# BUILDING ECONOMICS
# MAINTENANCE & REHABILITATION

Ivan M. Johnstone BSc, BArch(Hons), PhD
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## PRIMARY SOURCES:

Bon, R. Building as an Economic Process. Prentice-Hall, 1990.
Johnstone, I.M. The Mortality of New Zealand Housing Stock, PhD Thesis, 1993.
Lee, R. Building Maintenance Management. Collins, 1987, 3rd edn

## ECONOMIC SIGNIFICANCE OF MAINTENANCE AND REFURBISHMENT

- In 1990, New Zealand housing stock accounted for over 23% of the nation's total capital stock of buildings, infrastructure, plant, and equipment.
- Lee estimates that building stock accounts for two-thirds of Britain's capital stock.
- Maintenance, refurbishment, additions, and alterations in New Zealand currently form at least 45% of the total construction activities within the housing sector.
- In a recent study by BRANZ, it was found that 90% of New Zealand homes needed repairing right now and, for 11%, that maintenance is urgent.
- In 1994, householders spent an average of $900 per year on home maintenance. BRANZ has estimated that, in 1994, an average of $3200 will be needed to be spent per dwelling to bring it up to a satisfactory standard.

## DEPARTURES FROM BUILDING STOCK

Departures from a building stock can be categorised as follows:

- Building related demolition as a result of obsolescence.
- Land related demolition necessary to allow sub-division to proceed.
- Demolition to allow public works to proceed.
- Change in use, for example commercial to residential.
- Consolidation of multi-units into single-unit buildings.
- Natural disaster, such as fire and earthquake.

With the exception of departures due to natural disaster, departures from a building stock are the end result of an economic process.

## SERVICE LIFE, ECONOMIC LIFE, AND FUNCTIONAL LIFE

It is helpful to distinguish between service life, economic life, and functional life.

### Service life of a building

The service life of a building can be defined as that period between entry to the building stock (usually construction) and departure (usually demolition) during which the building provides a flow of building services and yields a stream of income.

- The service life of a building is determined and limited by the potential service life of its structural system.

- A minority of buildings would be demolished due to failure of the structural system so the service life of most buildings falls short of the potential service life of its structural system.

### Service life of building components

The service life of a building component is that period over which the component is able to provide a necessary minimum quantity of services without replacement.

### Economic life of building

The economic life of a building is that period during which any increase in value over and above the current value of the property which can be generated by redeveloping the site is less than the costs to clear the site and create that new value.

$$V_n - V_o < C_n + D_o$$

- The economic life of a building may coincide with the service life of that building but, in most cases, the economic life is likely to be shorter.

### Economic life of building components

The economic life of a building component is that replacement cycle which results in a minimum annual cost in use.

## Functional life

Over the course of time, a building will tend to become increasingly unsuitable for the functional purpose it was originally designed.

A building may have a series of different functional uses before it reaches the end of its economic life.

## OVERVIEW OF THE ECONOMIC PROCESS OF MAINTENANCE, REFURBISHMENT, DEPARTURE, AND REPLACEMENT

- Fund of services - a building is a fund of services which satisfies the psychological and physiological needs of people.
- Stream of prospective income - each building provides a flow of services and yields a stream of prospective income over time until that building departs from the building stock.
- Income is dependent on services provided by components - the stream of income yielded by the building is dependent on the flow of total services provided by a hierarchy of building components which collectively and individually provide general and specific flows of services.
- Durability and service life - building components have different inherent properties of durability resulting in these components having different service lives.
- Decay and degradation - building components undergo a process of decay and degradation, the rate of which can, to a certain extent, be reduced. Ultimately all building components need to be replaced.
- Periodic maintenance - some components require periodic maintenance to slow down decay and degradation.
- Replacement of components - some short-lived components may require to be replaced a number of times during the economic life of the building.
- Increase of maintenance with age - in order to sustain a flow of services as a building ages, progressively greater inputs of maintenance and replacement are required.
- Deferred maintenance can result in accelerated decay - absence of important items of maintenance lead to an accelerated rate of decay of components and, in extreme situations, lead to an accelerated rate of decay of adjacent components.
- Under-maintenance and a decline in services - under-maintenance leads to a decline in the flow of services and a reduction in the stream of income.
- Major work required to restore services - major refurbishment or demolition and replacement is then required to restore a flow of building services at that site.
- Redevelopment options become more attractive as a building depreciates in real value. Options for redeveloping the site become more economically attractive.

