REHABILITATION AND THE COSTS TO SUSTAIN DWELLING SERVICES

Rehabilitation of dwellings

I.M. JOHNSTONE
Department of Property, The University of Auckland, Auckland, New Zealand

Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 1718-1727.

Abstract

Although decisions to undertake rehabilitation of dwellings are based on private benefits and costs, spillover social benefits ensue because rehabilitation reduces the annual replacement rate of a housing stock below that which would be required otherwise to sustain a set quantity and quality of dwelling services. This paper uses a simulation model to make exploratory estimates of the potential for further reductions in the costs to sustain dwelling services. The model uses data and parameters based on New Zealand housing stock. The potential for further reductions in costs is substantial should a housing stock be stationary, but is insignificant at high expansion rates. A decline in the expansion rate of a housing stock has a greater impact on reducing costs in the long run than an increase in current levels of rehabilitation. The durability of the structural system used by dwellings ultimately limits the service life of dwellings and hence the potential for further reductions in costs.

Keywords: annual replacement rate, durability of structural system, dwelling services, housing stock, rehabilitation, simulation model, social benefits, total average costs.

1 Introduction

Seip (1979), a Norwegian economist and former Minister of housing, admonished that housing in the past had concentrated too much on new development to the neglect of the resources embodied in existing dwellings. The extent of these resources is considerable. For example, dwellings formed over 23% of the total value of New Zealand's capital stock of buildings, infrastructure, plant, and equipment in 1989 (Philpott 1992). Seip urged that future housing policies should be based on the optimum use of these resources. There is a commonly held viewpoint that free market economic forces alone promote an optimum use of resources, including those resources embodied in existing buildings. The basis for this viewpoint is summarised as follows.

Rehabilitation of buildings can be rationally justified only if the costs of doing so are equal to or less than an increase in the exchange value of the property. The level of rehabilitation is optimised when marginal costs equal marginal benefits. A partial level of rehabilitation may be optimal, irrespective of budgetary constraints, when building components undergo incurable depreciation. The costs of full reversing curable depreciation are less than or equal to the consequent value that will be added to the exchange value of the property, whereas the costs of fully reversing incurable depreciation is greater. Returns on a building may therefore be maximised while the quality of services declines.

Rises and falls in land values have an impact on the optimum level of rehabilitation. A rise in land values may justify full and complete rehabilitation, an upgrade, or an extension. When land values are sufficiently high, demolition and replacement or redevelopment may be justified. The economic life of a building reaches an end when the market value of the property plus the costs of demolishing and clearing the site are less than the value of the cleared site in a new and higher use. A building can still be technically efficient beyond its economic life by continuing to earn net annual returns. If redevelopment has not taken place by the time net annual returns are zero, then the property is left derelict.

Expenditure on rehabilitation does not guarantee an extension of services. Situations exist where buildings undergo extensive rehabilitation and are demolished shortly afterwards so as to enable redevelopment. Fully sunk costs are irrelevant and should not enter into economic decision-making because they represent no opportunity for choice. All economic decisions are made at the margin by weighing additional costs against additional benefits. Demolition and replacement of existing buildings which provide adequate services may appear to be wasteful of resources, but the alternative of foregoing opportunities which generate greater value is more wasteful.

What the above viewpoint overlooks is that what counts as a benefit or a loss to individuals or sectors within an economy does not necessarily count as a benefit or loss to the economy as a whole. There can be spillover social costs to a community which result from collective individual action, as in the example of the Tragedy of the Commons given by Hardin (1977), and there can be spillover social benefits. By extending the life expectancy of dwellings, each additional cycle of rehabilitation reduces the annual replacement rate of a housing stock below that which would be required otherwise to sustain a set quantity and quality of dwelling services. It is possible to further reduce the costs to sustain dwelling services by increasing current levels of rehabilitation. A reduction in the costs of supplying a good, such as dwelling services, can be directly translated into a benefit for society when there is a consequent increase in the consumer surplus (Mishan 1988).

This paper uses a simulation model to make exploratory estimates of the potential for further reductions in the costs to sustain dwelling services. The model uses data and parameters based on New Zealand housing stock. Factors which limit this potential are identified and incentives to enable and encourage further reductions in costs are discussed.

2 Mortality of the New Zealand housing stock

The mortality of housing stock is central to the dynamics of dwelling services. Measures of mortality include average life expectancy upon entry and life span. These measures are more appropriately referred to as average service life and service life span when applied to housing stock.

