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Strategic assessment of building adaptive reuse opportunities in Hong Kong

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Abstract

There is an increasing complexity and interplay between all the issues associated with property portfolio decisions. This paper explores the relationships between financial, environmental and social parameters associated with building adaptive reuse. An adaptive reuse potential (ARP) model is developed and discussed in the context of its application to the Hong Kong market. The model can assist in the transformation of the traditional decision-making processes of property stakeholders towards more sustainable practices, strategies and outcomes, by providing a means by which the industry can identify and rank existing buildings that have high potential for adaptive reuse. This in turn enhances Hong Kong's ability for sustainable, responsive energy and natural resource management by allowing issues regarding excessive and inappropriate resource use to be identified and assessed, and enabling appropriate management strategies to be implemented. The ARP model proposed in this paper provides, illustrated by a real case study, an important step in making better use of the facilities we already have and the residual life embedded in them.

Keywords: Adaptive reuse; Sustainability; Building age; Useful life; Obsolescence; Refurbishment potential

1. Introduction

The number of new residential completions in 2006 was 16,579, adding 1.5% to the stock of residential units in Hong Kong (including Kowloon and the New Territories) of 1,053,246 units in 2005 ([1], Table 2). Office space completion was unusually low at 108,200 m^2, adding just 1.1% to the 2005 stock of 9,769,700 m^2 ([1], Table 18). Commercial space rose 1.9% or 182,800 m^2 in 2006 from the previous stock of 9,522,400 m^2 ([1], Table 27). Industrial space (comprising private flatted factories, industrial/office, specialised factories and storage) rose 43,500 from 24,635,500 m^2 in 2005—just 0.18% in 2006 ([1], Tables 33, 40, 43 and 45). These figures exclude loss of stock through demolition, which equates to 1048 units (residential), 51,200 m^2 (office), 26,600 m^2 (commercial) and 64,600 m^2 (industrial) in 2006.

The construction industry normally contributes between 4% and 8% of national GDP—an average of 5.85% per annum over the period 1992–2005 inclusive (http://www.censtatd.gov.hk/). The value of annual activity is about HK$90 billion (2006) of which 46.3% is new private and public construction sites and the remainder is minor new construction work and renovation activities at existing building locations. At a global level, buildings consume 32% of world resources, 12% of water consumption, 40% of waste to landfill and 40% of air and greenhouse gas emissions [2–5].

A simple calculation shows that new construction adds less than 2% per annum to the built environment stock in Hong Kong. Yet greenhouse gas emissions (GGE) in Hong Kong are nearing 50 million tonnes (CO_2 equivalent) per annum and rising (http://www.epd.gov.hk/). Expressed in terms of emissions per square metre, Hong Kong is considered to be the largest producer of GGE in the world [6]. So it will take perhaps up to a century before the energy efficient strategies of new building construction can make any significant difference to the greenhouse gas reduction

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targets of the Hong Kong Government. Energy efficient design should therefore be focused on retrofit of existing buildings rather than demolition and new construction. This is a particular challenge for Hong Kong and the motivation for this paper. We must seek greater benefit from the buildings we already have [7].

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 [8] 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.

This research, for the first time, develops a conceptual framework for the assessment of potential adaptive reuse projects and discusses how this potential can be validated based on a triple bottom line (financial, environmental, social) philosophy. This paper therefore aims to

(1) develop an understanding of how to prioritise potential adaptive reuse projects to maximise the effective allocation of resources while conserving our national heritage and
(2) propose a methodology and resultant strategies for enhancing the contributions of our built environment stock in terms of financial, environmental and social benefits.

To achieve these aims, a tool for estimating the useful life of buildings based on potential obsolescence from physical, economic, functional, technological, social and legal criteria is first proposed. Application of the sustainability assessment tool SINDEX is then discussed as a potential method for validation and application by industry. Finally, a case study of the historic Western Market building is briefly discussed.

2. Background

2.1. Refurbishment and obsolescence

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 [9].

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 may 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.

Johnson ([10], p.209) indicates that, as society has advanced, its use of buildings has become more temporal. He states that "advances in technology and commerce, including the growth of industrial and office automation, and user demands for more comfortable environments for work and leisure have led to large numbers of buildings becoming obsolete or redundant and these changes have provided an abundance of buildings suitable for rehabilitation and reuse."

