ON ARCHETYPES AND BUILDING ADAPTIVE REUSE

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ABSTRACT

Building adaptive reuse is increasingly being applied as a solution to urban renewal where existing facilities have become obsolete but where significant physical life remains embedded in their structure and materials and/or where heritage and cultural values deserve to be protected. Revitalisation of buildings in this context is a valid response to climate change and sustainability agenda as it has the potential to reuse a large proportion of resources in place without destruction or substantial replacement. There are now a large number of examples of successful adaptive reuse projects across a broad range of facility types worldwide. This paper applies an existing adaptive reuse potential (ARP) model to construct archetypes or patterns for various facility categories to provide insight into project feasibility decisions. The probability of success is tested using a unique application of PERT analysis for a range of obsolescence rates. The archetypes reflect distinct characteristics that help inform selection of potential reuse opportunities.

Keywords: adaptive reuse, obsolescence, useful life, strategic decisions, buildings

INTRODUCTION

Existing buildings that are obsolete or rapidly approaching disuse and potential demolition are a ‘mine’ of raw materials for new projects; a concept described by Chusid (1993) as ‘urban ore’. Even more effective, rather than extracting these raw materials during demolition or deconstruction and assigning them to new applications, is to leave the basic structure and fabric of the building intact, and change its use. This approach is called ‘adaptive reuse’. Breathing ‘new life’ into existing buildings carries with it environmental and social benefits and helps to retain our national heritage. To date, a focus on economic factors alone has contributed to destruction of buildings well short of their physical lives.

Adaptive reuse has great application to international efforts to conserve resources through more sustainable practice. Such actions in turn contribute to lower greenhouse gas emissions and waste and therefore form part of the array of adaptation strategies available to the property sector in the face of global climate change. In the developed world we have seen an increase in the proportion of capital expenditure directed to refurbishment works in recent years, and this now outweighs capital expenditure of new construction in many countries (Douglas, 2006). This trend will continue.

This paper aims to provide strategic insight into building adaptive reuse as a particular instance of refurbishment work. Previous research by Langston et al. (2008) has led to an adaptive reuse potential (ARP) model that can be used to rank and prioritise projects for renewal. Archetypes are constructed for ten generic facility classifications as a means of understanding the potential value and risk of adaptive reuse intervention. The outcomes indicate that each facility type has a distinctive pattern that can be used to inform strategic decision-making at an early stage. Facility classification is shown to be a key factor in adaptive reuse success.

BACKGROUND

Buildings are major assets and form a significant part of facility management operations. Although buildings are long lasting they require continual maintenance and restoration. Eventually, buildings can become inappropriate for their original purpose due to obsolescence, or can become redundant due to change in demand for their service. It is at these times that change is likely: demolition to make way for new construction, or some form of refurbishment or reuse (Langston and Lauge-Kristensen, 2002).

Refurbishment can of itself take many forms, ranging from simple redecoration to major retrofit or reconstruction. Sometimes the buildings are in good condition but the services and technology within them are outdated, in which case a retrofit process may be undertaken. If a particular function is no longer relevant or desired, buildings may be converted to a new purpose altogether. This is adaptive reuse.

Older buildings often have a character that can significantly contribute to the culture of a society and conserve aspects of its history. The preservation of these buildings is important and maintains their intrinsic heritage and cultural values. Facility managers are frequently faced with decisions about whether to rent or buy, whether to extend or sell, and whether to refurbish or construct. Usually these are financial decisions, but there are other issues that should bear on the final choice, including environmental and social impacts.

For a wide range of reasons buildings can become obsolete long before their physical life has come to an end. Investing in long-lived buildings may be sub-optimal if their useful life falls well short of their physical life. It is wise to design future buildings for change by making them more flexible yet with sufficient structural integrity to support alternative functional use.

