SUSTAINABLE RETROFIT POTENTIAL IN LOWER QUALITY OFFICE STOCK IN THE CENTRAL BUSINESS DISTRICT

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ABSTRACT

Given the relationship between energy consumption, greenhouse gas emissions and climate change, the built environment has significant potential to lessen overall emissions. With around half of all greenhouse gas emissions attributed to the built environment; it has a significant role to play in mitigating global warming. With large percentages of office stock structurally vacant in some city centres and only 1 or 2% of new buildings added to the total stock each year; the scope for reductions lay with adaptation of existing buildings. The stock with the highest levels of vacancy and obsolescence offers the highest potential of all.

Many cities are now aiming to become carbon neutral. Successful retrofit demands that social, technological, environmental, economic and legislative criteria are addressed. Buildings have to meet user and community needs. City centres comprise a range of different type of office stock with regards to age, size, location, height, tenure and quality. All buildings present challenges and opportunities with regards to retrofit and sustainability and integrating retrofit measures that reduce energy, water and resource consumption.

Using a selection of low grade office buildings to develop retrofit profiles, this paper addresses the questions; (a) what is the nature of retrofits in relation to low quality office building stock in the Central Business District (CBD) and, (b) what is the extent and scope for sustainable retrofits to low quality office buildings. Using Melbourne CBD retrofit events of low quality office buildings were analysed between 1998 and 2008 to identify the scope and extent for integrating sustainability into retrofits projects.

Keywords: office buildings, sustainability, refurbishment, building adaptation, Australia

Introduction

Building owners increasingly look to retrofit existing stock as a means of delivering sustainability in the built environment. Akin to many developed countries, Australia needs to increase the retrofit of existing office stock to reduce building related greenhouse gas emissions (Garnaut, 2007). This is recognised by the City of Melbourne who aim to bring about a carbon neutral city by 2020 with a goal of 1,200 building retrofits to deliver greenhouse gas reductions through sustainability measures (AECOM, 2008). Clearly not all buildings are the same, for example there is a great variance in building quality and some properties may experience greater levels of retrofit and greater frequency of adaptation (Wilkinson & Remøy 2011). The questions this paper addresses are: *(a) what is the nature of retrofits in relation to low quality office building stock in the CBD and, (b) what is the extent and scope for sustainable retrofits to low quality office buildings.*

Defining Retrofit

The definition of retrofit is derived from Douglas's (2006) definition of adaptation as: "*any work to a building over and above maintenance to change its capacity, function or performance' in other words, 'any intervention to adjust, reuse, or upgrade a building to suit new conditions or requirements*"; it is a broad definition. Retrofit can occur to a whole building or to part of a building; for example, to one or more floors of high rise buildings. The definition encompasses within use and across use retrofits. The term 'retrofit event' includes all activity related to individual building permits on existing buildings. In the case of tenanted buildings, events can be referred to as alterations and extensions, upgrade, change of use and renovation; as such multi-tenanted buildings will experience multiple events in the one building. High rise buildings experience a greater number of retrofit events, though the value of scope of those events may be smaller. There are a plethora of terms used to cover retrofit such as adaptation, refurbishment, upgrade, conversion, renovation – all of which often exist in a 'state of happy confusion' (Markus 1979, Mansfield 2002). This paper examines the lower quality office buildings, the need to retrofit existing stock and the scope for enhancing sustainability through retrofit. One reason buildings are retrofitted is to meet tenant and owner requirements and low grade office buildings particularly need to adapt to changing preferences if they are to compete with newer sustainable buildings.

