**Delivering sustainability through the adaptive reuse of commercial buildings: the Melbourne CBD challenge.**


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## Abstract


The City of Melbourne is aiming to be carbon neutral by 2020 (Arup 2008) and have set a target of adapting twelve hundred commercial buildings to incorporate sustainability initiatives to reduce greenhouse gas emissions from the sector (AECOM 2008). In order to meet this target the City of Melbourne is taking a proactive approach to establish strategies to deliver sustainability in the built environment within the 2020 timeframe. With regards to upgrading and building maintenance 71% of investment is used for such works (Department of the Environment 2008) and the total Australian property stock was worth over $6 trillion in June 2008. Given that building services in commercial buildings typically lasts between 20-30 years and the average age of the stock is 31 years – it appears that many properties are due for adaptation and there is major opportunity for adaptation that alleviates the impact of global warming and climate change.

Uncertainty surfaces such as; *how much adaptation of existing stock is typically undertaken?*; *And is the target of 1200 adaptations before 2020 achievable? Furthermore how could the City identify which buildings are most probable to be adapted prior to 2020?* This paper details the configuration of a database of Melbourne buildings populated with data about physical, social, economic, legislative and environmental attributes. There is a discussion about how the database will be used to determine; how much adaptive reuse has been undertaken historically; if any triggers to adaptation can be identified; and whether any relationships between adaptation physical, social, economic, legislative and environmental attributes and adaptation exist. The relevance of this research is obvious to all policy makers where adaptation of existing commercial buildings is perceived a as key component of delivering sustainability.

**Keywords:** Australia, policy makers, commercial buildings, adaptation, reuse, sustainability.

**Introduction**

With an estimated $267 billion of new commercial property to be built in Australia before 2018, the performance gap between the new and the old stock looks let to increase (Romain 2008). The existing Australian stock, which totals 423 million square metres of floor space, is ageing and the rate of ageing is set to increase given the likelihood that new stock will be sustainable, and as time passes the level of sustainability within buildings will increase. In addition the existing stock in the cities of Melbourne and Sydney has a median age of around 31 years which means that this stock is at a stage where adaptation or retrofit is usually undertaken (JLL 2005).

When the various elements of commercial buildings are examined each element or component has a typical life span or life cycle. The building envelope or skin will typically last for 60 years or so, structure should last 80 - 100 years plus and the interior fit out should last 5 - 10 years (Brand 1994). Building services typically last between 20 years and often represent a significant proportion of the total construction costs, up to 60% (Douglas 2006). Therefore in Melbourne and Sydney, it is likely that most buildings would need an upgrade of the services which is also an excellent opportunity to increase the operational sustainability of the building. Over the lifecycle of the building most expenditure and environmental impact occurs during the operational phase and energy and other operating costs have increased much over the last three decades (Romain 2008). The need to focus attention on existing stock is a conclusion many are reaching (Swallow 1997; Kincaid 2000; Blakstad 2001; Ball 2002; MaCallister 2007; ARUP 2008) and in 2008 71% of investment is used for upgrading and building maintenance (Department of the Environment 2008); this figure indicates the significance of the sector. With the total Australian property stock estimated to be worth over $6 trillion in June 2008, it is imperative that this investment is appropriately managed and maintained overtime (Romain 2008).

Another driver for sustainability comes from Government; at federal, state and local levels. At a federal level the Australian government is set to implement the Carbon Pollution Reduction Scheme in 2010. The Carbon Pollution legislation is perceived to be legislation that will make 'everyone [in the property sector] change their processes' (Romain, 2008). At a local level, the City of Melbourne is aiming to be carbon neutral by 2020 (Arup 2008). The strategy they have developed includes a number of measures such as carbon trading (sequestration), reductions in transport related emissions and, after considering the performance of existing commercial stock, building adaptation. The City of Melbourne have set a target of adapting around twelve hundred commercial buildings incorporating sustainability initiatives to reduce greenhouse gas emissions from the sector (AECOM 2008). They are taking a proactive approach to establish strategies to deliver sustainability in the built environment within the 2020 timeframe and have estimated that it possible to reduce the overall carbon emissions for the Central Business District (CBD) by 24% or 1004 kt $CO_2$ –e through building adaptation (Arup, 2008).