Atkinson (1988) modelled the process of obsolescence and renewal (of housing stock), and developed a 'sinking stack' theory to explain the phenomenon. Comparing total building stock over time produces a rising profile in total stock (accumulating via new construction each year) stratified according to building age (older buildings are at lower layers in the profile strata). New stock is added annually to the top of the stack. It degenerates over time and gradually sinks towards the base as new buildings are created and older ones demolished. If little new construction is added to the top of the stack, then the entire building stock will age, and greater resources will be required to maintain the quality and amenity level. Certain layers in the stack represent periods of poor quality construction, and these tend to age more rapidly and absorb greater maintenance resources (BDP, 1996). Each layer in the stack reduces in height with the passage of time. Only the top layer grows because it represents the current rate of construction. The net effect is a sinking of the stack, a phenomena that occurs whether or not maintenance takes place.

From an environmental sustainability perspective, it is preferable to minimise new additions to the stack, but at the same time to remove those layers of poorer quality stock that absorb excessive maintenance and operating resources. Increased resources should be allocated to maintenance of those better quality layers of the stack. Atkinson has developed computer models that illustrate the sinking effect dynamically for given input parameters. The philosophy of 'minimum decay' (Atkinson, 1988) involves retarding the rate of obsolescence and replacement – slowing down the sinking of the stack by decreasing the consumption of new resources, and assigning increased resources to maintenance and refurbishment. Where this can be linked to improving operating energy efficiency and comfort, the saving in embodied energy (energy already involved in manufacture and construction) is substantial.

Adaptive reuse is thus a special form of refurbishment that poses quite difficult challenges for designers. Changing the class (functional classification) of a building introduces new regulatory conditions and perhaps requires zoning consent. There are clear economic, environmental and social benefits that can make this option attractive to developers. In some cases increases in floor space ratios can be obtained and concessions received for pursuing government policy directions by regenerating derelict public assets. In recent years redundant city office buildings have been converted into high quality residential apartments, bringing people back to cities and in the process revitalising them.

Adaptive reuse has been successfully applied in many types of facilities, including defence estates (e.g. Doak, 1999; Van Driesche and Lane, 2002), airfields (e.g. Gallent et al., 2000), government buildings (e.g. Abbotts et al., 2003), and industrial buildings (e.g. Ball, 1999; Anon., 2006). Around the world, adaptive reuse of historic buildings is seen as fundamental to sound government policy and sustainable development – e.g. in Atlanta, US (Newman, 2001), Canada (Brandt, 2006), Hong Kong (Poon, 2001), North Africa (Leone, 2003) and Australia (Maggs, 1999; McLaren, 1996).

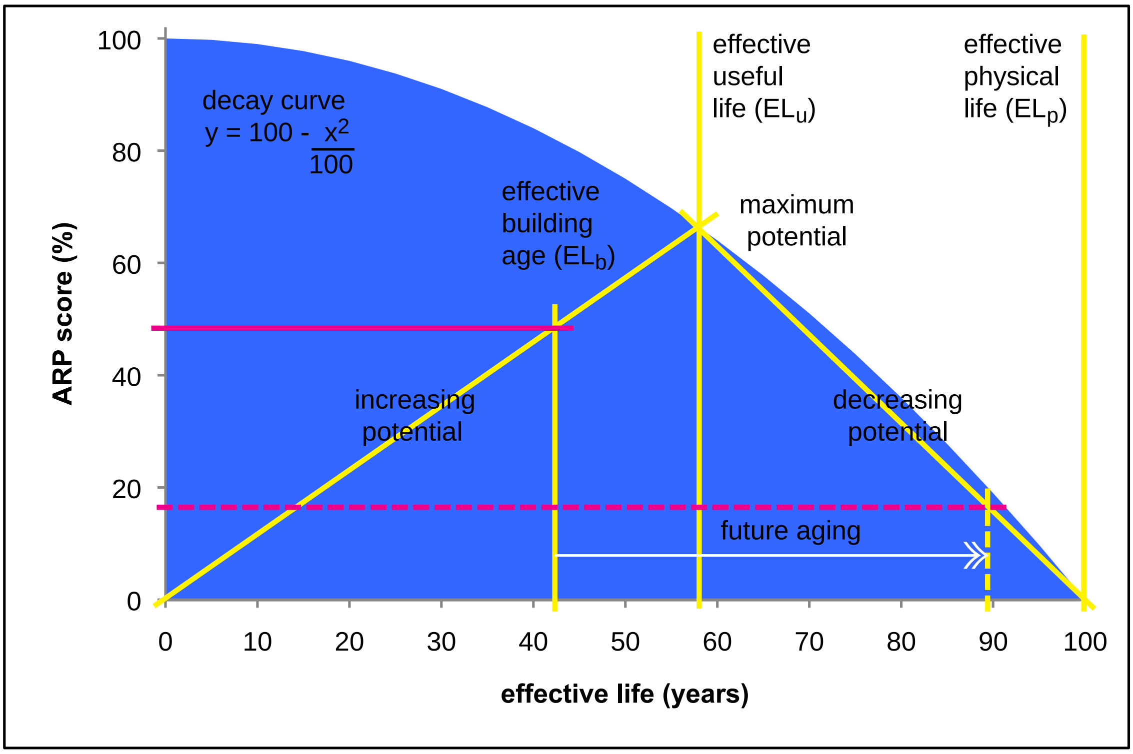
Adaptive reuse can be quite dramatic. For example, conversion of disused industrial factories into shopping centres or churches into restaurants is possible. Property managers should be conscious of adaptive reuse solutions to redundant space and continually think about more productive uses for existing premises. It is therefore critical that we have mechanisms in place to ensure that when buildings are created they represent value to society as their long-term stakeholder, rather than their short-term custodians or brokers. Unmasking the social ‘costs’ of renewal can provide strong incentives for a transition to more sustainable energy use, less profligate use of new materials, and greater service from constructed building stock.

