Alterations and extensions to commercial buildings in the Melbourne CBD: The relationship between adaptation and building attributes

Sara J Wilkinson
Faculty of Business & Law
Deakin University
Melbourne Australia
Ph: +61 3 9251 7047.
Email: s.wilkinson@deakin.edu.au

Richard Reed
Faculty of Business & Law
Deakin University
Melbourne Australia
Ph: +61 3 9251 7605
Email: richard.reed@deakin.edu.au

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

Abstract

Arguably buildings contribute around half of all greenhouse gas emissions and Australian offices alone account for approximately 12% of all greenhouse gas emissions. As government authorities seek ways of reducing the contribution of cities to climate change and global warming on a global scale, building adaptation now appears as the only realistic means of reducing building related emissions by 38%. The 1,200 building program developed by the City of Melbourne aims to adapt or retrofit 1,200 central business district (CBD) properties before 2020 with sustainability measures as part of their policy to become carbon neutral by 2020. This research undertakes an innovative approach by undertaking a detailed examination of building adaptations in a global city; then it is possible to identify the nature and extent of typical levels of adaptation, as well as determining the relationship between different types of adaptation and building attributes.

This paper addresses the question: *what is the relationship between building adaptation event, classified as 'alterations and extensions' in the CBD and building attributes?* Using the Melbourne CBD as a case study this research analysed 5,290 commercial building adaptation events and the relationship with specific building characteristics from 1998 to 2008. The inclusion of all adaptation events that occurred during this period ensure this research is the most extensive and comprehensive analysis of this level of building adaptation undertaken in Australia. The outcomes of this research is applicable on a global basis and relevant to urban centres where existing commercial buildings can become part of the solution to mitigate the impact climate change and enhance the city.

Introduction

Arguably buildings contribute around half of all greenhouse gas emissions; Australian offices alone account for approximately 12% of all greenhouse gas emissions. As government authorities seek ways of reducing the contribution of cities to climate change and global warming, building adaptation appears to offer the only realistic means of reducing building related emissions by 38%. The 1,200 building program developed by the City of Melbourne aims to adapt or retrofit 1,200 CBD properties before 2020 with sustainability measures as part of their policy to become carbon neutral by 2020. Through an examination of building adaptations in the CBD it is possible to identify the nature and extent of typical levels of adaptation, as well as determining the relationship between different types of adaptation and building attributes. Accordingly this paper addresses the research question: *What is the nature of the relationships between (a) building adaptation events in the CBD classified as 'alterations and extensions' and (b) building attributes?*

The emphasis was placed on the nature of the relationships between previously identified building adaptation events classed as 'alterations and extensions' in the Melbourne CBD between 1998 and 2008 and building adaptation attributes identified in the literature as being important decision making factors. Previous studies are restricted with regards to the total number of cases or buildings informing their research. This study overcomes this limitation as *every* building adaptation event in the Melbourne CBD that occurred between 1998 and 2008 is investigated.

Factors influencing building adaptation

For the purposes of this research the definition of adaptation is: "*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"*(Douglas 2006). Previous research identified and grouped factors under categories of economic, social, environmental, technological, legal and physical (Wilkinson et al. 2009). To sum up key factors for example, Ball (2002) found the local economy contributes to adaptation, along with building attributes such as age, physical condition, heritage value, size (i.e. smaller buildings were more marketable) and user demand (Fianchini 2007). An earlier study concluded building quality and character were determinants of successful adaptation

(Ball 1999). A later study found accessibility to be a critical success factor, along with layout and flexibility for a range of differing uses (Fianchini 2007), whilst Barras (1996) found a relationship between age and obsolescence in London offices.