The useful (effective) life of a building or other asset in the past has been particularly difficult to forecast because of premature obsolescence [11]. This may be described as comprising one or more of the following:

(1) *Physical obsolescence*: while all buildings experience natural decay over time, accelerated deterioration leads to reduced physical performance and obsolescence. Natural decay is not considered an attribute of obsolescence but rather of age.
(2) *Economic obsolescence*: the period of time over which ownership or use of a particular building is considered to be the least cost alternative for meeting a business objective governs investor interest and obsolescence based on economic criteria. Economic obsolescence can also include the need for locational change.
(3) *Functional obsolescence*: change in owner objectives and needs leads to possible functional change from the purpose for which a building was originally designed. Many clients of the building industry, particularly in manufacturing industries, require a building for a process that often has a short life span.
(4) *Technological obsolescence*: this occurs when the building or component is no longer technologically superior to alternatives and replacement is undertaken because of expected lower operating costs or greater efficiency.
(5) *Social obsolescence*: fashion or behavioural changes (e.g. aesthetics, religious observance) in society can lead to the need for building renovation or replacement.

(6) *Legal obsolescence*: revised safety regulations, building ordinances or environmental controls may lead to legal obsolescence.

These factors are reflected by a CII-HK report [12] that identified six issues, namely, building surveying, economics, building management, building services engineering, social science and law, as bearing directly on the sustainable repair and maintenance of ageing buildings in Hong Kong. However, it should be noted that there is some controversy over the definition of 'obsolescence' in literature (e.g. [13]), and its resolution is beyond the scope of this paper.

In addition to the above, environmental obsolescence is relevant to today's society. For the purposes of this paper, environmental issues are assumed to be within technological obsolescence, but as the marketplace becomes more environment-conscious both social and legal obsolescence will also reflect environmental actions.

For these 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.

2.2. Sinking stack theory

Atkinson [14] 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 [15]. 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' [15] 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.

In addition to the growing availability of obsolete or redundant buildings found in lower layers of the stack, a further benefit in favour of their rehabilitation is that many older buildings were soundly constructed using high quality materials, forming a suitable basis for restoration and improvement. But there are many other advantages of rehabilitating older buildings over demolition and construction of new space. These can be generally categorised as economic, environmental and social benefits. A focus on economic criteria alone will lead to sub-optimal solutions [16].

2.3. Economic benefits

Rehabilitated space can be created more quickly than new space, unless extensive structural reconstruction is required. Johnson [10] suggests that rehabilitation typically takes half to three-quarters of the time necessary to demolish and reconstruct the same floor area. The shorter development period reduces the cost of financing and the effect of inflation on construction costs, so organisations that wish not to relocate have less disruption to operations and cash flow, reducing temporary accommodation expenses.

Despite the time advantages, the cost of converting a building is generally less than new construction because many of the building elements already exist. Given there are no expensive problems to overcome, like asbestos removal or foundation subsidence, the reuse of structural elements is a significant saving. Older buildings, however, may not comply with present regulations, particularly in the area of fire safety, which may generate some structural changes or additional protective measures. It is essential that any building being considered for major refurbishment have a thorough survey undertaken to confirm its structural and constructional quality, and its compliance with building ordinances.

2.4. Environmental benefits

Environmental benefits from rehabilitation arise through the recycling of materials, reuse of structural elements and the reduction in generated landfill waste. These translate into cost advantages to the owner, but have much wider environmental implications. Older buildings sometimes were constructed using a range of quality materials that typically display a useful life well in excess of their more modern counterparts (e.g. use of solid stone walls, slated roofs, marble floors, etc.).

Furthermore, many older buildings employ massive construction in their external envelope, which can reduce energy consumption in heating and cooling and deliver long-term operational efficiencies. Opening windows, natural ventilation and natural lighting are all desirable qualities where external noise and pollution are not issues. Low-rise structures also eliminate the need for expensive vertical transportation systems.

The reuse of existing public infrastructure, like telecommunications, water, gas, sewerage and drainage, can relieve demands on local authorities to extend infrastructure and to reclaim natural landscapes for sprawling urban development.