Building quality and office stock in the Melbourne market

Office stock comprises a wide range of different attributes such as size, age, space plan, configuration and physical condition which are taken as measures of quality. Office buildings are classified in the Australian market using the Property Council of Australia building quality matrix. The matrix uses different measures such as size of floor plate, number and speed of lifts; environmental rating under Green Star and or NABERS, quality of the entrance foyer and so on to determine the level a building is rated at. Buildings are rated from Premium, the best quality, sequentially through A, B, C and D. The lowest levels of building quality measured in the matrix are C and D grade. 'Premium' office buildings typically attract the highest rental levels with the highest capital values. However many office buildings do not have the Property Council of Australia rating and such buildings are likely to be owned by private individuals and do not form part of property investment portfolios. Initial analysis of retrofit activity in Melbourne CBD showed that action is largely focussed on the superior quality offices and that the C and D grade stock has the least activity (Wilkinson & Remøy, 2011). Given that C and D grade office buildings typically have the lowest levels of building quality, equipment and amenity there is a great scope for stakeholders to implement sustainability improvements The Melbourne CBD office market contains 3,608,258 square metres of lettable space, of this, 55.6% is Premium and A Grade quality, with 26.4% of Grade B quality with the remaining 18% being Grade C and Grade D (Savills, 2010). The situation is that a significant minority of offices is lower grade and less likely to undergo retrofit than its contemporary higher grade offices.

Sustainable retrofit measures

Sustainability is defined in the context of the triple bottom line where three components of economic, environmental and social sustainability are perceived as equally important. With buildings the emphasis is placed often on the environmental sustainability of the structure and fabric and the operational phase of occupation, with thought also to deconstruction and recycling opportunities at the end of the building lifecycle. Langston (2010) noted building

retrofit can deliver economic, environmental and social benefits to society, which should be at the forefront of thinking about existing stock.

The key environmental sustainability measures that can be considered in the retrofit of office buildings are energy efficiency, water efficiency, the reduction of waste, recycling and waste management, specification of low environmental impact materials and effective building operation and facility management (GBCA, 2010). Energy efficiency and reductions in building related greenhouse gas emissions may be improved by using high efficiency luminaires, high frequency ballasts and energy efficient lighting controls and purchasing 'green power' (Arup, 2008). Tenancy sub-metering enables the improved management of energy use. Depending on the individual building substantial improvements can be made with minimal costs through a housekeeping review, energy purchase, improved maintenance and re-commissioning building's services (Arup, 2008). Furthermore reusing existing buildings allows owners to capture the embodied energy already invested in the existing structure and fabric of the building, rather than commit new resources.

Water economy measures include installation of waterless urinals and 3/6 litre dual flush toilets, water efficient fixtures and water tanks to collect rainwater to flush toilets (GBCA, 2010). Such measures can reduce the environmental impact of buildings and are recognised by their inclusion in the environmental assessment tools used to evaluate the sustainability achieved in green buildings such as Building Research Establishment Environmental Assessment Method and the World Green Building Council's Green Star (Langston, 2010).

Other sustainability measures that may be adopted include reusing timber and using timber from renewable certified sources. Furthermore using carpets, paints, sealants, glues and adhesives with low Volatile Organic Compounds incorporates sustainable materials into buildings (GBCA, 2010). The provision of bicycle storage and shower facilities promotes the adoption of more environmentally friendly transportation. Clearly there are a range of measures which may be adopted and the list above is not exhaustive, however each building has to be assessed on its merits to identify specifically those parts which may be retrofitted with sustainability measures.

Social sustainability is a broader concept and relates to society, the community and /or individual people. The social sustainability of the building is considered by stakeholders and within environmental assessment tools. An illustration of social sustainability is the notion that sustainable buildings are healthier for users due to the specification of materials that do not contain chemicals detrimental to human health (Clements-Croome, 2006). Another example of social sustainability is building aesthetics where buildings having pleasing aesthetic qualities enhance surrounding areas and the environment in which they are sited (Ohemeng 1996, Zunde 1989).

A powerful argument for economic sustainability is the view that sustainable buildings are healthier buildings which result in less employee absenteeism due to sickness and higher productivity thus increasing the overall profitability of business occupiers (Clements-Croome, 2006). Given that typically businesses attribute about 85% of all costs to staffing; it is a powerful case. Lower operating costs within sustainable buildings are a further driver and potent reason for implementing sustainability, given increasing energy costs. It is evident that there is a close and often overlapping relationship between the three components of the triple bottom line.