I previously estimated (Johnstone 1994) the average service life of New Zealand housing stock to be 90 years by using a simulation model which effectively links a series of generation, or longitudinal, life tables. The mortality experienced by the New Zealand housing stock between 1860 to 1980 had been dynamic in that the probability of loss of dwellings from each cohort had simultaneously increased and decreased with each increase and decrease in the expansion rate of the housing stock. Estimates of life expectancy are based on the assumption that mortality which applied in the past will continue in the future. Given the same assumption, the average service life of New Zealand dwellings would increase from 90 years to 130 years should the expansion rate of the housing stock decline to zero.

I define the service life span of a housing stock to be that age beyond which less than 0.1% of the oldest dwelling cohort still stands and provides dwelling services. This definition based on Shryock et al. (1973) enables sensible comparisons of the service life spans of different housing stocks as exceptional dwellings are excluded. The current service life span of New Zealand dwellings is 140 years.

3 Simulation model

The simulation model of periodic rehabilitation used in this paper estimates the total average costs to sustain one unit of dwelling services. Costs include that of new-build construction which adds to the size of a housing stock, maintenance, rehabilitation, demolition and replacement. Costs are expressed in construction units (cu), the costs to construct one dwelling. Dwelling services are expressed in dwelling service year equivalents (sye), the services provided by a dwelling over one year after adjusting for depreciation. The model is an extension of my simulation model of single-cycle rehabilitation (Johnstone 1998a). A mathematical description of the model is contained in Johnstone (1998b).

Dwellings are assumed to be homogeneous. Heterogeneity can be taken into account by constructing separate models for distinct classes of dwellings. The services of Ricardian land are separated from the services provided by improvements to land and are not modelled. Real costs of construction are assumed to remain constant over time. It follows that the long run supply curve of the construction industry is perfectly elastic and returns to scale are constant as the construction industry expands.

Parameters are set to extreme limits in order to estimate the full impact of periodic rehabilitation. Dwellings undergo ‘full’ and complete rehabilitation to the extent that depreciation of dwelling services and the probability of loss of dwellings are fully reversed. The effective age of dwellings is zero immediately after undergoing full rehabilitation. Entire dwelling cohorts are set to undergo full rehabilitation at regular cycles. Partial rehabilitation is not modelled. The costs of full rehabilitation are set to be the maximum that can be justified as estimated by my actuarial model of rehabilitation versus new construction (Johnstone 1997). If full rehabilitation can take place within a maximum justifiable budget, then private investment is better diverted from new housing to rehabilitation of existing dwellings. The real discount rate is set to be 6.0%.

Depreciation of dwelling services is set to be that based on an inverted ‘S’ curve as described by Baer (1991). Annual maintenance costs are set to be constant at 1.0% of the costs to construct a dwelling. This level of maintenance is based on a sample of New Zealand dwellings (Johnstone 1998a).

The simulation model is driven by a dynamic mortality regime which applies for a primary housing stock in which no rehabilitation takes place. The service life span of a primary housing stock is 80 years when stationary, 55 years when the expansion rate is 1.0% per year and 50 years when the expansion rate is 2.3% per year. The mortality regime of a housing stock which undergoes full rehabilitation is an amalgam of the primary mortality regime and reversals in probability of loss with each cycle of rehabilitation.

The optimum interval between each cycle of full rehabilitation is the shortest interval at which it is feasible to undertake full rehabilitation. This interval is set to be 20 years. The corresponding maximum justifiable budget is 26.6% of the costs to construct a new dwelling. Expenditure on full rehabilitation is set to be the same regardless of the expansion rate. The number of cycles of full rehabilitation are increased under each expansion rate so that the service life span of the simulated housing stock is as close as possible to the service life span of the New Zealand housing stock with increments of 100 years thereafter.

4 Results and analysis

The results of a primary housing stock are listed in table 1. Total average costs of a primary housing stock which undergoes expansion at the constant rate of 2.3% per year are 63.9% greater than that of a stationary primary housing stock. A stationary housing stock is able to provide dwelling services at a lower cost for the following reasons.

