

LIFE CYCLE COSTING DECISIONS FOR RETROFITTING EARTHQUAKE VULNERABLE BUILDINGS

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ABSTRACT

In New Zealand, buildings must comply with earthquake codes. These codes were adopted in the 1970's and have been used as a basis for determining the strength for buildings to withstand an earthquake. Buildings built prior to the earthquake codes do not conform to these codes making them more vulnerable to damage and destruction during an earthquake. Decisions about the future use of these buildings need to be made. In particular, the decisions on whether these buildings should be retrofitted and strengthened or demolished. An important part of this decision is the comparative cost of retrofitting versus demolition. Life cycle costing is a valuable technique for assisting with making this decision. In this paper, the application of life cycle costing to the retrofitting of buildings for earthquake protection is explained and assessed. The usefulness of life cycle costing for assisting with the demolition/retrofit decision is demonstrated. The results of this paper will aid building decisions in the local (New Zealand) environment and the international community by adding cost appreciation to decisions about vulnerable earthquake prone buildings.

Introduction

This paper discusses the process of life cycle costing and the application of this technique to retrofitting earthquake vulnerable buildings. Life cycle costing can aid decisions when clients, property owners and others need to develop strategies for dealing with such vulnerable buildings. A building owner may need to weigh up various options such as not retrofit, retrofit with different solutions or demolish and rebuild. Increasingly, and especially in New Zealand, not retrofitting is no longer an option. Therefore, costs of various systems against demolish and rebuild strategies becomes an important factor. This paper discusses how life cycle costing can help these decisions and the limits of the technique for aiding retrofit decisions.

Background

Life cycle costing is accepted to be a process to determine the total cost of a building over the term of its life. The costing takes account of initial costs, running costs, repairs and maintenance, periodic replacement and disposal. It is most commonly used when making decisions regarding the selection of a particular design or component, either during the initial design of a building or at the time of refurbishment. Life cycle costing can be applied to retrofitting when deciding on the types of retrofit systems or on new designs for earthquake strong buildings.

Essentially the life cycle costing method involves several steps. Raw data is collected. The raw data for life cycle costs will typically consist of a set of data representing the predicted costs of events spanning over the life cycle of the building or component in question. Whilst this raw data can be of some use to a building owner for determining affordability within budget constraints, it may be too complex to enable comparison between alternatives under consideration to be easily made (Ashworth, 2004). The data is therefore further processed to bring it to a single figure representing the total life cycle cost (Flanagan and Norman, 1989). This cannot be achieved by simple addition as the current value of future expenditure diminishes according to the distance into the future of its timing. The life cycle costing methodology therefore requires all costs to be brought to a common time period by means of discounting. The total costs are typically expressed either as a “present value” or an “annual equivalent cost”. Thus, when comparing different systems, such as retrofit systems, a single figure for each system can be calculated which represents the systems life cycle cost.

Earthquake Risk and Legislation in New Zealand

New Zealand is at risk from earthquakes. This means that buildings need to be designed and built to withstand earthquakes. In order to minimise earthquake losses, the government has introduced legislation which sets out the required earthquake. The overarching legislation is the Building Act (2004). This act sets out provisions for earthquake prone buildings and policy guidance for buildings not meeting the required standard. Recent legislation in New Zealand (Building Act, 2004) regarding earthquake prone buildings may be summarised as follows: (a) New buildings and extensions to new buildings must be designed to current code - which embodies best available practice. (b) Existing buildings including unreinforced concrete or unreinforced masonry (i.e. brick buildings) are required, through the Building Act (2004), to be strengthened as nearly as practicable to current code standards. The responsibility of assessing earthquake prone buildings in a region is that of the territorial authorities. The Building Act (2004) requires these authorities to assess buildings and make recommendations on what needs to be done to the building to make it safe, including having powers to require demolition of a building. A suggested approach to this assessment (Earthquake Prone Building Provisions, 2004) is for territorial authorities to develop a profile of likely earthquake prone buildings in their region, first through an initial desk study, then through an initial evaluation of performance. The territorial authority will then require an owner to seek a detailed assessment on those buildings that the initial assessment indicates may be earthquake prone. If earthquake prone, buildings will require remedial work, owners will have to make decisions between various options. In order to make these decisions, with property owners, the costs of the building changes need to be considered. The overall purpose of these requirements is to identify non-residential buildings which are seriously at risk (Hopkins, 2005). The extent of the problem will only be known once each building is examined. A building could be classified as sufficiently unsafe in an earthquake to require attention. Buildings not meeting a certain threshold would be required to be strengthened, not to full code compliance, but to a level that is as near as is reasonably practicable, possibly to at least two thirds of current code. Once identified in need of reducing or removing earthquake risk, decisions will need to be made for the building on the strengthening technique to be adopted given the relative cost of the different options. Being a commonly used decision-make tool at the time

of refurbishment, the life cycle costing technique is an ideal tool to evaluate the cost-effectiveness of proposed alternative solutions from a life-cycle perspective, accounting for capital outlay for retrofit implementation, plus operation, maintenance and insurance costs.