Physical attributes impact on adaptation potential and should be considered in decision- making. Gann and Barlow (1996) showed the technical issues in adapting offices were building size and height, depth, structure, envelope and cladding type, internal space layout and access, services, acoustic separation and fire safety. Other attributes were site (e.g. car parking, orientation, external noise and external access), size (e.g. floor area, height, depth, floor shape, grids, and floor to ceiling height), structure (e.g. penetration for services), envelope (e.g. cladding and thermal issues), services (e.g. to meet new use requirements), acoustic separation (e.g. floors and partitions, flanking transmission) and fire protection (e.g. means of escape, brigade access, detection and alarms, prevention of spread of flames).

Location is an important criterion for adaptation, with older buildings occupying prime locations (Ball 1999, 2002). Ellison and Sayce (2007) noted that within the paradigm of sustainability, location can be interpreted as accessibility to the building's user group and transport nodes such as rail and bus transport systems add to the desirability of a property for adaptation. Table 1 summarises building adaptation attributes identified in previous research.

Table 1 Summary of building adaptation criteria.

Adaptive reuse criteria for existing buildings	Relevant study
Age	(Barras and Clark 1996; Ball 2002) Ball, 2002; Fianchini 2007.
Condition	Boyd et al. 1993; Isaacs (in Baird et al.) 1996; Swallow 1997; Snyder 2005; (Kersting 2006)
Height	Gann & Barlow 1996.
Depth	Gann & Barlow 1996; Szarejko & Trocka-Lesczynska 2007.
Envelope and cladding	Gann & Barlow 1996.

Structure	Gann & Barlow 1996; Kersting 2006
Building services	Gann & Barlow 1996; Snyder 2005; Szarejko & Trocka-Lesczynska 2007.
Internal layout	Gann & Barlow 1996; Swallow 1997; Fianchini 2007; Szarejko & Trocka-Lesczynska,2007
Flexibility (for differing uses and functional equipment)	Gann & Barlow 1996; Fianchini 2007
Location	Isaacs (in Baird et al.) 1996; Bryson 1997; Ball 1999, 2002; (Remoy and van der Voordt 2006)
Heritage	Ball 2002;. Snyder, 2005.
Size	Gann & Barlow 1996; Ball 2002.
Accessibility	Gann & Barlow 1996; Ball 2002;. Snyder 2005; Kersting 2006; Remoy & van der Voordt 2006; Fianchini 2007; Ellison and Sayce 2007.
Parking	Sayce & Ellison 2007.
Character / aesthetics	Ball 1999.
Acoustic separation	Gann & Barlow 1996.
User demand	Ball 2002.
Site conditions	Isaacs in Baird et al. 1996.

Research methodology

Previous studies have examined the criteria for building adaptation, where researchers overwhelmingly adopted a case study approach based on in-depth analysis of a limited number of cases (Austin 1988; Barras and Clark 1996; Ohemeng 1996.; Blakstad 2001; Heath 2001; Ball 2002; Kincaid 2002; Kucik 2004; Arge 2005; Remoy and van der Voordt 2007). From these studies the adaptation criteria have been identified, however this research approach is fundamentally different from this point. The research was undertaken in two stages. Stage one examined adaptation criteria which formed the fields for the building attribute database, where stage two analysed the relationship between the adaption criteria and the adaptive reuse of the building.

For this research a building attribute database of commercial buildings in the Melbourne CBD was assembled and populated from numerous sources including the Cityscope database (RPData 2008), the PRISM database produced by the State Government of Victoria's Department of Sustainability and Environment (DSE 2008) and through commercial data produced by the Property Council of Australia (PCA 2007; PCA 2008). Building adaptation events were extracted from building permits received by the Building Commission in Victoria. Empirical data was gathered by visual building surveys. The building attribute database included variables listed in table 2, which have been categorised as physical, social, legal, economic and environmental characteristics or attributes of adaptation. The risk of an unrepresentative sample was avoided through the adoption of a census approach. As this research examines all building adaptation events in the Melbourne CBD between 1998 and 2008, 13,222 building adaptations was contained in the database complied for the study.