- Redevelopment becomes more attractive as the value of the site on which the building stands rises. This may dictate the replacement of the building with one that will exploit the potential of the site to greater advantage.

The owner is confronted with the economic choice of whether to abandon the building (cutting one's losses), demolish the building and redevelop the site, or undertake major refurbishment.

Maintenance, refurbishment, and replacement are a continuous ongoing process.

Maintenance, by arresting decay, extends the service life of buildings, delays replacement and defers expenditure on new construction.

- Generally, the more adaptable a building, the longer the period of use, resulting in higher total maintenance but lower construction costs.

Appropriate and timely refurbishment reduces the annual replacement rate of the building stock.

## MANAGEMENT OF MAINTENANCE

Maintenance is typically covered by the current account.

- Maintenance and minor repair work is typically handled by "in-house" crews.

Replacement typically draws upon the capital account.

- Replacement expenditures are commonly treated as investment expenditures in building economics.
- Replacement of building components often entails the services of a specialised contractor.

Current and capital accounts are usually handled by different people in an organisation.

- The departments are usually independent.
- There is not necessarily co-operation between the two departments to reduce total costs.

Building maintenance and replacement policies should be pursued as active responses to economic changes in addition to “value preservation”.

- Although buildings and the built environment appear to change little over time, they are in fact continually adjusted to the changing economic conditions faced by the building owner.
- Maintenance and replacement activities are among the main vehicles of change.
- Contrary to the customary view that these activities merely ‘preserve’ the building value, they represent mechanisms of continual adjustment.
- Differential policies of maintenance and replacement for individual buildings can also be explained in terms of capital regrouping.
- Buildings that fit new plans better than others warrant a higher level of maintenance and replacement expenditures.
- Some buildings may be converted to new uses at a lower cost than others, all things being equal.

Building owners should adopt deliberate maintenance and replacement policies that correlate with their business plans.

MAINTENANCE AND THE BUILDING PROCESS (DIAGRAM)

It is necessary to view maintenance in the context of the overall building process.

- Design stage and subsequent user - the extent to which maintenance is considered at the design stage is likely to depend upon whether or not the owner or the person commissioning the building, will be the subsequent user.
- Financial constraints - both new construction and maintenance are usually subject to financial constraints.
- Proper balance between costs - an attempt should be made to achieve a proper balance between the costs of these activities by analysing the costs-in-use of alternative design solutions.

## TRADE-OFF BETWEEN MAINTENANCE AND REPLACEMENT (DIAGRAM)

There is a trade-off between maintenance and replacement costs.

- An increase in the level of maintenance of a particular building component will result in a decrease of its replacement cost per unit of time, other things being equal.
- Improved maintenance will tend to increase expected useful life of a building component.
- As the level of maintenance increases, the maintenance costs monotonically increases, while the replacement cost monotonically decreases.
- The total cost of maintenance and replacement will have a minimum, indicating the best level of maintenance when all costs are expressed in time-equivalent currency units.
- Note that the above argument concentrates exclusively on cost and implicitly assumes that the income stream does not vary over time.

Contrary to the assumption that more maintenance is better, a particular building component may be either under- or over-maintained.

The relationship between benefits and costs of maintenance and replacement ultimately depend on the income stream expected from the entire building.

- If gross profits are inadequate to support the planned maintenance expenditures, the expected useful life of a particular building component would decrease.

Deferred maintenance may lead to the need for more costly replacement.

- A prolonged period of deferred maintenance would ultimately lead to a need to replace the entire building.
- For example, progressive building deterioration is often the result of water penetration due to the initial failure of roofing or wall claddings.
- This process unfolds rapidly if it is not checked by repair and replacement.
- If there is a need for deferred maintenance, then deferral should be highly selective.
- By deferring maintenance, the difference between the present value of future capital and maintenance costs of the old standards and new standards are reduced.