Whilst it is possible, with a well planned retrofit, to increase the office quality grade and simultaneously increase the rental and capital value of the building; previous studies concluded that this is largely dependent on the condition and location of the building (Boyd et al 1993, Sinclair, Isaacs *(in Baird et al)* 1996, Swallow 1997, Snyder 2005, Kersting 2006). With regards to sustainability improvements, one UK study showed that post retrofit office buildings typically had lower running and operating costs than prior to the retrofit even if the retrofit did not have sustainability as a priority (Kincaid, 2002). Kincaid (2002) confirmed Wilkinson's global study of thermal improvements in office refurbishments (Wilkinson, 1997). The lower running costs accrue as a benefit of technological advances in building services since the original installation was provided. This reduction in running costs is a positive economic outcome for the party which pays for the operating costs, which can contribute to higher rental levels or higher capital values (Kincaid, 2002). Lower running costs result in less greenhouse gas emissions thereby reducing the overall environmental impact of the building. The potential for integrating a broad range of economic, environmental and social sustainability measures are explored in the context of the type and extent of retrofits that have been undertaken to C and D grade buildings from 1998 to 2008 in the Melbourne CBD.

Building attributes in retrofit

Earlier work identified attributes which are important or affect retrofit (Kincaid 2002, Snyder 2005). For a fuller discussion on building retrofit and building attributes readers are referred to Wilkinson et al (2009). This paper focuses on selected important attributes in the context of C and D grade buildings, sustainability and retrofit; the number of retrofits overall, trends over time, age, location, building quality, aesthetics, plan shape and operating and energy costs. Some of these attributes are associated with sustainability such as building quality as defined by the Property Council of Australia and described above. Premium grade offices typically have the best quality services for example the fastest lifts and air conditioning which results in high operating costs per metre squared and consequently high greenhouse gas emissions. However it is also true to say that lower grade offices with older services installations can have higher running costs on a per metre squared basis (PCA, 2008). Aesthetic qualities are a measure of social sustainability in the context of this research.

Age has an important affect on retrofit; as buildings age they wear out and need components repaired or replaced (Douglas, 2006). Barras & Clark (1996) and Baum (1991) argued the correlation between time and building obsolescence, establishing that as time passes retrofit of some form is necessary to avert a decline which otherwise leads to demolition. Previous studies considered location and its affect on retrofit as important; with some properties sited in favourable locations which enhances the frequency and likelihood of retrofit (Kincaid, 2002; Douglas, 2006; Highfield, 2000). Building location within a geographical area can be interpreted into zones, in Melbourne the CBD has five zones from Prime, Low Prime, High Secondary, Low Secondary to Fringe. The best location is Prime where the highest rental and capital values are found and there is a view that buildings in better locations are likely to undergo more retrofit (Swallow 1997, Ball 2002). Building quality is measured in various ways, it can be either provision of a greater number of amenity features, attributes and, or a higher standard of services, features, fixtures and fittings.

Ohemeng (1996) found that aesthetics was an important attribute in determining whether or not a building was adapted in his UK study of 400 building owners. Plan shape was an important attribute in retrofit and that some plan shapes such as deep plan shapes were easier

to adapt than others such as irregular shaped ones (Kincaid, 2002; Povall & Eley *in Markus*, 1979). Building height or the number of storeys in a building was found to effect retrofit in studies conducted by Povall & Eley (in Markus 1979) and Gann & Barlow (1996).

Research Approach

A database of office buildings was compiled to appreciate the nature of retrofit and the extent and scope for sustainable retrofit using multiple sources such as the commercial database Cityscope, and public databases such as PRISM (Victorian Government) and the Heritage database. In addition data from the Property Council of Australia, Google Earth and Google Streetview (www.google.com.au/maps) was used to gather building related data (PCA 2007). Information relating to retrofit events was derived from the records for building permit applications. Visual inspections and photographic records of CBD office buildings were carried out. The database contains records for 13222 retrofit events to commercial buildings from 1998 to 2008 and allows the researcher to provide an overview of what has happened on a CBD scale with retrofits to commercial C and D grade buildings.