Within the Building Act (2004) there are also provisions made for building codes and standards for building design. NZS1170.5 (2004) the New Zealand standard for structural design actions, part 5, earthquake actions New Zealand sets out the standards under which buildings must be designed. Supplementary comments to this standard (NZS1170.5 Suppl, 2004) set out the underlying objectives to the standard as "...buildings achieve a level of performance during earthquakes so that (1) Frequently occurring earthquake shaking can be resisted with a low probability of damage sufficient to prevent the building from being used as originally intended and (2) The fatality risk is at and acceptable level." This supplementary document goes on to say that for objective 1 "This objective is intended to limit both the number of times the loss of amenity is likely to occur and the cost of damage repair over the life of the building". Hence, the new standard is signalling the need to consider costs over building life, essentially life cycle costs, when making earthquake design decisions.

Life Cycle Costing Decisions for Retrofitting Earthquake Prone Buildings

This section examines how the life cycle costing technique can be used to assist with retrofit decisions and the limitations of the technique for aiding these decisions. Hoar and Norman suggest that a lack of understanding of the life cycle costing technique can limit the extent of its use (Hoar & Norman, 1990). In New Zealand life cycle costing is well understood as a technique for assisting with refurbishment decisions (Wilkinson et al., 1995). In the research by Wilkinson et al. (1995), nearly all consultants and clients interviewed had a clear understanding of the concept of life cycle costing. This extended to knowledge of which components to include in a life cycle costing analysis.

Ashworth suggests that there is still a significant need to convince clients that life cycle costing is worthwhile (Ashworth, 2004). This has been a longstanding problem. Flanagan et al. also commented on the potential limitation of life cycle costing due to client knowledge suggesting that since life cycle costing has a seemingly scientific basis some clients may not like it as they feel it removes managerial decision making (Flanagan et al., 1989). Wilkinson et al., (1995) found that, despite understanding the technique, life cycle costing is, according to consultants, infrequently requested by clients. Some of the reasons for this have been examined in previous research. For instance, the research by Picken on life cycle costing suggested that "... the respondents from the USA felt that the reluctance of clients to pay for life cycle cost studies was an important factor in holding back life cycle costing. " (Picken, 1989) Drake considers why life cycle costing is not often used. He suggests that clients do not want to commit increased capital expenditure to gain uncertain future benefits. In other words when faced with the need to make a decision to commit further capital expenditure now, to obtain future savings in operating costs, they will do so only if the benefits can be clearly demonstrated (Drake, 1976). Clients need to know why a procedure is being used and the benefits. For retrofitting earthquake prone buildings there is a clear need to understand what the options are financially.

Flanagan and Norman (1989) argue that one of the key benefits of life cycle costing is that it assists with effective decision making. They suggest that this is done in four ways; by identifying the total cost commitment undertaken in the acquisition of any asset, rather than merely concentrating on the initial capital costs; by facilitating an effective choice between alternative methods of achieving a stated objective; by detailing the current operating costs of assets such as machinery, individual building elements (heating systems, roof coverings), or complete building systems and finally by identifying those areas in which operating costs might be reduced, either by a change in operating practice, or by changing the relevant system (Flanagan & Norman, 1983). Other researchers have also commented that one of the prime uses of life cycle costing is as a decision making tool used to evaluate the financial differences between a finite number of mutually exclusive schemes (Dale, 1993; Ruegg & Marshall, 1990; Ashworth 2004). By being able to accurately compare alternative solutions, decisions on whether to demolish and rebuild or retrofit earthquake prone buildings can be made. Within New Zealand, use of life cycle costing has been documented for environmental and product selection (BRANZ, 1994). The most common use in the New Zealand building industry is for making comparisons of alternative solutions to services requirements, particularly those services with high energy use components such as heating and air conditioning but has not been extended to retrofitting.

In the New Zealand construction industry, two main benefits of life cycle costing technical were repeatedly mentioned in the survey conducted by Wilkinson et al., (1995). The first was that life cycle costing enables alternatives to be considered in a manner that takes account of all costs over the life cycle of the building or particular component under consideration, and not just initial capital costs, as suggested by Flanagan and Norman's work (Flanagan & Norman, 1983). The second benefit was understood to be the ability to make economic comparisons of alternatives such as between higher initial costs and lower operating costs or lower initial costs and higher operating costs (Dale, 1993; Ashworth, 2004). There was general agreement that the life cycle costing technique aided the decision making process. In terms of retrofit solutions, various maintenance costs of different systems can be reflected in the overall life costs. Thus if one system requires maintenance and another does not this can be reflected in the life cycle costs of the building and could potentially impact on the choice.

Life cycle costing requires prediction of the discount rate over the life study period. Choosing a discount rate is a subject much of the life cycle costing literature discusses as there are different approaches. For instance, Hoar and Norman argue that the discount rate is set so that the present value represents the sum of money if set aside today which would just cover the future forecast expenditure (Hoar & Norman, 1990). Whereas Flanagan & Norman suggest the discount rate should be based on the opportunity cost of capital (Flanagan & Norman, 1989). However, Ruegg and Marshall suggest a risk adjusted discount rate should be used to allow for varying degrees of risk between projects and the uncertainty of future events (Ruegg & Marshall, 1990). Reflecting uncertainty of future events would be required in retrofitting decisions but is difficult to undertake. For instance, choosing one system over another and receiving less damage as a result of the chosen system but having to pay an initial higher cost.