*Is the target set by the City of Melbourne for building adaptations a realistic and achievable one?* A snapshot view of the Melbourne office market in July 2008 indicates that it may be optimistic. In July 2008 a total of 34 building projects were being undertaken in the CBD, of these only 11 were classed as full or partial refurbishments (PCA 2008). The City of Melbourne envisages that policies and programmes are to be developed and implemented by 2012 that will lead to around 1200 adaptations before 2020; approximately 150 per annum. It is apparent that the rate of adaptation will need to increase substantially over current levels to achieve this target. Another apparent flaw in the City of Melbourne's thinking appears to be the rationale for the figure of 1200 buildings. *It begs the question which 1200? Is it the medium sized buildings, the smaller ones or the large ones?* Other questions arise such as*; how could the City identify which buildings are most probable to be adapted prior to 2020?* And *how do you decide which buildings should be adapted?* This research sets out to address these questions and others.

The case for and against building adaptation has been strongly argued previously (Wilkinson and Reed 2008). There are convincing arguments economically, socially, environmentally and technologically for and against building adaptation which vary according to factors such as the prevailing economic climate, local supply and demand, and physical and locational factors (Wilkinson et al, 2008). Each property has to be evaluated individually to determine whether adaptation is appropriate and desirable and also the degree of adaptation required. Many studies have determined key attributes for adaptation (Swallow 1997; Ball 2002; Kincaid 2002; Vijverberg 2002; Kincaid 2003; Douglas 2006; Remoy and van der Voordt

2007; PCA 2008). Examples of the building attributes affecting adaptation include building floor height, structural frame, floor layout and plan shape (Wilkinson et al, 2008). It is the presence or otherwise of these attributes which are evaluated by decision makers in the decision to adapt an individual building.

The definition of the term is important as adaptation is referred to by a number of terms such as refurbishment, retrofitting, renovation and conversion to name a few. The different interpretations of the term are also discussed in greater detail below. For the purposes of this research the authors have decided to adopt the definition posited by Douglas (2006) that 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"*.

**Decision-making issues in building adaptation**

There is consensus that decision making with regards to adaptation is complex (Blakstad 2001; Douglas 2006). There are many stakeholders / decision agents in building adaptation and each represents a different perspective. Kincaid (2002) identified the decision-makers as investors, producers, developers, regulators, occupants / users and marketeers. It is the difference in perspectives that gives each stakeholder a different set of priorities when the adaptation of a building is considered. For example an investor will want to see that the long term future value of the building is considered as a priority whereas the marketeers (letting agents) would want to see certain features provided in the adaptation that the market is currently demanding. Another layer of complexity is that, these decision agents can make their decisions with respect to the adaptation at different stages in the process (see figure 1).

The authors posit that another decision agent could be added to Kincaid's model; policy makers. Although their impact is less direct the policies this group create nevertheless affect the decision to adapt. In recent times policy makers have sought to influence the amount of sustainability that is incorporated into buildings to a greater extent in order to mitigate global warming and climate change. To date, this intervention has taken the form of building code changes to incorporate energy efficiency in Australia and the use of grants to offset the costs of implementing sustainability measures (Dong and Wilkinson 2007.). In other countries such as the UK, there has been a history of government lead schemes organised by groups such as the Energy Savings Trust (EST) to encourage the uptake of energy efficiency in property (Wilkinson, Goodacre et al. 2001.). Furthermore the authors predict that intervention in Australia is set to increase both in breadth and depth as the time in which mankind can make an impact on climate change diminishes.

In addition each decision agent exerts their influence in decision making at different stages of the process of adaptation and also has different degrees of influence. Generally decisions made at the early stages of the process have an ongoing impact throughout the project, for example the decision to change the use affects all decisions that follow on. It can also be said that the capacity of agents to influence the decision or decisions (as many decisions are involved in adaptation) may be classed as either direct (as in the case of producers) or indirect (as in the case of policy makers). Another layer is the situation where, a decision agent also intends to be an occupier or user, in which the decisions will have a daily impact on their ongoing business operations. To sum up, the decision agents are multiple and exert their influence to different degrees at different stages.

