LAND USE SUCCESSION CRITERIA AND THE SUSTAINABILITY OF BUILDINGS

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ABSTRACT: Each day professionals in the property industry make financial decisions that determine the current level and affect the future level of resources used to sustain services provided by buildings. This paper has examined whether the standard land use succession criterion applied to an individual building leads to results consistent with that of a benefit-cost ratio criterion applied to a stationary and stable stock of buildings. A typical New Zealand dwelling has been used as an example building and the effects of taxation have not been examined. The author has demonstrated that the standard land use succession criterion is anomalous due to the criterion being a function of the assumed service life of buildings whereas the benefit-cost ratio criterion provides a single unambiguous estimate of the costs to sustain a given quantity of services provided by a stationary and stable building stock.

Keywords – buildings; demolition; optimisation; replacement; stock; sustainability.

INTRODUCTION

Professionals in the property industry throughout the world make financial decisions each day that determine the current level and affect the future level of resources used to sustain the services provided by buildings. These decisions are based on and are driven by economic theory underpinned by Fisher (1906). For example, capital theory forms the basis of the valuation of buildings and investment criteria used to determine capital expenditure, levels of maintenance and refurbishment, and the timing of land use succession. Standard procedures of discounting have serious deficiencies from an environmental and intergenerational perspective, for examples see Price (1993), and these deficiencies apply especially to buildings that are among the most durable forms of capital stock. Investment criteria as applied to buildings are normally applied only to individual buildings. This paper examines whether the standard land use succession criterion applied to an individual building leads to results consistent with that of a benefit-cost ratio criterion applied to a stationary and stable stock of buildings. The building example used in this paper is that of a typical New Zealand dwelling constructed of lightweight timber framing.

LAND USE SUCCESSION CRITERIA

Constraints of examination

The size and initial quality of all dwellings are set to be the same and a stock of dwellings is set to be in a stationary and stable state with land density and intensity of development fixed. The highest and best use of each site is fixed for residential use and the costs of construction are also fixed. The effects of taxation are not examined.

Standard land use succession criterion

Demolition and replacement can be profitably undertaken only if

$$V_n - C_n \geq V_o + D_o \quad (1)$$

where V_o is the market value of a given site with an existing building on it and V_n is the anticipated market value of the same site with a new building on it (Heilbrun and McGuire, 1987). V_n and V_o include the reversionary value of the site (Smith, 1970). This value is the present value of future uses that are expected to succeed the proposed or current use. C_n is the costs of constructing a new building, inclusive of the developer's normal profit and exclusive of the costs of purchasing and clearing the site. D_o is the cost of demolishing the existing building and clearing the site. V_n - Cn represents the maximum price that a developer can afford to pay for a cleared site and still earn a normal profit while $V_0 + D_o$ represents the costs of acquisition and clearance.

The capital value K of any economic process is given by

$$K = \sum_{t=0}^{\omega} \frac{B_t - C_t}{(1+i)^t} \quad (2)$$

where B_t and C_t are benefits and costs respectively at time t and ω is the end of the process (Fisher, 1906). In this paper real discount rates are used and benefits and costs are paid in advance at the start of each time period.

The capital value K_y of a proposed use or current use of a site, excluding the reversionary value of future building cycles, is given by

$$K_y = (1+i)^y \sum_{t=y}^{\Omega-1} \frac{B_t - C_t}{(1+i)^t} \quad \text{with} \quad K_0 = \sum_{t=0}^{\Omega-1} \frac{B_t - C_t}{(1+i)^t} \tag{3}$$

where y is the age of the building and Ω is the service life of the building adopted by the developer. The costs of construction, land acquisition, and demolition are not included in the stream of cash flows at the start of the initial building cycle and $K_\Omega = 0$ at the end of the cycle.

The service life Ω is an assumed service life that often falls well short of the potential service life of buildings. The potential service life ω of lightweight timber framing is at least 180 years, the life of the oldest surviving dwelling in New Zealand.