Table 1: Results of primary housing stock

	Service Life Span (years)	Average Service Life (years)	Total Average Costs (cu/sye)	Marginal Increase in TAC (%)	Annual Replacement Rate (%)
Expansion rate = 0%	80	47	0.0360		2.13
Expansion rate = 1.0%	55	36	0.0485	34.7	2.35
Expansion rate = 2.3%	50	33	0.0591	23.1	2.08

Expenditure on new construction forms a new dwelling cohort that yields dwelling services which are fully realised over future time intervals. When a housing stock is stationary and stable, the quantity and quality of dwelling services provided by each dwelling cohort within the housing stock over the same time interval are in a one to one correspondence with the quantity and quality of dwelling services provided by a single dwelling cohort over successive time intervals. The dwelling services yielded by expenditure on new construction (replacement construction only in the case of a stationary housing stock) are effectively realised over the same time interval. In contrast, when a housing stock undergoes expansion, increasingly larger expenditures on new construction (new-build and replacement construction) are made over successive time intervals before the yield of any previous expenditure has been fully realised. Total average costs are accordingly larger.

Table 2 lists the total average costs of a housing stock in which entire dwelling cohorts undergo full rehabilitation. The average annual replacement rate of dwellings as a percentage of the size of New Zealand housing stock between 1921 to 1981 was 0.39% per year and the average annual expansion rate of the housing stock over the same period was 2.3% per year (Johnstone 1994). Although the full extent and level of rehabilitation undertaken within the New Zealand stock in the past is unknown, it is certain that entire dwelling cohorts did not undergone full rehabilitation and that the mortality of all dwellings was therefore not full reversed with each cycle of rehabilitation. The annual replacement rate of the simulated housing stock under the same expansion rate and service life span as above should therefore be less than 0.39% per year, provided the primary mortality regime used by the simulation model is realistic. The annual replacement rate of the simulated housing stock is 0.27% per year, a rate which is 70% of the average annual replacement rate of the New Zealand housing stock.

The annual replacement rate of a primary housing stock which undergoes expansion at the rate of 2.3% per year is 2.08% per year, a factor of 5.3 times greater than the average annual replacement rate of the New Zealand housing stock. A precise estimate of the decrease in total average costs due to partial rehabilitation cannot be made because the full costs of rehabilitation have not been enumerated. A lower limit can be estimated by assuming that full rehabilitation had taken place every

20 years and that the maximum justifiable budget had been fully expended at each cycle. On this assumption, partial rehabilitation undertaken within New Zealand housing stock has reduced total average costs by at least 6%. The annual costs of rehabilitation used in this estimate are 70% of the annual costs of new construction (new-build and replacement). The value of additions and alterations estimated for building consent purposes has averaged 14.4% of the value for new construction between 1921 to 1989 (Statistics New Zealand 1921-1990). The full extent of partial rehabilitation may be double that work undertaken with a building consent. If the costs of partial rehabilitation were assumed to form 35% of the costs of new construction, then an estimate of the reductions in total average costs due to partial rehabilitation would be 22%.

Table 2: Results of full rehabilitation

	Service Life Span (years)	Average Service Life (years)	Total Average Costs (cu/sye)	Marginal Decrease in TAC (%)	Annual Replacement Rate (%)
Expansion rate = 0%					
	140	106	0.0286		0.94
	240	202	0.0260	9.1	0.49
	340	296	0.0252	3.1	0.34
Expansion rate = 1.0%					
	135	110	0.0356		0.52
	235	195	0.0336	5.6	0.21
	335	271	0.0331	1.5	0.13
Expansion rate = 2.3%					
	149	121	0.0456		0.24
	249	196	0.0450	2.2	0.15
	349	259	0.0450	0.0	0.14

The potential for further reductions in costs is substantial should a housing stock be stationary, but is insignificant at high expansion rates. Total average costs of a stationary housing stock decrease by 9.1% should additional cycles of full rehabilitation extend the service life span from 140 years to 240 years. In contrast, total average costs decrease by 2.2% when the expansion rate of the housing stock is 2.3% per year and the service life span of 149 years extends by 100 years. Greater reductions in total average costs would be possible should full rehabilitation be undertaken within the maximum justifiable budget.

Reductions in total average costs which ensue from each additional cycle of rehabilitation are subject to diminishing returns. This is because there are fewer surviving dwellings at the start of each cycle that can take advantage of rehabilitation. Diminishing returns are more pronounced when a housing stock undergoes expansion because there are proportionately fewer older dwellings that are able to take advantage of rehabilitation.