The ARP model developed by Langston et al. (2008) identifies and ranks adaptive reuse potential in existing buildings, and therefore can be described as an intervention strategy to ensure that collective social value is optimised and future redundancy is planned. The model has generic application to all countries and all building typologies. It requires an estimate of the expected physical life of the building (a worksheet has been developed to assist with estimation) and the current age of the building, both reported in years. It also requires an assessment of physical, economic, functional, technological, social, legal and political obsolescence, which is undertaken using surrogate estimation techniques as no direct market evidence exists.

Obsolescence is advanced as a suitable concept to objectively reduce the expected physical life of a building to its expected useful life. A discounting philosophy is adopted, whereby the annual obsolescence rate across all criteria is the ‘discount rate’ that performs this transformation. An algorithm based on a standard decay (negative exponential) curve produces an index of reuse potential (known as the ARP score) and is expressed as a percentage. Existing buildings in an organisation’s portfolio, or existing buildings across a city or territory, can therefore be ranked according to the potential they offer for adaptive reuse at any point in time. The decay curve can be reset by strategic capital investment during a renewal process by the current owner, or a future developer, at key intervals during a building’s life cycle.

ARP scores in excess of 50% have high adaptive reuse potential, scores between 20% and 50% have moderate potential, and scores below 20% have low value, representing about one-third of the area under the decay curve in each case. Potential means that there is a propensity for projects to realise economic, social and environmental benefits when adaptive reuse is implemented. ARP is conceptualised as rising from zero to its maximum score at the point of its useful life, and then falling back to zero as it approaches physical life. Where the current building age is close to and less than the useful life, the model identifies that planning activities should commence.

The ARP model is summarised in Figure 1. Its application was first demonstrated for a real case study in Hong Kong in Langston and Shen (2007).



$$\text{ARP (increasing)} = \frac{100 - \frac{EL_u^2}{100}}{EL_u} \cdot EL_b \qquad \text{ARP (decreasing)} = \frac{100 - \frac{EL_u^2}{100}}{100 - EL_u} \cdot (100 - EL_b)$$

Figure 1: Adaptive reuse potential model (Langston, 2008)

The shape of the 'mountain' depicting the rise of fall of adaptive reuse potential (hereafter called 'ARP profile') is a function of the obsolescence factors that are deemed to apply. Rather than envisage these as accurate estimates, they are more appropriately understood as ranges within which reasonable estimates occur. High rates of obsolescence mean lower useful lives and ARP profiles skewed towards the short term, while low rates of obsolescence mean higher useful lives and ARP profiles skewed towards the long term. The problem with the latter is that ARP scores are lower as the point of optimal intervention is delayed and leaves relatively little time to enjoy the benefits of the new purpose before the end of the facility's life cycle. Strategically, projects with the highest potential for adaptive reuse are those that have the greatest rate of premature obsolescence and ARP profiles skewed left.