**Figure 1. Decision agents for adaptation of existing commercial buildings**

Decision agents for adaptation of existing commercial buildings *(Adapted Kincaid, 2002:13).*

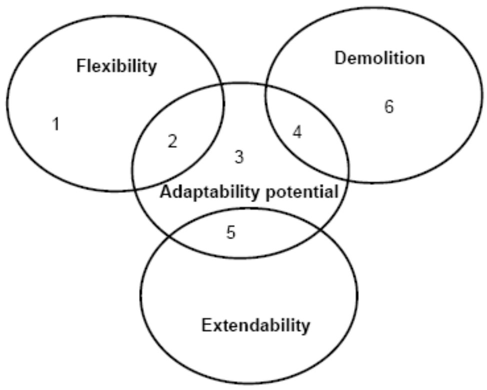
| Decision agents | Description & professional affiliations | Stage in adaptation where decisions made |
|---|---|---|
| *Investors* | Pension / super funds, insurance companies, banks, independent investors, professionals who find capital to invest | Beginning / early |
| *Producers* | Professional team – PM, QS, Architects, Engineers, contractors, surveyors, suppliers (RICS, AIAA, AIQS, AIBS, Fire engineers, structural and M&E engineers) | QS / A at feasibility stage<br>Design stage<br>Construction stage |
| *Marketeers* | Surveyors, agents, professionals who find users for buildings (API, RICS) | During design (if selling off plan) and /or construction stage |
| *Regulators* | Local Authorities, Planners, Heritage, Building Surveyors, Fire engineers (PIA) | During design stage (and possibly during construction if amendments are made) |
| *Policy makers* | Federal, State and Local Government departments. | Indirect effect on decision making in adaptation at all stages |
| *Developers* | Organisations who combine investment, production & marketing in whole or in part. Professionals from above bodies and others | Beginning / early |
| *Users –<br>Corporate<br>Residential* | Large institutional owners and users<br>Individuals | |

Note the relationship between the developer group and investors / producers and marketeers

*(Adapted Kincaid, 2002:13).*

Another aspect to consider is the range of decision options available to the decision agents. As Kincaid (2002) noted there are a number of development or adaptation combinations possible. The first option is to change the use with minimum intervention because of the inherent 'flexibility' of the building. The quest for flexibility is akin to the quest for the Holy Grail for architects of commercial space; the theory being that the more flexible the building is to adaptation and change the longer the life cycle and the lower the overall environmental impact. Stage two is for adaptation with minor change. The following stage (three) requires a higher degree of intervention and is typically referred to as 'refurbishment' or 'retrofitting'. Stage four involves some selected demolition in order to maximise the utility of the building to contemporary users, whereas stage five demands extension of the facility, either laterally or vertically to accommodate a new use or user. Finally stage six is demolition and redevelopment option and is selected when the social, economic, environmental, regulatory and physical conditions are such that the building is said to be at the end of the lifecycle and lacking in utility (Bottom, McGreal et al. 1999; C.W. Bottom 1999). This research is focussed on the decision making that occurs through stages two to five and the relationship between the stages and is shown diagrammatically in figure 2.

Figure 2. Development combinations (source Kincaid, 2002:55)




KEY
1. Change of use through flexibility of the building 'as found'
2. Change of use through flexibility with minor adaptation
3. Change of use adaptation / refurbishment of vacant facility
4. Change of use adaptation with selective demolition
5. Change of use adaptation with extension of the facility
6. Change of use through demolition and redevelopment

*(Source Kincaid, 2002:55)*

Effective decision-making demands the consideration of issues such as framing the issue properly, identifying alternatives and evaluating alternatives and selecting the best option (Turban, Aronson et al. 2005; Luecke 2006). The literature review undertaken by the researcher means the issue of adapting existing commercial buildings and implementing sustainability is understood at a deep level. In accordance with best practice in decision-making theory the options or development combinations for building adaptation are identified and possible alternatives known. The research design and methodology illustrate the framework that was developed to allow the alternatives to be evaluated so that the best option may be chosen.