2.5. Social benefits

Older buildings sometimes provide social benefits such as intrinsic heritage values. They can retain attractive streetscapes, add character, and provide status and image to an organisation through the use of massive and highly crafted materials. Older buildings are often in advantageous locations in city centres and close to transport making reuse (where appropriate) more viable. They add to a sense of community and are often appreciated as comfortable working environments by occupants. Reduction in vacant or derelict buildings potentially adds vibrancy to communities, reduces crime and other unsocial behaviour, and raises living standards through added investment and revitalisation.

However, issues of legislative compliance, fire safety, disabled access and heritage constraints (such as a requirement for facade retention) are possible disadvantages that should be properly explored.

2.6. Adaptive reuse

Adaptive reuse is a special form of refurbishment that poses quite difficult challenges for designers. Changing the class (functional classification) of a building will introduce new regulatory conditions and perhaps require 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 revitalizing them. In Hong Kong, the Urban Renewal Authority plays an important role in overseeing such projects (http://www.ura.org.hk).

Adaptive reuse has been successfully applied in many types of facilities, including defence estates (e.g. [17,18]), airfields (e.g. [19]), government buildings (e.g. [20]), industrial buildings (e.g. [7,21,22]), offices [23–25], schools [26] and religious buildings [27,28]. Around the world, adaptive reuse of historic buildings is seen as fundamental to sound government policy and sustainable development—e.g. in Atlanta, US [29], Canada [30], Hong Kong [31], North Africa [32] and Australia [33–35].

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.

Newman [29] discussed various political issues relating to historic building reuse, noting that preservation in many cases was predicated on reuse, finding a balance between the interests of developers, property owners and preservation advocates. Stakeholder involvement is critical. Ball [7] found that persistently vacant buildings are less able to be reused than newly vacated premises. So timeliness in some cases may be an important characteristic in identifying adaptive reuse potential (ARP).

In making decisions about whether to reuse a building or to demolish and rebuild, the energy and waste disposal costs of new action usually do not include all the environmental and social costs [36]. Unmasking these costs can provide strong incentives for a transition to more sustainable energy use, less profligate use of new materials, and greater use of existing building stock. Refurbishment is also a greater employment generator than new construction. According to Tully [37], refurbishment generates 25% more employment than new building construction per square metre of floor space as a result of the typical labour-intensive activities involved in renovation.

Furthermore, Henehan and Woodson [38] discussed which buildings could be reused and suggested how design professionals can use their understanding of redevelopment analysis and renovation to offer a greater and more valuable service to their clients. Kincaid [39] looked at the impact of information technology and sustainability, and how existing buildings can be adapted. In doing so, he considers the direction that policy should take in order to support the development of greater sustainability of cities. Fournier and Zimnicki [40] formulated specific guidelines to help planners integrate concepts of sustainability into the adaptive reuse of historic buildings in a way that will enhance the built environment while preserving the nation's cultural endowment.

Interestingly, in regard to this research, Shipley et al. [41] formulated the characteristics of a successful renovation or adaptive reuse project in terms of factors such as building type, architectural and marketing approach, financing and the regulatory environment.

3. Significance and innovation

The outcomes of this research are valuable to industry globally in their strive to implement ecologically sustainable development more rigorously by facilitating the identification and justification of buildings suitable for adaptive reuse before they fall into disrepair or are demolished. They are particularly valuable in the context of Hong Kong due to the density of its urban environment and a propensity to demolish and rebuild. The balance between project feasibility, environmental impact and social benefit is possible to be objectively evaluated in the light of project-specific constraints and stakeholder interest. Projects with high potential for adaptive reuse can be ranked accordingly.

The significance of this research is in developing the initial evaluation tool for estimating the useful life of buildings based on obsolescence criteria. Once useful life is reliably determined, it can be compared with both the building's current age and its estimated maximum physical life to determine the potential for adaptive reuse. Buildings that have a large time period between useful and physical life would be favoured, while those with a small time period between current age and physical life would not. Where useful life is close to current building age, the decision to look at adaptive reuse options should be imminent. By identifying buildings suitable for adaptive reuse, and ranking them according to their real potential to communities, this research helps facilities managers to target their resources better and make more substantial contributions to Hong Kong's net worth.