METHOD

ARP profiles can be readily created for a range of obsolescence values for any facility. In this research, ten generic facility classifications are developed and tested to produce archetypes or patterns that can inform selection decisions. High ARP scores have been shown to lead to superior economic, social and environmental benefits in practice via an Australian Research Council grant (2008-2010).

The Program Evaluation and Review Technique (PERT) is used in planning and scheduling activities as a means of assessing the impact of task duration on overall completion of time estimates (Uher, 2003). In this research, PERT analysis is applied in a unique manner to assess the range of obsolescence values that could reasonably be expected for each facility classification. This involves estimating the typical value for each obsolescence category, as well as the pessimistic (worst case) and optimistic (best case) values. They are combined using a simplified beta distribution to calculate the most likely value (t_e). The probability (z-score) based on a normal distribution is then used to indicate the extent of skew of the most likely value to either the pessimistic or optimistic values.

The following standard PERT equations (1-3) are used in this process:

$$t_e = \frac{(a + 4m + b)}{6} \qquad (1)$$

where:

t_e = *most likely value based on simplified beta distribution*
a = *optimistic value*
m = *typical value*
b = *pessimistic value*

$$s = \left[\frac{(b - a)}{6} \right]^2 \qquad (2)$$

where:

s = *variance*
a = *optimistic value*
b = *pessimistic value*

$$z = \frac{(\sum m - \sum t_e)}{\sqrt{s}} \qquad (3)$$

where:

z = *probability based on normal distribution*
m = *typical value*
t_e = *most likely value based on simplified beta distribution*
s = *variance*

Reasonable assumptions are made regarding the description of generic facility classifications. The obsolescence factors are described using either 0, 5, 10, 15 or 20% for each of physical, economic, functional, technological, social and legal obsolescence categories, and -20, -15, -10, -5, 0, 5, 10, 15 or 20% for the political obsolescence category as per the ARP model definition. High values indicate more premature obsolescence is expected – refer to Langston (2011) for a detailed explanation of the method of surrogate estimating used to value each obsolescence category.

The facility classifications included in this paper comprise ten of the most common building typologies:

- Commercial (based on an office tower)
- Residential (based on a detached house)
- Retail (based on a shopping centre)
- Industrial (based on a warehouse)
- Landmark (based on a museum)
- Civic (based on a community centre)
- Recreational (based on a hotel)
- Healthcare (based on a hospital)
- Educational (based on a school)
- Religious (based on a church)

For each facility classification, the following values were computed:

- Annual obsolescence rate
  $\sum t_e / 100$
- Skew (z)
- Obsolescence range
  $\sum b / 100 - \sum a / 100$
- ARP score
  pessimistic, most likely and optimistic: using Figure 1
- Coefficient of variation (cv) for ARP
  σ / μ

RESULTS

Obsolescence estimates are made based on the experience of the author. Tables 1-10 (see Appendix) list these key inputs and display the calculation of most likely value and variance. All columns are summed.

The use of PERT analysis to arrive at the most likely rate of obsolescence is analogous to determining the most likely duration for tasks in a critical path network. In the former, all obsolescence categories are included. In the latter, only tasks that lie on the critical path are included (i.e. the sum of critical path durations equals the total time for completion of the project). This is a unique application of PERT, and is further extended below to describe the degree of skew in the ARP profile in preference to other statistical measures like skewness and kurtosis.

The ARP model itself assumes that each obsolescence category is equally weighted. No attempt is made here to vary that assumption. The annual obsolescence rate, used to 'discount' physical life to useful life in the model, is computed as the sum of obsolescence values across the seven categories, expressed as a fraction. The key results are summarised in Table 11.