A preliminary task was to define the geographic area for the study. This research sought to investigate activity in a well developed, mature commercial market. The central business district (CBD) was the first area laid out in Melbourne in 1834, it has been continuously occupied and is the most mature property market in Victoria. The CBD area used in this research is the orginial grid laid out by a surveyor named 'Hoddle'. The streets within the CBD area for this research are as Flinders Street (southern boundary), Spencer Street (western boundary), Spring Street (eastern boundary) and La Trobe Street (northern boundary).

Principal Component Analysis (PCA).

PCA is a reliable, proven method of highlighting dimensions in cross sectional data (Horvath 1994) with the capacity to uncover, disentangle and summarise patterns of correlation within a data set (Heikkila 1992). PCA condenses information contained in a number of original variables into a smaller set of new composite factors with a minimum loss of information (Hair et al. 1995) and was used to reduce the dimensionality of office building attribute data relating to adaptation in the CBD between 1998 and 2008. The initial step is to enter all the variables into the PCA to produce a smaller number of components. The next decision is based on the actual number of factors to retain and this decision was based on the Kaiser criterion where factors with eigenvalues exceeding 1.0 only are retained. The factors were rotated using an oblique 'Oblim' rotation method with a final result being a table of identifiable factors which includes the loadings of individual building attributes. The contribution of a building attribute variable to each factor could be; completely positive (+1.0), completely negative (-1.0) or somewhere between.

Assigning meaning to a PCA solution involves interpretation of the pattern of the factor loadings (Hair et al. 1995). After analyzing the loadings across the factors, the threshold cut off was set 0.6 as recommended by Tabachnick & Fidell (2001). After a list of individual factors had been assembled where each factor contained high loading building attribute variable suggested correct factor names could be assigned. This analysis examined all events classed as 'alterations and extensions' the most extensive level of adaptation in the study and coded as level 4 adaptations in the study. The initial analysis examined 5,290 building adaptation events between 1998 and 2008. Each individual event was analysed further and 13 separate attributes were identified for each event as follows:

1. Aesthetics
2. Vertical services
3. Parking
4. Street frontage (metres)
5. Historic listing
6. Number of storeys (height)
7. Age in years (2010 minus construction year)
8. Typical Floor Area
9. GFA
10. PCA grade
11. Site boundaries
12. Site access
13. Property location

The PCA produced a total of 13 separate factors (table 3) where only the first three were significant with eigenvalues exceeding 1.0. Overall these first three factors contributed approximately 74% of the variance.

Table 3 Total Variance Explained PCA Level 4 adaptation events

Factor No.	Eigenvalues			Extraction Sums of Squared Loadings		Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.832	44.861	44.861	5.832	44.861	44.861	5.790
2	2.572	19.784	64.645	2.572	19.784	64.645	2.332
3	1.214	9.338	73.983	1.214	9.338	73.983	1.918
4	.858	6.597	80.580				
5	.761	5.851	86.430				
6	.614	4.720	91.151				
7	.387	2.973	94.124				
8	.290	2.233	96.357				
9	.255	1.958	98.316				
10	.118	.911	99.227				
11	.053	.405	99.632				
12	.042	.320	99.952				
13	.006	.048	100.000				

Table 4 Factor loadings - 'Alternations/Extensions' (Level 4) events

Attributes	Factors		
	Physical Size (Factor 1)	**Land** (Factor 2)	**Social** (Factor 3)
Number of Storeys	**.958**	.048	.050
GFA	**.958**	-.009	.037
PCA grade	**-.822**	.023	.115
Site boundaries	**.775**	.203	-.009
Typical Floor Area	**.743**	-.053	.061
Site access	**.737**	-.057	.297
Aesthetics	-.203	-.144	**.485**
Parking	.427	-.005	.423
Street frontage (metres)	.225	**.886**	.015
Vertical services location	.041	**.861**	.030
Property location	-.625	**.695**	.125
Historic listing	-.177	.175	**.823**
Age in 2010	-.476	-.123	**-.632**