The innovation of this research lies with its practical application, so that in the future, instead of society being faced with countless options to evaluate, actions can be more targeted and the outcomes more effective. It is clever because it uses a tested multi-criteria methodology to 'sift' through the existing building stock within an organisation's portfolio and identify buildings that have high residual value (physical life less current age) and relative low useful life, and where the timing is appropriate, to flag these properties for possible adaptive reuse. Designers could then focus their time on those projects with the greatest potential value-add.

Two research outcomes are clear. Improvement in adaptation of existing buildings leads to more efficient use of domestic resources and less demand on our environment, as well as elevating the performance of buildings in lower strata of the built environment 'stack'. Furthermore, national heritage is conserved through reusing buildings that have outlived their original purpose yet are still making significant contributions to our urban landscape.

The outcomes of the research make a significant contribution to knowledge, as there is a substantial gap in literature on this topic. This applies especially to the problem of building environmental assessment, critical to this research as the fundamental environmental benefit from reusing buildings is the saving of the energy and water embodied in the equivalent new materials that would otherwise be required for a completely new building.

4. Adaptive reuse potential (ARP) model

The conceptual framework of an approach to identify and rank ARP for existing buildings is described in this paper. It has generic application to all countries, although it is discussed here specifically in relation to Hong Kong. The model requires an estimate of the expected physical life of the building and the current age of the building, both reported in years. It also requires an assessment of physical, economic, functional, technological, social and legal obsolescence. Obsolescence is advanced as a suitable method to reduce expected physical life in order to calculate objectively the useful life of the building. An algorithm is proposed that takes this information and produces an index of reuse potential 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. Where the current building age is close to and less than the useful life, the model identifies that planning should commence.

Physical obsolescence can be measured by an examination of maintenance policy and performance. Useful life is effectively reduced if building elements are not properly maintained. A scale is developed such that buildings with a high maintenance budget receive a 0% reduction, while buildings with a low maintenance budget receive a 20% reduction. Interim scores are also possible, with normal maintenance intensity receiving a 10% reduction.

Economic obsolescence can be measured by the location of a building to a city centre or central business district. Useful life is effectively reduced if a building is located in a relatively low populated area. A scale is developed such that buildings sited in an area of high population density receive a 0% reduction, while buildings sited in an area of low population density receive a 20% reduction. Interim scores are also possible, with average population density receiving a 10% reduction.

Functional obsolescence can be measured by determining the extent of flexibility embedded in a building's design. Useful life is effectively reduced if building layouts are inflexible to change. A scale is developed such that buildings with a low churn cost receive a 0% reduction, while buildings with a high churn cost receive a 20% reduction. Interim scores are also possible, with typical churn costs receiving a 10% reduction.

Technological obsolescence can be measured by the building's use of operational energy. Useful life is effectively reduced if a building is reliant on high levels of energy in order to provide occupant comfort. A scale is developed such that buildings with low energy demand receive a 0% reduction, while buildings with intense energy demand receive a 20% reduction. Interim scores are also possible, with conventional operating energy performance receiving a 10% reduction.

Social obsolescence can be measured by the relationship between building function and the marketplace. Useful life is effectively reduced if building feasibility is based on external income. A scale is developed such that buildings with fully owned and occupied space receive a 0% reduction, while buildings with fully rented space receive a 20% reduction. Interim scores are also possible, with balanced rent and ownership receiving a 10% reduction.

Legal obsolescence can be measured by the quality of the original design. Useful life is effectively reduced if buildings are designed and constructed to a low standard. A scale is developed such that buildings of high quality receive a 0% reduction, while buildings of low quality receive a 20% reduction. Interim scores are also possible, with average quality receiving a 10% reduction.