Given the objectives; to understand the nature of retrofits to C and D grade office stock and the extent and scope for sustainable retrofit to C and D grade office buildings this stock only was extracted for analysis. The criteria used to examine the scope and the potential for sustainability in the retrofit were number of adaptations, location, building quality, aesthetics, plan shape and costs in use. As this study determines the nature of and the scope and extent for adopting sustainability in retrofits within the Melbourne CBD, details on the individual characteristics of the buildings is not examined or discussed. The results are a uni-variate and a bi-variate analysis of the data. The answer to the first question; *what is the nature of retrofits in relation to low quality office building stock in the CBD,* is given on the basis of a quantitative statistical analysis derived from the database and reflects the empirical reality. The answer to the second question is derived from the literature outlining different types of sustainable retrofit measures and their impact on building performance.

**Figure 1 CLUE block and region map Melbourne**
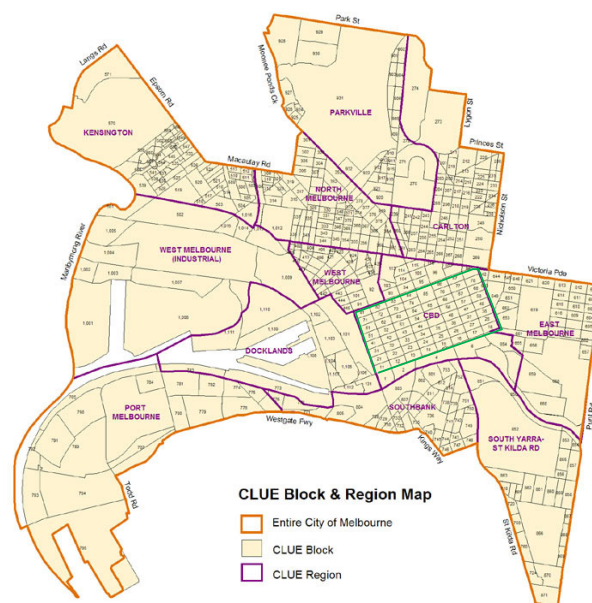
The research investigated activity in a developed, mature commercial market; the Melbourne CBD which was first set out in 1834 and has been continuously occupied. It is the most mature property market in Victoria with a diverse range of stock. The streets bounding the CBD area are as Flinders Street, Spencer Street, Spring Street and La Trobe Street highlighted in green in figure 1.

Results and discussion

All retrofit events to C and D grade buildings were analysed to ascertain the level of retrofits undertaken. A total of 978 retrofit events occurred to 197 C and D grade buildings from 1998 to 2008. Minor retrofits accounted for 5.8% of works, alterations 16.8%, change of use retrofit 0.8%, alterations and extensions adaptations, the most extensive level 72.8% and new build and demolition work accounted for 4.5% of works. This pattern maps closely figures for retrofits to all building grades. The most frequent level of work undertaken was 'alterations and extensions' retrofits which indicates a high level of confidence in the market to recoup the costs involved in the construction works, as well as the loss of income during the works in order to achieve higher rental levels post retrofit. It is indicative of the prevailing median age of 31 years of the building stock during the time period which means that buildings are at an age where retrofits are required to bring them up to market expectations (Jones Lang LaSalle 2005, Duffy in Brand 1994).

Examining the amount of all retrofits by Property Council of Australia building quality grade, Premium quality stock accounted for 12.9% of the works, with A grade at 20.7% and B grade recording the highest amount of activity at 27.3%; therefore 60.9% of the work is undertaken to the highest quality stock. Unclassified office buildings accounted for 24.2% of work, leaving work to the lowest quality stock the C and D grade stock accounting for 11.1% and 3.8% respectively. Within the Melbourne market there are lower vacancy rates for the prime quality office stock (Knight Frank, 2010) which implies that work undertaken results in higher levels of stock occupancy. Reviewing the retrofits to C and D grade stock to ascertain what level of retrofits are undertaken, more work occurs to the C grade stock overall and that alterations and extensions retrofits are most popular.

Figure 2 Retrofits to C and D grade offices and Property Council of Australia building quality grade.