The subsequent replacement cycles for the proposed and current use include the costs of construction and demolition at the start of each building cycle. If K_s is the capital value of each subsequent building cycle as valued at the start of each cycle, then the capital value of an infinite number of cycles K_∞ is simply the annual equivalent value of K_s (the product of K_s and the capital recovery factor *CRF*) divided by the discount rate i as follows:

$$K_\infty = \frac{K_s \,.\, CRF_i^\Omega}{i} = \frac{K_s}{i} \cdot \frac{i(1+i)^\Omega}{(1+i)^\Omega - 1} = \frac{K_s(1+i)^\Omega}{(1+i)^\Omega - 1}. \tag{4}$$

The market value of the current use V_o is given by

$$V_o = (1+i)^y \sum_{t=y}^{\Omega-1} \frac{B_t - C_t}{(1+i)^t} + \frac{K_\infty}{(1+i)^{\Omega-y}}. \tag{5}$$

The market value of the proposed use V_n is given by

$$V_n = \sum_{t=0}^{\Omega-1} \frac{B_t - C_t}{(1+i)^t} + \frac{K_\infty}{(1+i)^\Omega}. \tag{6}$$

Benefit-cost ratio of stock criterion

There is a tacit assumption in using the previous excess of benefits over costs investment criterion that alternative investment streams are exactly of a given size: no increase is possible (Mishan, 1988). The benefit-cost ratio (BCR) criterion is a more appropriate criterion to use when investment streams allocated to construction, maintenance, refurbishment, and demolition need to increase and decrease in any proportion in order to optimise the use of resources to sustain dwelling services.

The BCR of a stationary and stable stock or population of dwellings is not a direct function of a discount rate because the annual benefits and costs for the entire stock remain the same over each successive year.

$$\mathrm{BCR} = \frac{\sum_{t=0}^{\omega} \frac{B_{stock}}{(1+i)^t}}{\sum_{t=0}^{\omega} \frac{C_{stock}}{(1+i)^t}} = \frac{B_{stock} \sum_{t=0}^{\omega} \frac{1}{(1+i)^t}}{C_{stock} \sum_{t=0}^{\omega} \frac{1}{(1+i)^t}} = \frac{B_{stock}}{C_{stock}} \qquad (7)$$

where B_{stock} and C_{stock} are the flows of benefits and costs within the stationary stock over one year. These benefits and costs mirror the undiscounted present and future benefits and costs of an individual dwelling. The BCR for a stock with a service life span of *y* years is simply

$$\mathrm{BCR}_y = \frac{\sum_{t=0}^{y} B_t}{\sum_{t=0}^{y} C_t}. \qquad (8)$$

A first measure of viability is that BCR ≥ 1. The optimum service life of the stock λ occurs when

$$\mathrm{MAX}(\mathrm{BCR}_y) = \mathrm{BCR}_\lambda \quad \text{for} \quad 0 < \lambda \leq 180. \qquad (9)$$

DATA

Rent and economic depreciation

The building example used in this paper is based on the National Modal House (NZIV, 1996) which comprises a typical New Zealand dwelling of lightweight timber framed construction with a floor area of 100 m^2. The rent, or imputed rent, for the National Modal House is set to be NZ$260 per week in 1997 dollars based on rents for a typical suburb in Auckland, New Zealand.

Empirical data on the economic depreciation or decline of rent over the full service life of New Zealand dwellings are not available. Estimates of economic depreciation $\mathrm{D}(x) \leq 1$ where x is the age of the dwelling are taken to follow a reversed S-shaped curve that declines to a threshold value based on the standard logistic curve.

$$\mathrm{D}(x) = \frac{\mathrm{P} - \mathrm{Q}(x)}{\mathrm{P} - \mathrm{Q}(0)} \quad \text{for } \mathrm{P} \geq \mathrm{Q}(x), \quad \mathrm{Q}(x) = \frac{\mathrm{K}}{1 + ce^{-r_m x}}, \quad c = \frac{\mathrm{K}}{\mathrm{Q}(0)} - 1 \qquad (10)$$

The current service life span of the New Zealand housing stock is 140 years. D(140) is set to approach a threshold value of 0.50 with P = 10,010, Q(0) = 10, and D(70) = 0.75.