Results and discussion

This section interprets the analysis and discusses each factor and their aggregate contribution to understanding adaptive reuse of buildings. Level 4 adaptations were those involving the most extensive works, short of demolition and rebuilding, such as alterations and extensions. The highest number of events featured in this category, illustrating that building owners of all commercial office buildings are more likely to engage in this type of adaptation than any other during the period 1998 to 2008. That owners are prepared and do engage in this level of adaptation is indicative of a high level of confidence in the Melbourne CBD market; that is to say that level 4 adaptations will recoup the investment through higher rental yields, increased capital values and lower vacancy rates than if the building was either not altered at all or adapted to a lesser extent. The contribution of the individual attributes to each factor was then examined where each factor was allocated a name based on the loadings (table 4).

Table 5 Summary of PCA Factors 'Alterations and extensions' (Level 4)

Factor number	Factor name	Factor variables
1	Physical / size	Height (number of stories) Gross Floor Area (GFA) PCA Grade Site boundaries Typical floor area Site access
2	Land	Street frontage Vertical services location Property location
3	Social	Historic listing Age Aesthetics

Factor one: Physical size

The variables number of storeys, Gross Floor Area (GFA), PCA Grade, site boundaries, typical floor area and site access are strongly to very strongly loaded on factor one. These variables explain 44.86% of the original variance. Factor 1 has six variables and three relate to the physical dimensions/size of the property in terms of floor area and height (i.e. physical attributes). Of the remaining variables, two relate to site boundaries; that is the degree of attachment to other neighbouring buildings and site access; the number of access/entry/exit points to the building. It is possible to refer to these attributes as 'physical - size'. The final variable 'PCA Grade' is strongly and negatively loaded and relates to building quality. With a loading of .427 Parking is too weak to be included in the final interpretation.

Factor two: Land

Three variables are loaded very strongly to strongly on factor 2 being street frontage, vertical services location and location (table 4). The variables explain 19.78% of the variance. In this factor the variables may be described as influenced by land/design factors. The street frontage or width of the land parcel and the location of the property relate to land attributes. The vertical services are a design attribute that influence the flexibility of the space plan to adapt to different configurations of the floor plate.

Factor three: Social

The variables historic listing and age are very strongly and moderately loaded on factor 3 and explain 9.33% of the variance (table 4). The age variable is negatively loaded and this can be interpreted as buildings age they are more likely to be adapted. The variables can be described as social attributes. Aesthetics, which is weakly loaded on factor three, relates to building appearance and indicates that buildings having a poor appearance; that is to say being outmoded or outdated are less likely to be adapted. It is included in this factor given the relationship to age and historic listing.

Conclusions

There are two primary findings from the PCA. Firstly the results reveal three defined and readily interpreted factors (table 4). Secondly the initial finding from this 'alterations and extensions' adaptations (level 4) analysis is that the PCA has correlated variables that previous studies identified as being separate and distinct (Blakstad 2001; Kucik 2004; Arge 2005) which indicates that the relationship between building adaptation and building attributes is more complex than previously considered. Specifically the PCA has confirmed the following;

- There are distinct levels of commercial office building adaptation in the Melbourne CBD ranging from minor to major works.
- Most adaptations are in the form of 'alterations and extensions' adaptations (level 4), the most extensive type of adaptation prior to demolition works and reconstruction.
- Physical building and size attributes are the most important building characteristics in 'alterations and extensions' adaptations (level 4).
- Building appearance or aesthetics is more important in level 4 adaptation than other types of adaptation.
- Building quality (PCA Grade) is an important attribute in 'alterations and extensions' adaptations (level 4).
- The degree of attachment to other buildings (site boundaries) is an important variable in 'alterations and extensions' adaptations (level 4).
- Floor area influences the amount of adaptation undertaken at level 4.
- The number of entry and exit points highly influences 'alterations and extensions' adaptations (level 4).
- To a lesser extent building width is important and is associated with location of vertical services and property location.
- Building age is associated with historic listing in 'alterations and extensions' adaptations (level 4).