**Research Questions and Methodology**

Given the issues raised by the literature review the research questions that have been established for this part of the research are:

1. *what are the essential criteria for undertaking an effective robust decision making process involving the adaptive reuse of existing commercial buildings?;* and,
2. *what is the optimal weighting of the decision making criteria for the adaptive reuse of existing commercial buildings?*

To answer research questions a research methodology has been designed. A fundamental question faced by all researchers is whether the research with which they are engaged is qualitative or quantitative or a combination of both types. Each form has different characteristics or attributes (Naoum 2003).

Quantitative research is described as 'objective' in nature, defined as an inquiry into a social or human problem based on testing a hypothesis or a theory composed of variables, measured with numbers, and analysed with statistical procedures to determine whether the hypothesis or theory holds true' (Creswell 2003). The purpose of this research was to discover evidence and measure the relationship between a number of building adaptation attributes derived from the literature review (desktop analysis of secondary data) and the incidence of building adaptations to commercial buildings within Melbourne CBD. Quantitative research is generally used with large databases (Naoum, 2003). The database from which the statistical analysis was drawn in this investigation comprised all commercial building in the Melbourne CBD, some 528 properties.

Qualitative research on the other hand, is 'subjective' in nature and emphasizes meanings, experience, often verbally described and can be exploratory or attitudinal (Naoum, 2003). Exploratory research is used when the researcher has limited knowledge about the subject and the raw data is what people have said or a description of what they have seen (Naoum 2003). Attitudinal research is used to subjectively evaluate the opinion, view or perception of a person towards a particular object Naoum (2003). Given that the research aimed initially to develop knowledge and understanding of the relationships between building adaptation events and physical, locational, social, environmental and economics attributes of buildings, a qualitative approach was not the most appropriate method for stage one of this research.

The research methodology is required to address issues of reliability, internal and external validity (De Vaus 1996) and these issues have been addressed by consultation with academics and practitioners and through the preparation and presentation of papers and research seminars to conferences for discussion and debate. The literature review provided secondary data to determine the key attributes of adaptation and the understanding of decision-making as a process. Further issues relating to reliability and internal and external validity are explained with regards to the different phases of the research method below.

**Methodology - Stage 1 Construction of Building Adaptation Database (BA db)**

A major issue was the method of validating the key attributes for building adaptation derived from the literature review. There are a number of research method options available and the case study approach, postal questionnaire survey, focus group and Delphi approach were considered and rejected as explained below. Previous studies favoured the case study approach (Blakstad 2001; Ball 2002; Remoy and van der Voordt 2006), whereby a relatively small number of cases were explored in depth by the researchers to establish how the decision to adapt a building had been undertaken and achieved. Conclusions were drawn with regards to key attributes or features considered desirable and essential for successful adaptation. Whilst this approach has merit and is validated to some degree by the number of researchers opting for this research method, it was not considered appropriate here. The main reason was that the studies had relied on so few cases, which though it satisfied the decision to adapt with regards to a small number of very similar buildings, the outcomes did not satisfy the issues of generalisability to the existing stock as a whole. This study examines the entire commercial building stock in a CBD, to determine the adaptation potential of the stock to deliver the sustainability target outlined by the City of Melbourne (Arup, 2008). This equated to a reduction of 24% of building related greenhouse gas emissions.

Another option was to canvass the views of the six or seven groups of decision agents themselves via a postal or email questionnaire survey. However there are issues with regards to response rates, the integrity of the person competing the survey and the reliability of the data provided and sampling of the population that can affect the validity of the data gathered (Moser and Kalton 1971; Naoum 2003). Given these issues it was decided that the questionnaire survey approach did not suit this research. A variation on this approach is the use of either focus groups or a Delphi group.