Table 11: Summary of findings

	annual obsolescence	range	arp score (%)	life cycle (%)	skew (%)	cv (%)
commercial (office tower)	0.51	0.65	63.7	60.2	20	58.5
residential (detached house)	0.18	0.35	29.5	84.0	80	72.7
retail (shopping centre)	0.79	0.15	79.3	45.5	33	4.1
industrial (warehouse)	0.32	0.40	46.9	72.9	72	43.8
landmark (museum)	0.65	0.30	72.6	52.3	50	11.6
civic (community centre)	0.37	0.40	51.9	69.4	70	35.7
recreational (hotel)	0.45	0.30	59.3	63.8	50	21.4
healthcare (hospital)	0.73	0.35	76.4	48.6	18	12.9
educational (school)	0.58	0.40	68.8	55.9	84	16.0
religious (church)	0.25	0.60	39.3	77.9	86	78.0
mean	0.48	0.39	58.8	63.0	56.3	35.5
cv (%)	42.9	37.2	28.2	20.4	46.1	75.4

As explained earlier, ARP scores above 50% are described as 'high', scores between 20 and 50% are 'moderate', while scores below 20% are 'low'. All but residential, industrial and religious facility classifications have 'high' ARP scores.

The above data can be expressed as an archetype to visualise the impact of implications of adaptive reuse potential to each facility classification. Archetypes are patterns that have generic application. The derived archetypes are provided in Figure 2. The higher the ARP score, the better is the potential of success. The shaded area indicates the likely range of ARP scores (large ranges are more uncertain). The solid triangle indicates the ARP profile, while the two dotted triangles indicate the range boundaries for best and worst ARP outcomes. A low skew value (i.e. <50%) indicates a more favourable ARP profile that a high skew value (i.e. >50%). The archetypes provide strategic advice at a glance.

It should be noted that prediction of physical life is not required here, as useful life is expressed as a percentage of physical life (i.e. life cycle %) rather than in years. However, years can be determined by making an explicit estimate of physical life. The number of years of expected useful life, when added to the date of the original construction (or last major refurbishment), gives the date of optimum adaptive reuse intervention.