A decline in the expansion rate of a housing stock has a greater impact on reducing total average costs than an increase in current levels of rehabilitation. For example, if current levels of rehabilitation remain unchanged and entire dwelling cohorts were to undergo full rehabilitation, then an immediate decrease in the expansion rate from 2.3% per year to 1.0% per year would reduce total average costs by approximately 20% in the long run. Reductions in costs would be gradual due to the time lags inherent in the dynamics of housing stock.

The differential costs of using more durable structural systems have not been included in the model. Parallel estimates of the break-even costs of using more durable structural systems within a stationary housing stock are given in brackets. If the service life span of the housing stock should extend from 140 years to 240 years and the expansion rate is 1.0% per year (0% per year), then decreases in total average costs would completely dissipate should the costs of using a more durable structural system be 1.9 times greater (3.8 times greater) than that of the less durable system.

5 Discussion

Rehabilitation of dwellings reduces the total average costs to sustain a unit of dwelling services. If no rehabilitation had taken place within the New Zealand housing stock in the past, then annual replacement rates would be as much as 5 times greater and total average costs would be at least 6% and perhaps as much as 22% greater.

Further reductions in total average costs can be gained by increasing current levels of rehabilitation. The potential for further reductions in costs is substantial should the housing stock be stationary, but is insignificant at high expansion rates. A decline in the expansion rate of the housing stock has a greater impact on reducing costs in the long run than an increase in current levels of rehabilitation. A combination of a decline in the expansion rate and an increase in current levels of rehabilitation would dramatically reduce the costs to sustain dwelling services.

Further reductions in the costs to sustain dwelling services can be translated into social benefits. Apart from an increase in the consumer surplus, spillover social benefits include a decrease in the throughput of resources, a reduction in the rate of formation of waste products from demolition, and a reduction in the impact of manufacturing and construction processes on the environment. Some social benefits would be immediate, such as a decrease in levels of pollution, whereas others would gradually increase over time. All social benefits would be made possible by reducing the rate of draw down on the resources embodied in existing dwellings.

Although departures from a housing stock are the end result of an economic process, it is the durability of the structural system used by dwellings that ultimately limits the service life of dwellings and hence the potential for further reductions in costs to sustain dwelling services. For example, although isolated rotting timber piles, bearers, floor joists, wall studs, rafters, and the like can be replaced, an entire lightweight timber framing system has to be replaced when general structural failure occurs.

The contrast between the durability of the structural systems commonly used by New Zealand and British dwellings and their corresponding service life spans is of note. The predominant structural system used in New Zealand is lightweight timber framing (Nana 1981), a system that is prone to decay, whereas the structural walls of British dwellings are predominantly of brick and stone, both durable materials. The service life span of New Zealand dwellings is 140 years whereas the service life span of British dwellings is at least 273 years. Riley (1973) estimated that 0.1% of the British housing stock had been constructed prior to 1700.

New Zealand has a performance based building code that requires those items which contribute to structural stability to have a service life of 50 years (Building Industry Authority 1992). This service life falls well short of the 90 year average service life and 140 years service life span of the housing stock. There are two issues here. The first is that new structural systems, such as galvanised steel framing, need only comply with the shorter service life of 50 years. The second is that the prediction of the long run durability of building components based on accelerated ageing is fraught with difficulties (Masters 1987). The most reliable predictor of durability is a successful past history of performance. Lightweight timber framing and brick and stone structural systems have already demonstrated their ability to match and exceed a service life of 140 years. The prudence of allowing structural systems with unproven long run durability to enter the housing stock and setting a minimum service life which falls well short of the current average service life and service life span of the housing stock should be closely examined.

When there are spillover benefits for society, it is worthwhile for society to provide incentives to increase spillover social benefits to the point where the marginal social costs of providing incentives equal the marginal social benefits that ensue. Incentives to enable and encourage an increase in current levels of rehabilitation include charges and subsidies in the form of grants, loans, and tax allowances.

Charges levied on the demolition of dwellings would retard the rate of demolition and replacement and encourage recycling of demolition wastage to offset the costs of demolition.

Until recently, the lowest income groups in New Zealand have either rented state owned dwellings at subsidised rents, purchased state owned dwelling with subsidised loans, or purchased new housing with subsidised loans (Lowes 1990). The process of filtering down has been bypassed, but should take place in the future due to recent changes in governmental policies. Future assistance to low income families could take the form of grants to undertake rehabilitation.