Type of Adaptation
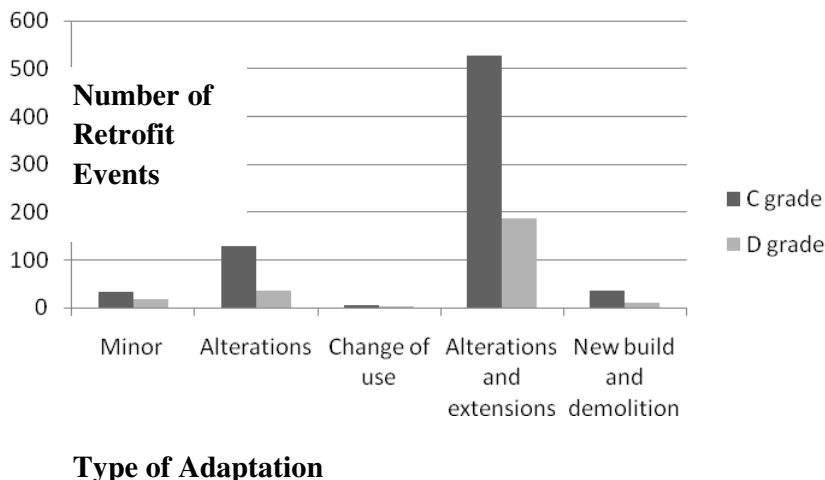
Characteristics of the stock

Overwhelmingly the C and D grade stock has an irregular plan shape (48.2%), followed by deep plan configurations at 28.4%, with 17.1% having a narrow frontage and the remaining 6.3% being of a wide frontage to the street. The buildings retrofitted were purpose built for commercial usage, with only 13.8% having undergone a change of use prior to current use.

Brick was the primary façade or envelope material for 72.7% of buildings, followed by curtain walling (9.8%) and with concrete cladding and stone at 8.6% each. Opportunities exist for making changes to openings with brickwork construction and with overcladding for brick and concrete clad buildings. Brick and stone construction has high thermal mass and are relatively effective at heat retention and resisting rapid thermal gain when temperatures increase. There is scope for overcladding externally or retrofitting internally with insulated panels to improve thermal performance. Curtain walled buildings typically have poor thermal performance on the other hand, and great opportunities exist for improving energy efficiency with this stock. Significantly when visually inspected, 92.8% of the external envelope or cladding of the stock was in good or very good condition with only minor surface imperfections noted. There is little in the physical condition to drive owners to undertake alterations externally that could provide an opportunity to improve thermal performance. Furthermore when building appearance is evaluated 65.8% of events happened to buildings classified as aesthetically pleasing, with 17.2% classed as neither 'beautiful' nor 'ugly'. This result confirms Ohemeng's (1996) study that more attractive stock is retrofitted compared to less attractive buildings. However given that 17% of retrofits were undertaken to buildings classed as 'ugly'; there is scope in around one in five C and D grade retrofits to update and improve external appearance and thermal performance.

When the location of the vertical services core is considered, 48.8% of events occurred in buildings with multiple services cores, followed by 31.6% with central locations. This implies that these buildings undergoing the highest frequency of retrofit are those which are more amenable to different configurations of space plan on individual floor levels, a finding supported by (Arge, 2005).

The C and D grade stock is predominately of single land use; that is 63.5% of events occurred to buildings classed solely as offices. However a large minority of 35.3% were office and retail land use, with the remaining 1.2% classified as office and residential land use. Ownership of mixed use properties can make retrofits to the external envelope complex particularly with residential land use. Here buildings without a mixed land use undergo more frequent levels of retrofit possibly because less negotiation is required with co-owners and other stakeholders. This has implications in future as more mixed use buildings appear in city centres; especially under planning policies encouraging mixed land use combining residential and office uses.

Where regulatory requirements are concerned, 67.7% of retrofits occurred to buildings with no listing or heritage overlays. Owners of non listed stock are more likely to undertake retrofit and municipal authorities need to consider programmes to incentivise owners of heritage stock to adapt. Having stated this, older heritage stock has high levels of embodied energy and were constructed using traditional methods and materials likely to have high thermal mass and relatively good thermal performance.