No other research has investigated such a large number of events in any geographical area, in effect providing a census analysis of all events which occurred during a decade of activity.

The research questions have been answered with a high degree of detail and discussion and the importance of a relatively small number of building attributes has been found to influence adaptation to a high degree, some 73.98% of adaptation is explained by twelve attributes. The most influential variables or building attributes affecting 'alterations and extensions' adaptations are; physical / size (height, Gross Floor Area, PCA Grade, site boundaries, typical floor area and site access), followed by land characteristics (street frontage, vertical services location and property location) and lastly by the social attributes (historic listing, age and aesthetics). Another major finding is that attributes previously considered influential have been found to have limited influence on adaptation events in this study. These findings begin to place important parts of the adaptation jigsaw in place. Through the enhanced understanding of the pattern of commercial building adaptation, it is possible to strategically plan and target policy making to optimise efforts to deliver the 38% reductions in building related greenhouse gas emissions and the objectives of the 1200 buildings program.

References

Arge, K. (2005) "Adaptable office buildings: theory and practice" Facilities **23**(3): 119-127.

Austin, R. L. (1988). Adaptive Reuse. Issues and case studies in building preservation. New York, Van Nostrand Reinhold Company.

Ball, R. M. (2002). Re use potential and vacant industrial premises: revisiting the regeneration issue in Stoke on Trent. Journal of Property Research. **19:** 93-110.

Barras, R. and P. Clark (1996). "Obsolescence and performance in the Central London office market." Journal of Property Valuation & Investment **14**(4): 63-78.

Blakstad, S. H. (2001). A Strategic Approach to Adaptability in Office Buildings. Faculty of Architecture, Planning & Fine Arts, Norwegian University of Science & Technology. **Doktor Inegnior** 282.

Bryson, J., R. (1997). "Obsolesence and the process of creative reconstruction." Urban Studies **34**(9): 1439-1459.

DSE (2008). PRISM, State Government of Victoria.

Fianchini, M. (2007). "Fitness for purpose. A performance evaluation methodology for the management of university buildings." Facilities **25**(3/4): 137-146.

Heath, T. (2001). "Adaptive reuse of offices for residential use." Cities **18**(3): 173-184.

Kersting, J. M. (2006). Integrating past and present: The Story of a Building through Adaptive Reuse. The School of Architecture & Interior Design. Cincinnati, University of Cincinnati. **Master of Architecture:** 76.

Kincaid, D. (2000). "Adaptability potentials for buidlings and infrastructure in sustainable cities " Facilities **18**(3): 155-161.

Kincaid, D. (2002). Adapting buildings for changing uses. Guidelines for Change of Use Refurbishment, Spon Press.

Kucik, L., M. (2004). Restoring Life: The Adaptive Reuse of a Sanatorium. School of Architecture and Interior Design. Cincinnati, University of Cincinnati. **masters of Architecture:** 93.

Markus, T. A. (1979). Building Conversion and Rehabilitation. Designing for change in Building Use. London, The Butterworth Group.

Ohemeng, F. (1996.). The application of multi-attribute theory to building rehabilitation versus redevelopment options. COBRA, RICS.

PCA (2007). Benchmarks Survey of Operating Costs. Melbourne Office Buildings. P. C. o. Australia**:** 36.

PCA, A. (2008). existing buidlings // survival strategies. A toolbox for re-energising tired assets. PCA**:** 67.

Remoy, H. T. and T. J. M. van der Voordt (2006). A new life: Transformation of vacant office buildings into housing. CIBW70 Changing User Demands on Buildings. Needs for lifecycle planning and management, Trondheim.

Remoy, H. T. and T. J. M. van der Voordt (2007). "A new life: conversion of vacant office buildings into housing." Facilities **25**(3/4): 88-103.

RPData (2008), Melbourne Cityscope, Cityscope Publications Pty. Ltd.

Swallow, P. (1997). "Managing unoccupied buildings and sites " Structural Survey **15**(2): 74-79.