Costs and refurbishment cycles

The total costs of the National Modal House, including vinyl flooring is NZ$95,155.40 in June 1997 dollars. The costs of demolition and disposal are NZ$1,700 and annual maintenance costs are NZ$269.91. The costs of refurbishment and cycles of refurbishment are listed in Table 1 and are the same as used and sourced in Johnstone (2001). No refurbishment takes place unless the expected remaining service life is at least half the normal cycle of refurbishment.

Component	Proportion (%)	Cost 1997 NZ$	Cycle z (years)
Substructure	15	1,326.87	40
Wall framing	15	1,246.02	40
External cladding & trim	100	5,611.42	50
Internal linings & trim	30	2,138.27	40
Aluminium windows & doors	100	7,975.61	40
Fittings: kitchen, bathroom	100	8,307.88	25
Combustion heater	100	3,472.78	40
Roofing	100	4,530.88	50
PVC spouting, downpipes	100	1,128.60	20
Plumbing piping & traps	100	1,812.82	40
Plumbing fittings	100	2,825.88	40
Electrical: wiring	50	1,452.42	40
Electrical: stove & HWC	100	1,477.80	25
Prep & painting interior	100	3,575.09	8
Prep & painting of roof	100	1,117.80	7
Prep & painting of cladding	100	1,705.72	9
Floor covering: vinyl sheet	100	360.00	30
Polyurethane floor finish	100	1,027.40	10

Table 1. Refurbishment costs and cycles

RESULTS

Results of standard land use succession criterion

Table 1 sets out the age ϕ at which the land use succession inequality is first satisfied over a range of discount rates *i* and assumed service Ω. The inequality is first satisfied at the age $\phi = \Omega$ for $\Omega \leq 70$ years over the discount rate range of $3.0\% \leq i \leq 12.0\%$. The inequality is also first satisfied at the age $\phi = \Omega$ for $\Omega > 70$ with the discount rate $i = 12\%$. The age ϕ decreases when lower discount rates and assumed service lives greater than 70 years are adopted. Similar results apply when depreciation of rent is set to different thresholds and when maintenance and refurbishment costs are set to increase exponentially over the service life of each dwelling.

Ω	Discount rate *i*									
	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
50	50	50	50	50	50	50	50	50	50	50
60	60	60	60	60	60	60	60	60	60	60
70	70	70	70	70	70	70	70	70	70	70
80	72	80	80	80	80	80	80	80	80	80
90	60	67	70	90	90	90	90	90	90	90
100	40	60	66	69	72	79	80	100	100	100
110	40	59	63	69	72	79	110	110	110	110
120	39	58	63	68	72	75	80	120	120	120
130	39	50	62	68	71	75	80	130	130	130
140	38	50	62	67	70	75	80	100	119	120
150	38	50	62	67	70	75	80	100	119	150
160	38	50	62	67	70	75	80	100	119	160
170	38	49	61	67	70	75	80	100	119	170
180	37	49	61	67	70	75	80	100	119	180

Table 1. Age at which land use succession inequality is first satisfied

Fig. 1 shows that the land use succession inequality is first satisfied with ϕ = 61 years when *i* = 5.0% and Ω = 180 years.