Useful life is determined from Eq. (1). The form of the equation applies the notion that useful life is indeed discounted physical life, and uses the long-established method of discount as its basis, where the 'discount rate' is taken as the sum of the obsolescence factors per annum (i.e. factors are divided by L_p).

$$\text{Useful life}\,(L_u) = \frac{L_p}{\left(1+\sum_{i=1}^{6} O_i\right)^{L_p}}, \tag{1}$$

where L_p denotes physical life (years); O_1, physical obsolescence (% as decimal p.a.); O_2, economic obsolescence (% as decimal p.a.); O_3, functional obsolescence (% as decimal p.a.); O_4, technical obsolescence (% as decimal p.a.); O_5, social obsolescence (% as decimal p.a.) and O_6 denotes legal obsolescence (% as decimal p.a.).

Using this approach, a building receiving the maximum reduction for each type of obsolescence will have a useful life calculated at about one-third of its physical life.

An index is calculated that prioritises buildings according to their potential for adaptive reuse, and expresses this potential as a percentage. Buildings with a high index possess the highest potential, while buildings with a zero index have no potential. The algorithm is summarised in Fig. 1.

Values for EL_u (effective useful life), EL_b (effective building age) and EL_p (effective physical life) are, respectively, determined by multiplying L_u, L_b and L_p by 100 and dividing by L_p, which enables a maximum scale for x and y axes of 100. L_b is defined as the current age of the building (in years).

The feasible zone for the ARP is defined by the shaded area under the curve (where x is in the range 0–100) as defined by Eq. (2), and takes the form of a negative exponential.

$$y = 100 - \frac{x^2}{100}. \tag{2}$$

The line of increasing ARP and the line of decreasing ARP are given by Eq. (3) and (4), respectively.

$$\text{ARP}_{(\text{increasing})} = 100 - \frac{(\text{EL}_u^2/100)}{\text{EL}_u} \times \text{EL}_b, \tag{3}$$

$$\text{ARP}_{(\text{decreasing})} = 100 - \frac{(\text{EL}_u^2/100)}{100-\text{EL}_u} \times (100-\text{EL}_b), \tag{4}$$

where EL_u stands for effective useful life (years) EL_b for effective building age (years).

Values of ARP above 50 are considered to have high potential for adaptive reuse, while values in the range 20–49 show moderate potential, and values in the range 1–19 show low potential. An ARP value of zero has no potential. When EL_u and EL_b are equal, the maximum ARP value possible for that stage of the building's life cycle is generated. Values above 85 would suggest strongly that planning activities should commence.

5. Discussion

The ARP model provides a reasonable straightforward method for accessing effective useful life and ARP in existing buildings. While different frameworks and algorithms can be invented to address this matter, the one

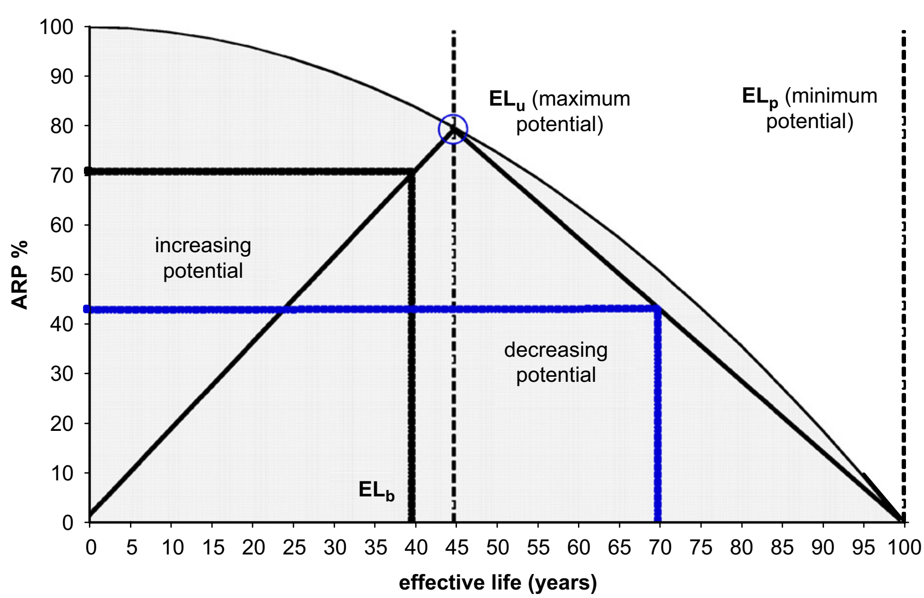

Fig. 1. ARP model concept.

proposed in this paper produces results that are considered reasonable and reflective of practice. It provides a range of values within known limits that enable rankings and prioritisation to be determined. It recognises that potential declines as building age approaches its effective physical life, and that the feasible zone should follow a negative exponential curve.