Focus groups involve the decision agents and a convener meeting to identify, discuss and then agree on the weighting of the attributes of building adaptation and decision-making. There were some inherent problems with such an approach. Firstly it can be difficult to gather an appropriately qualified, adequately experienced and representative group together and property professionals have little time for focus group meetings. Focus group methods require an initial meeting and possibly a follow up meeting to confirm agreement with the weighting and key attributes. Each meeting takes a minimum of an hour to generate a reasonable level of discussion and to reach consensus (Naoum 2003), thus with travel time participants would be required to commit a total of six to eight hours of time. This commitment was seen as unlikely to be achieved. Another issue was that optimum numbers for focus groups are six to eight people (Sekaran 2000) which meant that approximately one decision agent could be used in each focus group – but the question was: *would this provide a realistic appraisal of the relative weightings of the decision criteria and building attributes?* The focus group option was rejected.

The Delphi technique uses a panel of experts to identify the weightings and attributes and then reaching a consensus (Sekaran 2000; Munier 2004). One issue here is finding an appropriately qualified, adequately experienced and representative Delphi group. Another issue was: *would this provide a realistic appraisal of the relative weightings of the decision criteria and building attributes?* As with the focus group, the Delphi group option was rejected.

The method selected comprised the construction of a database of all the commercial buildings in the Melbourne CBD area. Figure 4 shows how stage one of the research fits into the whole research design, as well as summarising the research aims and data collection method and data source used for each research stage. The database is designed with the attributes for adaptation and sustainability derived from desk top study or literature review and in this way can be said to address and satisfy external validity (Moser and Kalton 1971). Table 1 below shows the building adaptation attributes used in the database. The incorporation of all buildings addresses issues of sampling.

**Table 1. Attributes used in the Building Attributes database (BA db)**

| | | |
|---|---|---|
| 1. Building ID number<br>2. Cityscope Code<br>3. Map Number<br>4. Property Number<br>5. Unit Number<br>6. Building Name<br>7. Street Address<br>8. Street Number<br>9. Street Name<br>10. Street Frontages<br>11. Description.<br>12. Historic Listings<br>13. Proposals<br>14. Number of floors<br>15. Year built<br>16. Year refurbished / adapted<br>17. Number of refurbishments / adaptations | 18. Extent of adaptation.<br>19. Parking<br>20. Number of car bays<br>21. Site Area<br>22. Total Building Area<br>23. Occupant classification - owner, lessee, vacant.<br>24. Occupancy type – sole occupier, multiple occupants, vacant<br>25. Zoning<br>26. GFA<br>27. NLA<br>28. PCA Grading.<br>29. Type of construction.<br>30. Plan shape. Elasticity potential – lateral extension | 31. Elasticity potential – vertical extension<br>32. Site boundaries.<br>33. Site access to building.<br>34. Tenure - institutional / private /government / educational.<br>35. Proximity to transport<br>36. Greenstar rating<br>37. NABERS rating<br>38. ABGR rating<br>39. Proactive legislation<br>40. Hostile factors<br>41. Roof overshadowing<br>42. PV option<br>43. Green roof option |

*(Source: Author)*

A number of different sources are used to populate the database; named BA db (Building Adaptation database). Cityscope is a commercially available database produced by R P Data, which is updated on a regular basis and covers all buildings within the Melbourne CBD.

Attributes such as building address, age, height, number of floors, number and date of previous refurbishments, gross floor area, net lettable area and street frontages are included in the database. Other databases referred to are the Victorian Heritage Database which is freely available and covers planning and heritage issues; the Land Victoria PRISM database. The Property Council of Australia (PCA) Office Market Reports (OMR) dating back over 18 years were reviewed for the number of projects undertaken in the Melbourne CBD. Ratings for existing sustainability attributes such as Greenstar, National Australian Building Environmental Rating System (NABERS) and Australian Building Greenhouse Rating (ABGR) were obtained via the internet at websites such as the Australian Green Building Council and also building owner websites and annual reports. Other tools used were search engines such as Virtual Earth, Google Earth, Google Maps, and Google Street View which enabled each building to be viewed remotely. In addition walk around surveys were necessary for some stock where data was unobtainable from the sources listed here.