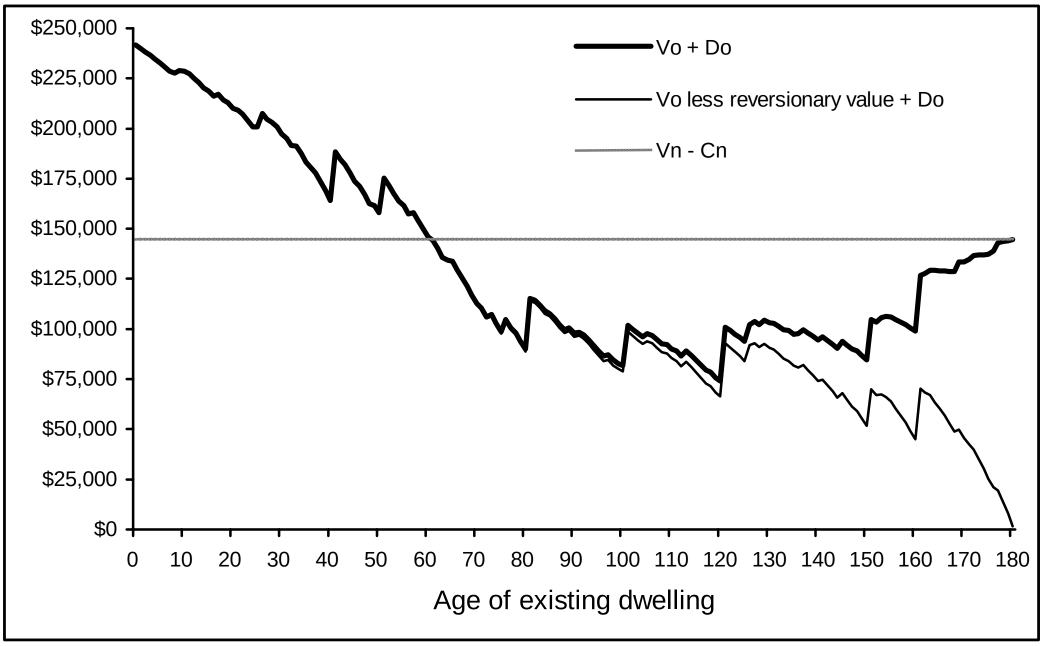

Fig. 1. Land use succession, (i = 5.0%, Ω = 180 years, ϕ = 61 years*)*

Fig. 2 shows that the land use succession inequality is first satisfied with ϕ = 80 years when *i* = 5.0% and Ω = 80 years.

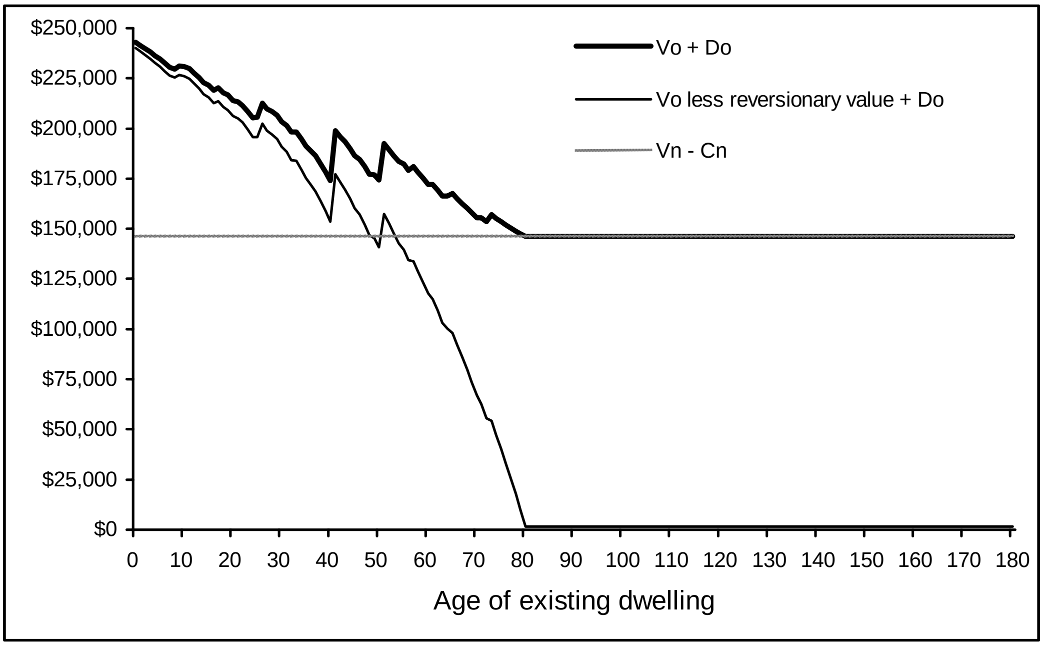

Fig. 2. Land use succession (i = 5.0%, Ω = 80 years, ϕ = 80 years)

Results of benefit-cost ratio of stock criterion

Fig. 3 graphs the benefit-cost ratio (BCR) for a stationary and stable stock of dwellings. The maximum BCR occurs when $\lambda = 74$ years and $BCR_{\lambda} = 3.63$. The New Zealand Building Code requires components that contribute to structural stability to have a service life of 50 years (Building Industry Authority, 1992). BCR_{λ} is 14.5% greater than BCR_{50}.