Kelly argues that life cycle costing cannot be used until a limited number of alternative schemes have been substantially developed. However at the outset of the design process for a building there are an almost limitless number of possible alternative solutions to the clients brief, the number being effectively limited only by the creative ability of the designer and the time and resources available to explore the alternatives (Kelly, 1990). To achieve the conditions necessary to make life cycle costing comparisons it is necessary to have already made most major decisions regarding the form and specification of the building. By the time this position is reached the decisions which have greatest impact on the capital cost have already been made (Kelly & Male, 1992). This suggests that at least when applied to the design of total buildings life cycle costing can contribute to the fine tuning process but not to fundamental decision making. In New Zealand, life cycle costing is not commonly used at the feasibility stage, or only a crude life cycle costing is made at this stage. The reason is lack of definition of one product or alternative against another. However, by the time the project reaches the detailed design phase, the technique starts to be commonly used. This is the stage where it is felt that the main benefits of life cycle costing are to be found (Wilkinson et al., 1995). This is the stage where retrofitting life cycle costing analyses would be most beneficial.

In New Zealand, various sources of information on behaviour of houses in earthquakes were reviewed by Beattie (Beattie, 2001). These included Earthquake Commission claim records, Edgumbe earthquake reconnaissance reports, house damage records from the Northridge earthquake, earthquake damage assessors, builders and Territorial Authority personnel interviews, museums and libraries. From this review the systems were chosen for testing as being the most in need of guidance to the New Zealand construction industry. Four systems, including an exterior wall clad with sheet sheathing, a braced pile foundation system, a brick veneer corner and gypsum plasterboard lined interior walls of a 1960s two-storey duplex housing unit, were selected as being areas where there was a need to formulate repair techniques for increasing levels of earthquake damage. As an extension to this analysis, comparative costs would have given additional weight to decisions or helped justify decisions.

Future use of Life Cycle Costing for Retrofitting Earthquake Vulnerable Buildings

The studies and surveys in New Zealand shows that use of the life cycle costing techniques is likely to grow in the future. With the pilot study of repair strategies for houses damaged in earthquake and the promotion of new legislation, it is certain that an applicable life cycle costing package for retrofitting earthquake vulnerable buildings will provide national benefit. However, it is suggested that certain conditions needed to be met before the technique can be widely used in this area.

The first is that the life cycle costing technique itself needs to be promoted by consultants. However, some consultants considered that before an increased use of life cycle costing eventuates, it will be necessary for clients to become better educated in the use of the techniques and more appreciative of the benefits.

Furthermore, it is generally believed that more sophisticated and better advised tenants are likely to take account of operating costs and safety when making decisions

regarding which building to lease. This makes the owner of the buildings to consider the whole life cycle cost when they make the decision about whether demolish or retrofit, or when and how to retrofit the earthquake vulnerable buildings. At this point the market will need to react by providing more efficient and safe buildings from a life cycle costing perspective.

Researchers argue that life cycle costing cannot be used until a limited number of alternative schemes have been substantially developed. However at the outset of the design process for a building there are an almost limitless number of possible alternative solutions to the clients brief (Kelly, 1990). To achieve the essential conditions to make life cycle costing comparisons in retrofitting earthquake prone buildings, it is necessary to have already made most major decisions regarding the form and specification of the building repair strategies in accordance with different types of building and different components of the building.

Being a decision-make tool, life cycle costing technique has to consider not only the economic but also cultural, social and environmental level (Ingenium, 2004). For the nature of pre-1970 buildings in New Zealand, many buildings have a desirable cultural or/and social value for the customers or community. This has to be considered into intangible benefits parameters when determine the optimal solution.

Most authors focus on the availability and reliability of life cycle costing data (Stone, 1980; Hutcheson, 1994). Costs of operation, maintenance and demolishment are felt to be less reliable than initial capital cost due to there being less data available, particularly in the form of standard data bases. Issues reported in the survey (Wilkinson et al., 1995) included a lack of historical records from building owners accounting systems, particularly in a form that enabled the required information to be readily accessed, and the difficulty of being able to predict future costs. These issues need to be treated at early stage of the study to smooth the promotion of life cycle costing technique applying to retrofitting earthquake prone buildings.

Conclusions

This paper discussed the process of life cycle costing and the potential application of this technique to retrofitting earthquake vulnerable buildings. The new legislation in New Zealand calls for earthquake building to be identified and work undertaken to mitigate potential problems. Life cycle costing can aid decisions when clients, property owners and others need to develop strategies for dealing with such buildings. A building owner may need to weigh up various options such as not retrofit, retrofit with different solutions or demolish and rebuild. Increasingly, and especially in New Zealand, not retrofitting is no longer an option. Therefore, costs of various systems against demolish and rebuild strategies becomes more important. Careful analysis using life cycle costing can aid the ultimate decisions for those involved in retrofitting earthquake prone buildings.

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