In the case of building components, the best economic horizon refers to the “best” replacement cycle of a building component.

- The test of profitability is the present value calculation.
- For example, a roof should be replaced every 20 years if the present value cost of this replacement cycle is less than the present value cost of any alternative cycle.
- Economic tests are based on assumptions, some of which may be implicit rather than explicit. All assumptions that underpin an economic test should be known before using the test.

LIFE CYCLE COSTS

The life cycle costs (LCC) are the total costs of owning and using an asset over its predicted life span.

LCC = Ic + (Mc + Ec + Cc + Oc + Rc) + Vc - Rv
where

Ic = initial costs
Mc = maintenance costs
Ec = energy costs
Cc = cleaning costs
Oc = overhead and management costs
Rc = refurbishment costs
Vc = utilisation costs
Rv = resale value

- Long term financial consequences - decisions on design and acquisition of durable assets should take into account the long-term financial consequences and should not be based solely on initial costs.

- Use of LCC at all stages - the LCC method can be used at all stages in the life cycle of a building from inception to eventual sale or demolition.

- Potential savings through early use of LCC - the earlier the LCC technique is applied, the greater the possible savings and the lower the committed costs.

EXAMPLES OF LIFE CYCLE COSTS (DIAGRAM)

CATEGORIES OF MAINTENANCE

Maintenance is a combination of actions carried out to retain an item, or to restore it to, an acceptable condition.

Planned maintenance is organised and carried out with forethought, control and to a predetermined plan.

Preventive maintenance is carried out at pre-determined intervals or to other prescribed criteria and intended to reduce the likelihood of an item not meeting an acceptable condition.

- Preventive maintenance is probably more applicable to plant and equipment which is subject to mechanical wear.

- Planned preventive maintenance is worthwhile if:

    1. It is cost effective,
    2. It is necessary in order to meet statutory or other legal requirements,
    3. It meets a client need from an operating point of view.

Corrective maintenance is work carried out after failure.

Running maintenance is work that can be carried out while an item remains in service.

Improvements are added facilities that were not previously present which are constructed in order to increase the efficiency in the use of a building.

- With passing of time, buildings are modified to accommodate new uses and it becomes increasingly unrealistic to think in terms of keeping or restoring initial standards.

GENERATORS OF MAINTENANCE (DIAGRAM)

The agencies that act upon a building and erode the initial standards include:

1. Climatic conditions
2. Use activities
3. Changing standards and tastes

The primary cause may be regarded as either ‘normal’ or ‘abnormal’ according to expectations based on past experience.

Causes of the extent of deterioration - the extent to which the agencies cause deterioration and thus create a need for remedial work will depend upon:

1. The adequacy of the design and the suitability of the materials specified.
2. The standard of workmanship in the initial construction and subsequent maintenance.
3. The extent to which the designer has anticipated future needs.

- Over a period of time the gap between the standards demanded by the user and those provided by the building is likely to widen.

TIMING OF MAINTENANCE OPERATIONS

The work necessary to combat progressive deterioration takes the following forms:

- Patching which involves the more or less regular replacement of small parts or areas.

- Replacement of whole elements of components because they:

1. are functionally unsatisfactory;
2. incur high maintenance or running costs;
3. are aesthetically unacceptable.

- Preservation of protective coatings either for extending the life of the protected material or to maintain appearance.

- Cleaning which, although often regarded as a separate activity, has important maintenance implications in arresting deterioration and preserving appearance.

MAINTENANCE CYCLES (DIAGRAM)

- Normal conditions of exposure and use are assumed.

- The building is assumed to have a 60 year life.

- The renewal periods are estimated in multiple of five years.

CASH FLOW AT CURRENT PRICES AS PERCENTAGE OF INITIAL COST (TABLE)

- Routine maintenance costs are assumed to amount to 0.5% of the initial costs per year.
- The cash flows are derived from the percentages and renewal percentages.

Different buildings will have different elemental cost patterns and renewal periods will vary according to design, location, and use.