By way of example, assume a project of 200 years physical life (L_p) and a current building age (L_b) of 80 years. Obsolescence ($O_1 \ldots O_6$) is assessed at 15%, 5%, 15%, 15%, 20% and 10%, respectively. The combined 'discount' factor per annum is calculated at 0.004 and the useful life (L_u) is calculated at 90 years (Eq. (1)). In other words, the project has 10 years of useful life remaining. EL_u is determined at 45 years and the maximum ARP possible for this project is 79.75% (Eq. (2)). EL_b is determined at 40 years, and as $EL_b < EL_u$, Eq. (3) is used to arrive at an ARP of 70.89%. ARP is high and increasing. But if the current building age (L_b) is 140 years, useful life (L_u) remains at 90 years. As $EL_b > EL_u$, Eq. (4) is used to arrive at an ARP of 43.50%. ARP is moderate and decreasing. These results are summarised in Fig. 1 earlier.

The question remains, however, about what to do with the rankings. Theoretically, the rankings indicate buildings that have a high potential for adaptive reuse, based largely on the embedded physical life that remains after the original useful life has expired. This potential is influenced to some extent by the current age of the building. Tiesdell et al. [42] indicated in some detail why decisions about reuse must take account of economic, environmental and social benefits if appropriate interpretation of a building's contribution is to be realised. A focus on monetary issues alone will lead to bias in decision-making.

The identification of value for money on development projects is indeed commonly related to monetary return. But other issues are also relevant, particularly for social infrastructure projects, and some are becoming increasingly significant. For example, issues such as functionality and resource efficiency are vital to the assessment of sustainable development in the wider social context. Since no single criterion can adequately address all the issues involved in complex decisions of this type, a multi-criteria approach to decision making offers considerable advantage.

Social costs and benefits (including those related to environment impact and heritage) need to be integrated into the evaluation and a strategy developed that gives these factors proper consideration in practice. Social costs and benefits should not be discounted alongside conventional cash flows as they bear little relationship to financial matters and do not reduce in importance exponentially over time. In fact, future generations may value environmental issues more highly than the present generation [43].

Alternatives have been developed to replace cost–benefit analysis completely with other techniques that do not require environmental or social costs and benefits to be monetarised. Cost effectiveness analysis and environmental impact assessment are leading solutions in this respect. Others have suggested supplementing cost–benefit analysis with a technique that can measure environmental costs in different ways [44–47].

When evaluating projects and facilities it is important to take a holistic view. John Elkington proposed the triple bottom line concept in 1997 (cited in Ref. [48]). This approach demands consideration of financial, social and environmental parameters (known as the 3Ps of profit, people and places). It is an approach that has received widespread international recognition and adoption [9,49–51]. Some people advocate a fourth parameter (ethics) to deal with issues of intergenerational equity. Such methodologies are examples of multi-criteria decision analysis.

Several methodologies and algorithms have been developed to provide decision makers with advice about selection, but they are either complicated or expensive to use [52,53], or narrowly focused [54]. Moreover, in the traditional decision-making process, weighting each criterion is a very difficult process and depends heavily on the personal preference of the decision maker. Various criteria can be measured using an appropriately matched methodology and assembled into a single decision model.

SINDEX is a recent software tool that uses multiple criteria to calculate a sustainability index, and has the potential to completely replace conventional net present value methodologies for ranking and selecting projects. Based on an extensive literature review, industry survey and testing in the field [55], key objectives were narrowed down and grouped into four criteria and identified as maximising wealth (investment return), maximising utility (functional performance), minimising resources (energy usage) and minimising impact (loss of habitat).