Multiple sources were used to construct and populate a unique database which was designed to provide information relating to the history of adaptation in the Melbourne CBD over time. Furthermore the database was designed to allow the researcher to determine whether certain attributes were related to adaptation and if so, to determine the strength of that relationship through regression analysis (Aiken and West 1991). For the statistical analysis, the database was exported from its excel format into the Statistical Package for Social Scientists (SPSS) Version 17, where univariate and bi-variate descriptive analysis of the data were undertaken. For example the relationship between the incidence of refurbishment and building size, building height, location, construction type, building age, proximity to transport nodes and so on could be identified. The results can be triangulated to previous studies to establish whether these findings corroborate previous investigations. Once the strength of relationships between the various attributes is established it is possible to rank the attributes form strongest to weakest and these rankings become the de facto weightings for the second phase of the research (see stage two below).

The database includes data relating to sustainability issues such as potential for Photovoltaics (PV) roof installations, provision of green roofs, existing Greenstar ratings, estimated energy and water consumption. The estimated energy consumption figures were derived from previous research by Wilkinson & Reed (2005) PCA data, and also owner data. The inclusion of such attributes allows the researcher to determine the estimated degree to which adaptation of certain sectors of the stock will deliver the target reductions identified by the City of Melbourne (Arup 2008).

Another outcome of this approach is that the incidence of adaptation over time can be mapped against economic cycles and property cycles to establish whether any 'triggers to adaptation' can be identified. Such triggers might be vacancy rates or interest rates going to a certain level.

**Methodology - Stage 2 - Multi Criteria Decision Making (MCDM).**

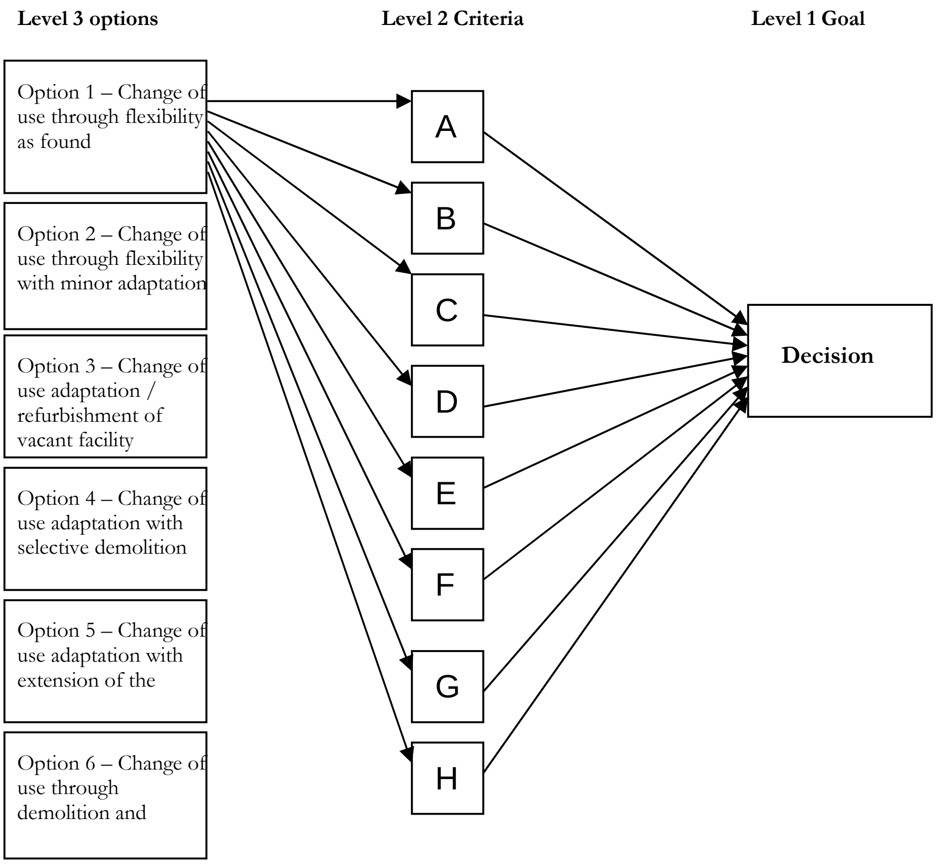
The second stage of the research design is to use the weighted attributes to develop a model for application in a decision-making tool (see figure 4). The use of Multi Criteria Decision Making (MCDM) tools is common in environmental disciplines and enables the researcher to apply a number of decision making criteria (here building adaptation attributes) into a decision making model (Munier 2004). This approach was first put forward by Ohemeng in 1996 with regards to decision making in redevelopment or refurbishment of buildings (Ohemeng 1996). It is an approach that has been adopted in a number of studies (Lee and Wu; Vincke 1992; Ohemeng 1996; Roy 1996) MCDM methods are frequently used in the environmental disciplines where evaluation of decisions involved multiple factors is often required, hence it is in this discipline where the application of MCDM theory is most advanced (Harding 2002; Munier 2004).