Given that as buildings age, they require retrofit (Barras & Clark 1996, Langston et al 2007), the age of buildings undergoing retrofit was examined with 20.4% of all events occurred to buildings less than 25 years of age. The largest number of events occurred to buildings aged 26 to 50 years, where 48% of events were undertaken. Buildings aged 51 to 75 years accounted for 12.6% of events, with 11.3% occurring to buildings aged 76 to 100 years and the remaining 7.7% of events occurred to buildings aged 101 to 152 years. Clearly C and D grade stock undergoes most retrofit activity during the 26 to 50 year period. It is possible that owners of this lower grade stock are inclined to wait as long as possible before paying for retrofit works as opposed to being keen to maintain a position within the market place. When the whole stock is analysed the median age for retrofit was 19 years. 15.8% of events occurred to 40 year old C and D grade stock.

Arge (2005) found that the potential for lateral and vertical extension of a building greatly enhanced it's desirability for retrofit. Not surprisingly none of the Melbourne stock had potential for lateral extension because entire sites were built out. Scope for vertical extension was based on an analysis of the structural frame type and condition of the property and 25.9% of retrofit events could support vertical extension, planning permission permitted. Depending on planning density requirements there is scope to increase net lettable floor area of CBD offices in over a quarter of retrofits to C and D grade stock, whilst retaining original structure and fabric and the associated embodied energy.

Arge (2005) noted that the degree of attachment to other buildings was important in determining the level of disruption to tenants of adjoining properties during retrofits. Most retrofits occurred to buildings attached on two sides (34.4%) closely followed by 31.9% to detached buildings. Only 15.4% of events took place to buildings which are attached on three sides and Arge's (2005) finding is supported. The authorities could consider incentivising retrofits to buildings which are enclosed by others to increase retrofit activity within this type of stock.

Access to the building was important in determining the ease of delivery of construction materials and retaining tenants in situ where necessary during retrofits (Arge 2005). No C and D grade retrofits occurred to buildings with access on all sides. Most retrofits occurred to buildings with access from the street front and side (35.2%), followed by street only access (27.3%) which contradicts Arge's (2005) findings. Fewer than one in five (19.2%) events took place to buildings which have access from street, side and the rear of the property. Finally 18.3% of events occurred to buildings having access from the street and rear of the building.

Building location is perceived as important in determining whether retrofit occurs (Swallow, 1997). Interestingly most events (25.9%) occurred in the Low Prime location which suggests that owners are conscious of the benefits of the location and strive to keep up with retrofit activity in higher quality stock (figure 3). Events in the Prime location accounted for 19.3% of all retrofits which is likely to be associated with the higher levels of activity generally in these areas. There is a distinct drop in High Secondary location activity where 14% of events occurred. However the activity rate increases in Low Secondary locations where 25.1% of retrofits took place; it is likely that these retrofits are what Chandler (1991) termed 'distress' retrofit where owners are obliged to undertake works to meet statutory requirements and to attract and retain tenants. Finally activity in the least desirable location of all, 'fringe' showed only 15.6% of events indicating that the lowest quality stock is largely unworthy of retrofit. The implication for policy makers is that incentives should target improving the stock quality

in the fringe locations where there is clear scope of improving building performance and reducing building related greenhouse gas emissions.

Figure 3 C and D grade building retrofits and location

Number of Retrofit Events
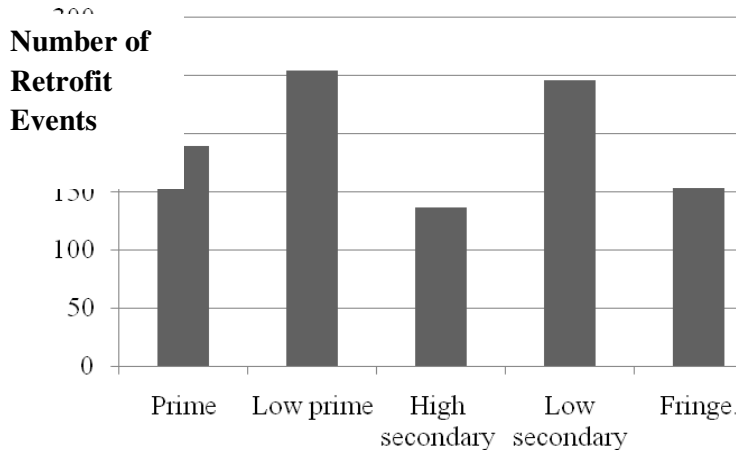
CBD Location

Another way of examining location and retrofit activity is to investigate activity by street address. In this instance, the retrofits happen primarily in two streets; Collins Street and Bourke Street. Figure 4 shows retrofits to individual buildings by street address; note that many buildings experienced multiple retrofit events from 1998 to 2008.

