on modifications to the facades. . Life cycle cost nor the recycling potential were specifically considered in finalising the design options.

Research teams are currently populating the framework proposed in figures 1, 2 and 3 with real data from the CH1 building. A set of alternative possibilities have been developed for structural strengthening to maximise floor space. In the context of estimation of residual life, a condition monitoring scheme has been developed to ascertain the degradation of building components. This is currently being applied to facades of the building.

Conclusions

The paper presented an integrated framework for decision making in office building re-life projects. Within the framework, two major areas of floor space optimisation and estimation of residual life were analysed and the methodology for developing two decision support frameworks have been presented and discussed. In comparing the progression of a real life situation with the proposed framework, it was clear that in practise the decision has been dominated by the cost of refurbishment (initial cost) and the functional requirements of the building. Other factors such as life cycle cost, procurement risk, potential for minimisation of construction waste are currently not being considered during the decision making process.

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