- No attempts has been made to allow for the effects of inflation on future maintenance costs, on the assumption that funds which bear the expenditure will inflate at the same rate.

It is unlikely that maintenance costs and new construction cost will continue to bear a constant relationship over a prolonged period of time.

- Labour forms a higher proportion of the costs of maintenance than of new construction.
- Because wage rates are currently increasing faster than the price of materials, it is expected that maintenance will become more expensive in relation to new construction.

DISCOUNTED CASH FLOW AS PERCENTAGE OF INITIAL COSTS (TABLE)

As the discount rate increases, future maintenance costs appear less and less significant.

- This effect is even more pronounced when taxation is taken into account as maintenance and running costs may be set against taxable profits.
- Maintenance and alterations are subject to GST, but if the building owner is a ‘taxable person’ then GST is recoverable.

MAINTENANCE PROFILES (DIAGRAM)

- The pattern of maintenance costs over the life of a building forms a maintenance profile.
- The peaks are due to major renewals and replacements.
- These costs could be deferred by incurring higher running repair costs and perhaps some loss of amenity.

PROBABLE INCIDENCE OF RENEWAL TIMES (TABLE)

- The uncertainties inherent in the timing of major items can be reflected by assessing the probabilities of work necessary at different times.

- The probabilities scale run from zero to unity (100% certainty).

- If there is a 50:50 chance that a particular component will have to be replaced in five years time, the probability is expressed as 0.5.

OPTIMISING RENEWAL CYCLES (TABLES)

The assessment of renewal cycles is based on knowledge of the rate of deterioration of similar buildings under similar conditions of exposure and use.

- It is possible to introduce a degree of objectivity in to the assessment by preparing an Anticipated State matrix for the element under consideration.

- The probable condition of the element is assessed at regular intervals throughout its life and the costs of remedial work are estimated.

MAINTENANCE STANDARDS (DIAGRAM)

The identification of appropriate building standards is an important factor in determining the maintenance workload.

A range of acceptability with upper and lower limits can be set.

- The higher limit is set by the cost of achieving it.

- The lower limit is set by the increasing probability of failure involving not only enhanced repair costs but also consequential losses where the normal use of the building is affected.

- Certain elements maintain a constant condition over the life of the building, while others are subject to sudden unpredictable failure.

- The model shown in the diagram needs to be adapted to the characteristic of the particular element.

The standard may be expressed in the following ways:

- The condition of the element specifying the magnitude of the defects which calls for remedial action.
- The performance of the elements or environmental systems. Where performance specifications have been used for the initial designs, these could be adopted for this purpose.

- Time at which repairs and replacements are to be made. This method is sometimes referred to as 'frequency based maintenance' and it requires certain knowledge of the rate of deterioration and of the point in time when either functional failure is imminent or the appearance will become unacceptable.

- Financial criteria. Financial expediency often takes precedence over the service needs of the building.

VALUE CONSIDERATIONS (DIAGRAM)

The value of a building is determined by the demand for the services that it offers in combination with other factors of production.

- In the absence of demand, a building has no value to be maintained and neither the initial cost nor the standard of maintenance has any economic significance.

Maintenance interacts with other costs and with revenue.

- For example, for shops it is assumed that a higher level of maintenance will draw more customers and induce them to but more or pay higher prices.

- It is often proposed that the optimum level of expenditure on maintenance is that which gives the maximum return. i.e. MC = MB.

There is often not a precise relationship between the standard of maintenance and the efficiency of user activities.

It is necessary to identify those user activities that are sensitive to the service condition of the building and to isolate those aspects that display measurable changes under different conditions.

- Where there is a relationship between building condition and user activities the consequences of delaying maintenance can be made explicit. In some cases, the loss in value (decrease in user efficiency) may be immediate and progressive.

When the benefits of maintenance are long-term, the expenditure is not unlike that of capital expenditure. The major difference is that maintenance does not produce any new capital asset.

Appropriate timing of maintenance should optimise the total costs.

Where work is deferred, the indirect costs should include the future cost of executing the work discounted to present value.