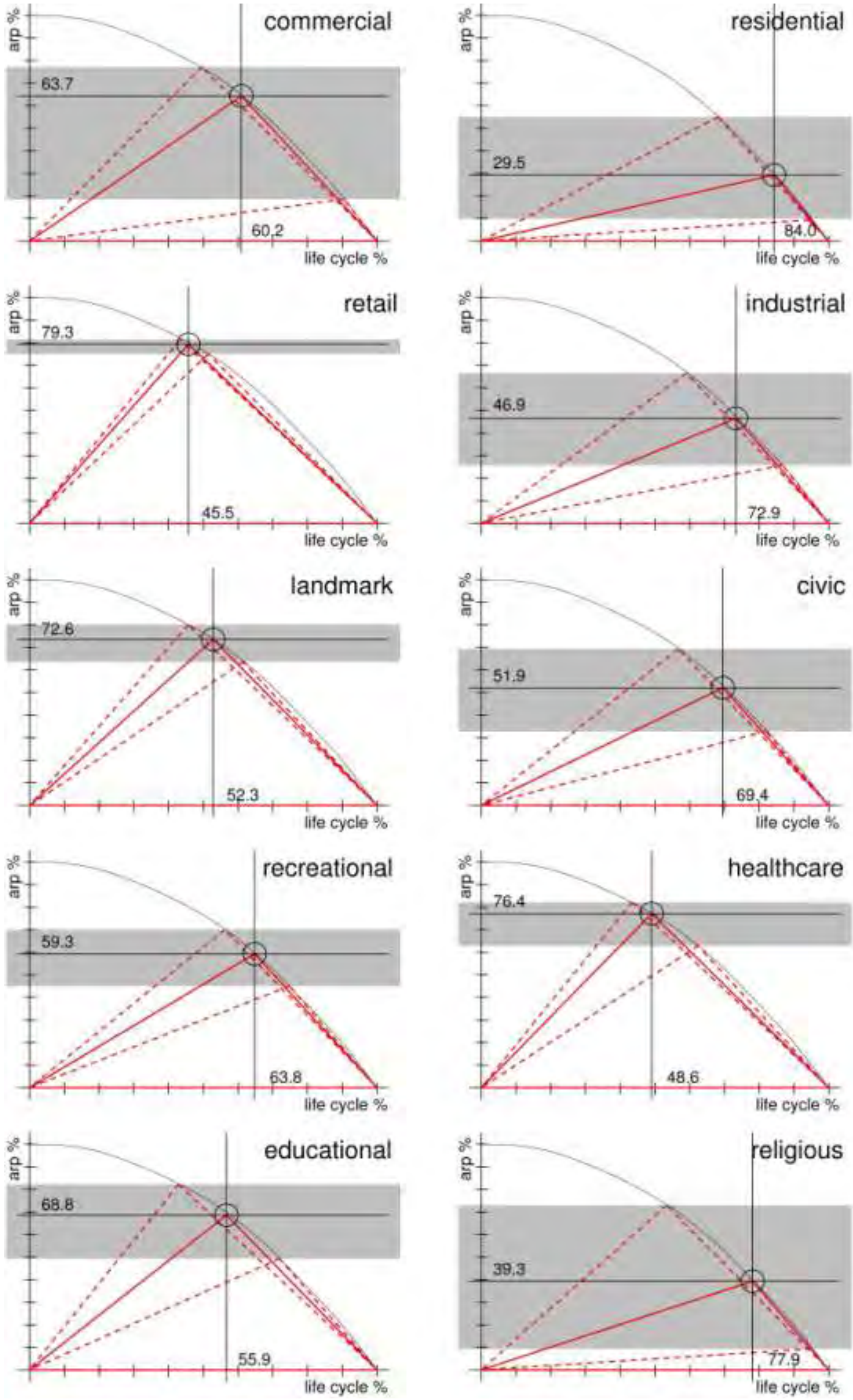


Figure 2: ARP archetypes for generic facility classifications

DISCUSSION

The previous results indicate that different facility classifications have different ARP profiles. These profiles are expected to apply to the majority of specific examples within each classification. So the facility classification is influential to the success of an adaptive reuse intervention, and should be used as a criterion to search for adaptive reuse opportunities. Based on most likely estimates of obsolescence formulated via PERT analysis, facility classifications can be ranked, as shown in Figure 3.

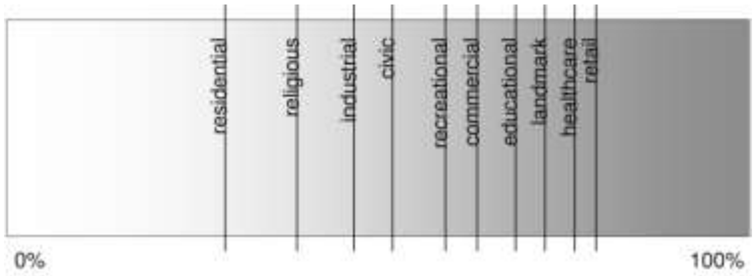


Figure 3: Expected ARP priority of generic facility classifications

Facility classifications such as retail, healthcare and landmark (for example) are more attractive as potential adaptive reuse projects than facility classifications such as residential, religious and industrial. Other examined classifications fall between. Interestingly, retail, healthcare and landmark have lower uncertainty than the remainder, indicating a higher level of confidence in the prediction. Healthcare, commercial and retail have a low skew value, which makes them attractive since earlier relative intervention is likely, although commercial also has high uncertainty (i.e. large range).

The ARP model, by its nature, correlates ARP score with useful life and follows the decay curve as its regression line. The timing of adaptive reuse intervention is critical, for to maximise benefit intervening too early or too late is counterproductive. The optimum intervention point is shown by the life cycle % value, which has a mean across all facility classifications of 63% and a very low coefficient of variation. In other words, the optimum intervention point appears to be around two-thirds of the facility life cycle on average. The largest value is for residential, which may partly explain why adaptive reuse to other functional purposes is rare. The time over which the benefit of the change can be enjoyed is the shortest of all facility classifications examined.

CONCLUSION

This paper demonstrates that facility classification is an important ingredient in project selection for adaptive reuse intervention. It uniquely uses PERT analysis to construct archetypes for each facility classification that define and inform likely success. While more detailed study for individual projects is certainly warranted in practice, this research has identified that the greatest opportunities for adaptive reuse and not necessarily confined to the traditional decisions of industrial or commercial transformations as has been widely witnessed. Making better decisions about adaptive reuse opportunities will significantly improve our sustainability performance and deliver economic, social and environmental benefits to property owners and investors. In particular, the reuse of valuable resources will offset the need to destroy existing buildings and contribute positively to climate change adaption initiatives that are increasingly urgent.