Wealth is measured as a benefit–cost ratio and includes all aspects of life cycle cost (e.g. maintenance, durability, future replacement). A weighted evaluation matrix (criteria and performance) is used to measure utility in a quantitative manner. Energy usage (including both embodied and operating energy) is measured as annualised GJ or GJ/m^2. Assessment scorecards (questionnaires) are used to quantify loss of habitat (both environmental and cultural) and can be expressed as a risk probability factor. When all four criteria are combined, an indexing algorithm (formula) is created that rank projects and facilities on their contribution to sustainable development. The algorithm is termed the 'sustainability index' [4]. Each criterion is measured in different units and later normalised and combined. Criteria will be left as equally weighted. Fig. 2 illustrates the main summary page and shows the calculation of the sustainability index for a recent test project [56].

The application of SINDEX as a means of interpreting the ARP rankings into solutions for existing buildings in Hong Kong that show ARP is explored briefly in relation to a real case study.

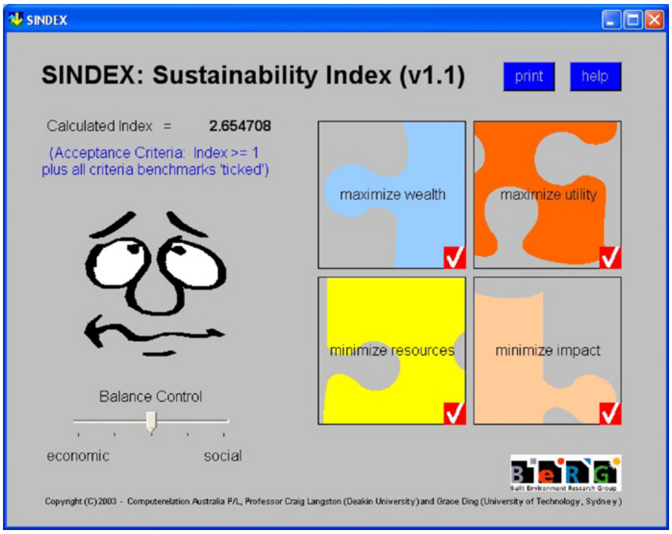

Fig. 2. SINDEX main screen.

Fig. 3. Western Market building.

6. Case study: Western Market[1]

The Western Market building is located at 323 Des Voeux Road, Sheung Wan, on the island of Hong Kong. It was built originally as a two-storey market in an Edwardian style. It is the oldest surviving example of a market building in Hong Kong. This style of building was very popular in England in the early part of the 20th century. Now it is reflective of another time, surrounded by high-rise office towers, overhead pedestrian walkways and freeways, and a busy city transport terminus.

The Sheung Wan Market consisted originally of two separate blocks. The south block at Queen's Road was built in 1858 and demolished in 1980. The remaining north block, smaller and more compact in design, was built in 1906 (see Fig. 3). When the former Urban Council's market facilities came into operation in 1989, the market building became vacant. It became a 'declared monument' of the Antiquities and Monuments Office (AMO) in 1990.

The Urban Renewal Authority (URA), formerly the Land Development Corporation, converted the market into a centre of traditional traders, arts and crafts in 1991 and renamed it as 'the Western Market'. Refurbishment took place again in 2003. Adopting the concept of adaptive-reuse, the building now accommodates a theme restaurant and boutique shops, creating a precinct of lifestyle shopping and leisure activities.

For the purposes of this case study, the date for the investigation is assumed retrospectively as 2003 when the last renovations were completed. The current building age is therefore 97 years. The physical life is conservatively estimated at 150 years. The useful life of the building is determined by 'discounting' the physical life by expected obsolescence, comprising physical, economic, functional, technological, social and legal criteria.

For the Western Market, maintenance was minimal for most of its life, so a score of 20% has been chosen to represent its physical obsolescence. Western Market would logically receive a 0% reduction for economic obsolescence as it sits in the heart of the Hong Kong central district. The building being of largely open design would attract a low churn cost for alterations, and so a reduction of 5% has been assumed for functional obsolescence. No actual data on churn costs exists for this building. The building is air-conditioned, but its massive external walls provide good thermal comfort performance and external heat gain is minimal. A value of 5% for technological obsolescence has been selected. Western Market relies on rental income from retailers. Even in its former glory, the building was a trading venue. A 20% reduction is therefore taken for social obsolescence. Finally, there is no doubt that the Western Market is solidly built and of a high standard back in 1906, and still today. A 0% reduction is applicable for legal obsolescence.