A random survey of 400 New Zealand dwellings has revealed that deferred maintenance averaged NZ$3,200 per dwelling (Page et al. 1995), or almost three times the average costs of annual maintenance. Those homeowners who have a limited income are more likely to defer maintenance and not undertake rehabilitation. Home improvement loans could be made available to these homeowners at subsidised interest rates. One sector of the community that could benefit the most from home improvement loans is that of the elderly. For many, their home represents their sole store of savings. Rather than allow these houses to sink into disrepair, a loss that ultimately a national loss, reverse mortgages for the purposes of home improvements should be made more readily available to the elderly at reasonable terms. Reverse mortgages also fulfil the role of a superannuation scheme.

Depreciation allowances could be modified to encourage rehabilitation by using diminishing value depreciation schedules which, in practice, apply to the effective age of buildings. Evidence of undertaking rehabilitation would result in a reversal to a higher depreciation rate. The issue of whether depreciation allowances should apply to owner-occupied dwellings is related to the wider issue of tax deductions of interest on mortgages and tax on imputed rent.

The effectiveness, efficiency, and equity of the above incentives to undertake higher levels of rehabilitation would need to be carefully examined before implementation. Baer (1991) cautions that the "when" or correct timing of intervention is equally as important as the "how". The importance of recognising local circumstances should also not be overlooked.

The simulation model used in this paper is based on an assumed schedule of primary depreciation and the primary mortality regime used to drive the model has yet to be fully validated. The exploratory estimates in this paper confirm that the model exhibits realism, but in order to improve precision, full validation of the primary schedule of depreciation and the primary mortality regime of housing stock needs to be carried out. The set of assumptions that underpin the model can, and should, be modified or relaxed. For example, full rehabilitation is assumed to take place at regular intervals whereas, in practice, partial rehabilitation takes place at irregular intervals.

6 References

Baer, W.C. (1991) Housing Obsolescence and Depreciation, Journal of Planning Literature, Vol. 5, pp. 323-332.

Building Industry Authority (1992) *The New Zealand Building Code Handbook and Approved Documents.* Standards New Zealand, Wellington.

Hardin, G. (1977) The Tragedy of the Commons, in *Managing the Commons* (eds. G. Hardin and J. Baden), W H Freeman, San Francisco, pp. 16-30.

Johnstone, I.M. (1994) The Mortality of New Zealand Housing Stock. *Architectural Science Review*, Vol. 37, pp. 181-188.

Johnstone, I.M. (1997) An extended actuarial model of rehabilitation versus new construction of housing. *Journal of Property Finance*, Vol. 8, pp. 126-133.

Johnstone, I.M. (1998a) The optimum timing and maximum impact of full rehabilitation of New Zealand housing stock. *Environment and Planning A*, Vol. 30, pp. 1295-1311.

Johnstone, I.M. (1998b) Periodic rehabilitation and the economic life span of housing stock. *Proceedings of the International Conference on Buildings and the Environment in Asia, School of Building and Real Estate, National University of Singapore, Singapore.* pp. 29-31.

Lowes, N.M. (1990) The Effect of Central Government Policy on the New Zealand House. *NZ Real Estate*, September 1990, pp. 31-37.

Masters, L.W. (1987) Service life prediction: a state-of-the-art report. *Building Research and Practice*, September/October, pp. 292-296.

Mishan, E.J. (1988) *Cost - benefit analysis: an informal introduction*, 4th edition, Routledge, London.

Nana, N. (1981) *Urban Housing Stock in New Zealand, Volume 10: New Zealand Totals*, Research Paper 81/6, National Housing Commission, Wellington.

Page, I.C., Sharman, W.R. and Bennett, A.F. (1995) *New Zealand House Condition Survey 1994*, SR62, Building Research Association of New Zealand, Wellington.

Philpott, B. (1992) *Provisional Estimates of New Zealand Real Capital Stock by SNA Production Groups 1950 – 1990*, PEP Internal Paper 233a, Economic Group, Victoria University of Wellington, Wellington.

Riley, K.M. (1973) An Estimate of the Age Distribution of the Dwelling Stock in Great Britain. *Urban Studies*, Vol. 10, pp. 373-379.

Seip, H. (1979) Building in Economic Terms. *Building Research and Practice* March/April 1979, p. 90.

Shryock & Siegel and Associates (1973) *The Methods and Materials of Demography: Volume 2*, US Government Printing Office, Washington DC.

Statistics New Zealand (1922-1990) *Building Statistics Series 1922-1990*, Statistics New Zealand, Wellington.