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APPENDIX: BASE DATA

Table 1: Obsolescence category estimates for commercial (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	10	10	0	8.33	2.78
economic	5	0	0	0.83	0.69
functional	10	5	5	5.83	0.69
technological	20	15	5	14.17	6.25
social	20	20	0	16.67	11.11
legal	10	5	0	5.00	2.78
political	0	0	0	0.00	0.00
sum	75	55	10	50.83	24.31

Table 2: Obsolescence category estimates for residential (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	5	0	0	0.83	0.69
economic	15	5	0	5.83	6.25
functional	10	5	5	5.83	0.69
technological	5	0	0	0.83	0.69
social	0	0	0	0.00	0.00
legal	5	5	0	4.17	0.69
political	0	0	0	0.00	0.00
sum	40	15	5	17.50	9.03

Table 3: Obsolescence category estimates for retail (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	5	5	5	5.00	0.00
economic	15	10	5	10.00	2.78
functional	15	15	15	15.00	0.00
technological	20	20	20	20.00	0.00
social	20	20	20	20.00	0.00
legal	10	10	5	9.17	0.69
political	0	0	0	0.00	0.00
sum	85	80	70	79.17	3.47

Table 4: Obsolescence category estimates for industrial (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	15	10	10	10.83	0.69
economic	15	10	5	10.00	2.78
functional	5	0	0	0.83	0.69
technological	5	0	0	0.83	0.69
social	0	0	0	0.00	0.00
legal	15	10	10	10.83	0.69
political	0	0	-10	-1.67	2.78
sum	55	30	15	31.67	8.33

Table 5: Obsolescence category estimates for landmark (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	5	5	0	4.17	0.69
economic	15	5	5	6.67	2.78
functional	15	10	10	10.83	0.69
technological	20	20	15	19.17	0.69
social	0	0	0	0.00	0.00
legal	5	5	0	4.17	0.69
political	20	20	20	20.00	0.00
sum	80	65	50	65.00	5.56

Table 6: Obsolescence category estimates for civic (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	10	5	5	5.83	0.69
economic	15	10	5	10.00	2.78
functional	10	5	5	5.83	0.69
technological	15	10	5	10.00	2.78
social	0	0	0	0.00	0.00
legal	10	5	0	5.00	2.78
political	0	0	0	0.00	0.00
sum	60	35	20	36.67	9.72

Table 7: Obsolescence category estimates for recreational (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	5	5	0	4.17	0.69
economic	5	0	0	0.83	0.69
functional	15	15	15	15.00	0.00
technological	20	15	15	15.83	0.69
social	5	5	0	4.17	0.69
legal	10	5	0	5.00	2.78
political	0	0	0	0.00	0.00
sum	60	45	30	45.00	5.56

Table 8: Obsolescence category estimates for healthcare (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	10	10	5	9.17	0.69
economic	15	10	5	10.00	2.78
functional	20	20	15	19.17	0.69
technological	20	20	15	19.17	0.69
social	0	0	0	0.00	0.00
legal	10	5	0	5.00	2.78
political	10	10	10	10.00	0.00
sum	85	75	50	72.50	7.64

Table 9: Obsolescence category estimates for educational (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	15	10	10	10.83	0.69
economic	20	10	5	10.83	6.25
functional	15	10	10	10.83	0.69
technological	15	10	5	10.00	2.78
social	0	0	0	0.00	0.00
legal	10	5	5	5.83	0.69
political	10	10	10	10.00	0.00
sum	85	55	45	58.33	11.11

Table 10: Obsolescence category estimates for religious (%)

	pessimistic (b)	typical (m)	optimistic (a)	most likely (t_e)	variance (s)
physical	10	5	5	5.83	0.69
economic	20	10	0	10.00	11.11
functional	5	0	0	0.83	0.69
technological	10	0	0	1.67	2.78
social	10	0	0	1.67	2.78
legal	10	5	0	5.00	2.78
political	0	0	0	0.00	0.00
sum	65	20	5	25.00	20.83