Figure 4 C & D Grade buildings adapted by street

Number of Buildings

Street Address
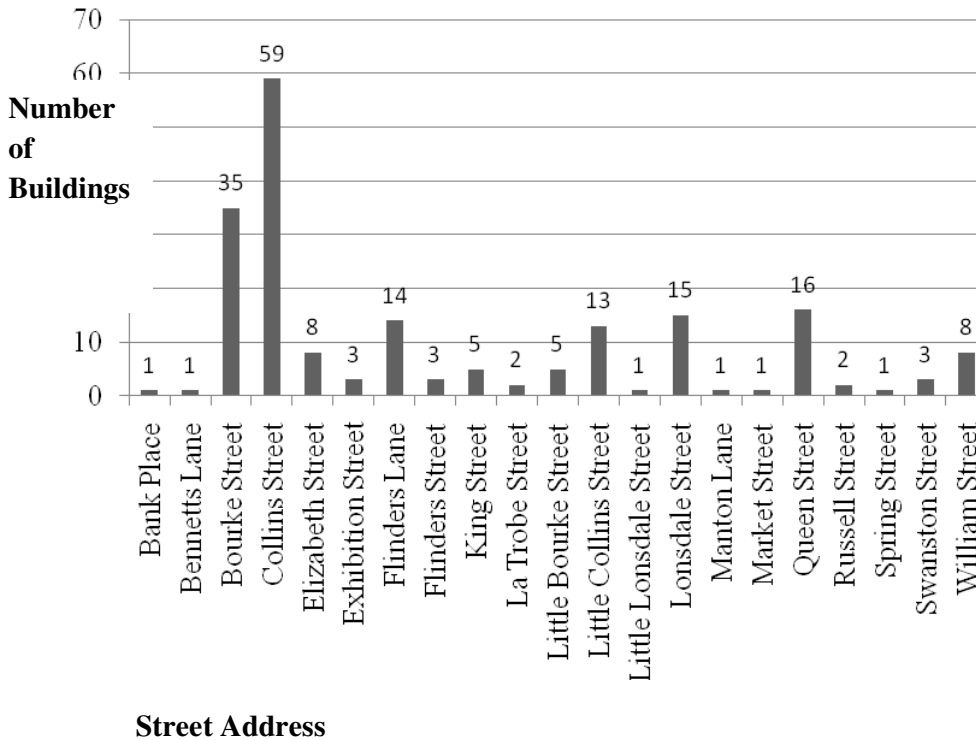
Sustainable retrofit

On the basis of Property Council of Australia building quality grade, it is possible to assess cost in use. The Property Council of Australia publishes data with regards to median gross income, and the costs of operating expenses, energy and water consumption based on grade (Property Council of Australia 2008). As expected gross income on a per metre squared basis is correlated to building quality with C grade stock grossing $274.01 per square metre compared to $395.92 per square metre for Premium and A grade stock and $300.95 per square metre for B grade stock (Property Council of Australia, 2008). No data is available for D grade buildings. The gap between income for C and B grade is narrow compared to the gap between B and A / Premium stock and possibly deters owners of C grade stock from high capital expenditure on improvements which may not lead to a substantial increase in gross income.

When operating expenses are examined no data is available for D grade stock, however C grade stock is more expensive to operate on a per metre squared basis at $73.35 per square metre compared to $62.11 per square metre for Premium and A grade and $54.17 per square metre for B grade (Property Council of Australia, 2008). Clearly there is scope to retrofit the buildings with energy efficiency measures to reduce these high operating costs. It is clear that any retrofit replacing worn out services will result in significant energy saving simply because the quality of replacement fittings far exceeds that of existing fittings (Wilkinson, 1997. Kincaid, 2002).