Using this data in the ARP model, useful life (L_u) is calculated as 91 years (Eq. (1)) and its ARP is 56.8% (high, and decreasing) as determined by Eq. (4) ($EL_b > EL_u$). According to the model, the Western Market's optimal potential for adaptive reuse was reached in 1997. This is somewhat arbitrary given the chosen value for L_p is conservative, but even at 200 years of physical life, the assessed ARP score is still high at 50.5%. For modern buildings, it would be typical to select a physical life less than 100 years. The maximum ARP score possible for Western Market is 63.1% (using Eq. (2), where $x = EL_u = 61$ years). While undoubtedly other projects in Hong Kong could be found to exceed this score, the timing for this project and its heritage value were clearly compelling.

[1] Case study information was obtained primarily from the Urban Renewal Authority (http://www.ura.org.hk) and Western Market (http://www.westernmarket.com.hk) websites.

In the Hong Kong context, given very high land values in the central district, the best decision from a purely financial perspective would be to demolish the Western Market and construct a high-rise tower. Fortunately, such action is not available given the 'declared monument' designation in 1990. So the remaining options were restricted to original or alternative uses for the current building form.

The next best economic option is retail/tourism. Other uses, such as boutique office space, accommodation or museum would not deliver the same cash-flow levels. Yet, all these alternative uses would provide strong social and environmental performance. While use as a public market is not longer relevant, the building can be retained for other retail/tourism activities such as arts and crafts and restaurants as ultimately selected. The careful addition of floor space adds to its economic performance without any significant disadvantage. Therefore, the actual adaptive reuse chosen appears credible.

Using SINDEX, the four criteria described earlier are assessed. The sustainability index for Western Market is 2.65, based on a balanced combination of all criteria. As this score is in excess of 1 and all criteria benchmarks are achieved, the project as actually pursued appears a wise decision. Its strength is in its economic contribution, heightened by the opportunity for additional floor space. The sustainability index rises to 3.17 when the decision is based solely on economic criteria, and falls to 2.14 when the decision is based solely on social criteria. A sustainability index about 3 is a good result (scores above 5 are rare).

The brief case study of the decision-making process for the adaptive reuse of the Western Market building in Hong Kong validates the processes that actually took place. This does not, of itself, validate the approach described in this paper, but does provide some evidence for its relevance to practice. It also demonstrates that such an approach is appropriate for use by practitioners without the need for highly specialised skills.

A sensitivity analysis of the results shows that they are not easily influenced by different assumptions. The main benefits of Western Market lie in its low embodied energy (resulting from the reuse of materials already in place) and its relatively high community values. Nothing special was evident in terms of environmental performance, and the score could have been further improved if this was more of a priority.

Western Market is considered to have around 50 years more of physical life remaining. Whether it remains a financially viable enterprise remains to be seen. Should circumstances change that make its current use redundant, further ARP may still exist.

Interestingly, if the building's physical life were reset following the revitalisation at 50 years, the ARP model would indicate another 30 years of useful life ahead. This must give additional confidence to the actions taken to preserve the building for the people of Hong Kong.

7. Conclusion

A valuable component in the holistic assessment of the contribution individual buildings can make to the communities in which they are sited is their potential for reuse once their original useful life has concluded. Providing a means for calculating this potential is important. A conceptual framework for how this potential can be quantified is one of the aims of this paper. Use of multi-criteria assessment tools like SINDEX enables the full effects of buildings to be properly considered over their entire life cycle rather than their immediate period of ownership or function. In time, such an approach will ensure that buildings with significant remaining capacity to serve our society will be retained and given a new breath of life. In this way, and only in this way, can we ever hope to achieve even a modest level of sustainability in the built environment.

This research assists in enhancing Hong Kong's ability for sustainable, responsive energy and natural resource management by allowing issues regarding excessive and inappropriate resource use to be identified and assessed, and enabling appropriate management strategies to be implemented. The outcomes of this project provide advancement in knowledge regarding the environmental impacts of construction, materials and related systems, particularly those impacts associated with the resources embodied in buildings and resultant greenhouse gas emissions.

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