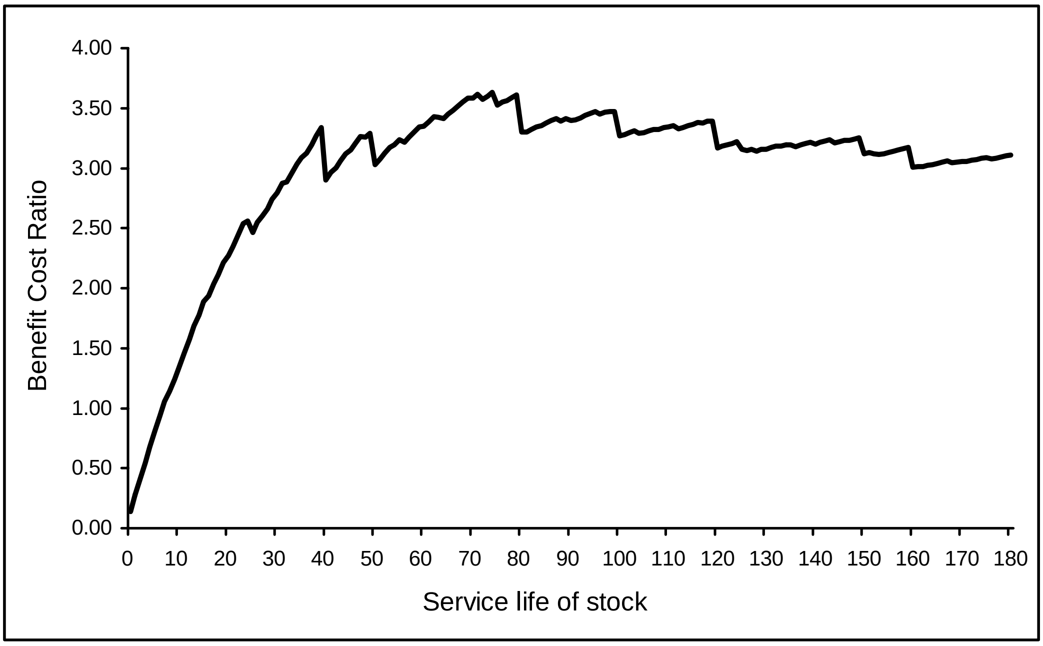

Fig. 3. Benefit-cost ratio of stock (λ = 74 *years*)

CONCLUSIONS

This paper has examined whether the standard land use succession criterion applied to an individual building leads to results consistent with that of a benefit-cost ratio criterion applied to a stationary and stable stock of buildings. A typical New Zealand dwelling has been used as an example and the effects of taxation have not been examined.

The author has demonstrated that the standard land use succession criterion is anomalous due to the criterion being a function of the assumed service life of buildings. For example, if a developer or property owner assumes that dwellings have a long service life, then the criterion estimates that the current dwelling can be demolished and replaced at an age much shorter than the assumed service life. However, if a developer or property owner assumes that dwellings have a short service life, then the criterion justifies that assumption as a self-fulfilling prophecy. Estimates of the optimum timing of land use succession are also determined by the discount rate that is adopted over a range of assumed service lives.

The benefit-cost ratio criterion does not involve assumptions as to the service life of dwellings. The criterion also does not make use of discount rates when applied to a stationary and stable housing stock because the benefits and costs of the housing stock over each time period mirror the present and future undiscounted benefits and costs of an individual dwelling. Unlike the standard land use succession criterion, the method of ranking of the benefit-cost ratio criterion provides a single unambiguous estimate of the optimum timing of land use succession that minimises the costs to sustain a set quantity of dwelling services provided by a stationary and stable building stock.

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