The costs of electricity consumption is highest in C grade stock at $25.93 per square metre, compared to $21.70 per square metre for Premium and A grade buildings and $19.72 per square metre for B grade stock. Even though the level of building services amenity, such as air conditioning and high speed lifts, is lowest in C grade stock; the cost of electricity consumption is highest. This is a result of the age, condition and efficiency of existing installations. Clearly there is an opportunity to reduce electricity consumption per metre squared to levels significantly below the higher quality stock with their intensive use of building services (Property Council of Australia, 2008). A similar picture emerges where gas consumption is considered. The costs of consumption is highest in C grade stock at $3.33 per square metre, compared to $1.29 per square metre for Premium and A grade buildings and $1.55 per square metre for B grade stock. Retrofit aimed at improving efficiencies in the existing gas installations will lead to lower levels and costs of consumption. Where water consumption is concerned a similar situation exists. C Grade stock has the highest costs associated with consumption at $3.51 per metre squared, compared to Premium and A grade at $3.34 per metre squared and B grade at $2.49 per metre squared (Property Council of Australia, 2008).

Swallow (1997) stated the type of building owner was an important factor influencing retrofit. Over 60% of events occurred to C and D grade stock in private ownership, where the breadth and depth of professional advice offered to and taken up by owners is unknown. Institutionally owned stock is likely to be professionally managed and accounted for 37% of events. It is considered these owners are more likely to consider sustainable retrofit compared to private owners. There is a significant opportunity to develop a programme to educate owners of C and D grade about the benefits of sustainable retrofit in terms of increased capital and rental values and to assist them financially to implement measures. No C or D grade buildings in the database had NABERS, Green Star or ABGR environmental ratings highlighting the environmental quality gap in this stock. This gap needs to be addressed by

policy makers as it will further encourage the evolution of a two tier market of buildings perceived to be either sustainable or non sustainable.

Conclusions

The questions this paper addresses are: *(a) what is the nature of retrofits in relation to low quality office building stock in the CBD and, (b) what is the extent and scope for sustainable retrofit to low quality office buildings.* There are some clear findings from this analysis;

a) Most retrofits are extensive; alterations and extensions adaptations,
b) C and D grade is least likely to be adapted,
c) Vacancy rates are higher in C and D grade stock,
d) Most retrofits occur in Collins Street and Bourke Street,
e) Retrofits largely occurred to buildings with irregular plan shapes, brick facades and envelopes, with multiple service core locations, classed as office land only, without heritage listing or overlay issues, aged between 26 and 50 years, attached on two sides or detached and in private ownership.

With the C and D grade stock there is scope to;
a) Overclad brick facades and envelopes to improve thermal performance, though given the good condition of stock overall building owners will need encouragement.
b) Reduce the relative high operating costs, electricity and gas consumption costs through sustainable retrofit.
c) Decrease water consumption costs through sustainable retrofit.
d) Over a quarter of retrofits could support vertical extension, planning permission permitted, to increase total area whilst retaining existing embodied energy.

Additional issues raised in this study are;
a) Owners of non listed stock are more likely to adapt and authorities need to consider programmes to incentivise this group.
b) Buildings with office land use only undergo more frequent adaptations. This has implications in future as more mixed use buildings appear in city centres.
c) The gap between gross income for C and B grade is narrow compared to the gap between B and A / Premium stock and possibly deters owners of C grade stock from capital expenditure on improvements which may not result in substantial increases in gross income.
d) To educate owners of the benefits of sustainable retrofit in terms of increased capital and rental values and to assist them financially to implement measures.
e) Authorities could incentivise retrofits to buildings which are enclosed by others to increase the rate of adaptation.
f) Incentives could be targeted at stock in fringe locations where there is scope to improve performance while reducing building related greenhouse gas emissions.

There are distinct differences in the patterns of retrofit based on building quality, as there are similarities, such as the level of retrofit and the locations in which work is undertaken. Sustainable retrofit measures have been identified on a CBD wide scale with specific stock characteristics offering the best potential for retrofit affirmed. The characteristics embody the facets of the economic, social and environmental aspects of the triple bottom line identified previously. Finally the results reveal clear evidence that an environmental quality gap is

appearing in the C and D grade stock which needs to be addressed as part of an all encompassing approach to improving the entire building stock.

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