Multi criteria analysis (MCA) facilitates the assessment of a project or projects against a set of criteria. The number of criteria and attributes is derived from the circumstance, here building adaptation, and these tools are used for the analysis of projects either with a single objective or with several objectives. One of the advantages of MCA is that it can work with weights for a single project or criteria, and also with many projects or criteria (Munier 2004; Turban, Aronson et al. 2005). Some of the techniques, like Analytical Hierarchy Process (AHP), does not provide a unique solution but a prioritised set of alternatives or projects and is perceived to provide a 'very useful guide for stakeholders and decision makers since it provides the elements conducive to an educated decision" (Munier 2004). It is a well used technique, proven in use and applied to many problems. Other techniques, such as Mathematical Programming (MP), work differently and provide optimal solutions to problems or decisions. The use of MP is useful where a ranking of projects is needed, however this is not the case here and MP was rejected as a suitable technique for this research.

The advantage of the MCDM method is that a consistent approach is developed and used in decision making based on accepted decision criteria (Luecke 2006). Furthermore it allows any number of 'cases' or 'decisions' to be compared on a like for like basis. Thirdly, and importantly, it reduces the level of risk associated with the decision, which is a critical area for property fund managers (Ellison and Sayce 2007). With the application of MCDM methods the level of risk is reduced in the decision making process because all the important decision criteria have been recognised and included, and then weighted according to their level of significance or importance in the decision.

AHP uses pair-wise comparisons matrices to compare criteria between themselves as well as projects or alternatives between themselves, and using a system of preferences. With the values of these comparisons a mathematical procedure is applied finding the eigenvalues and eigenvectors for the matrices (Munier 2004). The Eigenvectors are used to ascertain the weight of each criteria. Thirdly the values obtained from the pair-wise comparisons between alternatives are then affected by the criteria weights. Finally the final result shows the ranking of alternatives represented in a column vector called Global Priority. Figure three over shows the hierarchy structure applied to this research but for clarity with only one relationship between the adaptation options and a criterion, although the calculation involves all criteria. AHP is a comprehensive and straightforward mode of evaluation when preferences are involved. AHP is easy to understand and provides accurate results. A software package called 'Expert Choice' has been developed to run AHP analysis quickly and accurately and is used for this research. Whilst 'Expert Choice' does not compute the weights for the criteria and for alternatives it employs eigenanalysis principles. A criticism of 'Expert Choice' is that the values for comparison are derived from expert opinion or judgement typically which may or may not be representative or accurate (Munier 2004) – this criticism is acknowledged and has been overcome in this case because the data analysed from the Building Adaptation Database (BAdb) is based on adaptations that have been undertaken in the whole of the Melbourne CBD stock over time and not subjective expert opinion.

**Figure 3 - Hierarchy Structure.**




*(Adapted from Munier, 2004)*

**Stage three – Pilot and test Building Adaptation (BA) Tool**

In stage three of the research design case studies are used to pilot and test the validity and reliability of the Building Adaptation Decision (BA) Tool (see figure 4). Naoum (2003:46) stated that case studies are used when the researcher intends to support the argument by "an in-depth analysis of a project". This study uses the explanatory case study which is the theoretical approach to problems to show linkage between objects or attributes. Therefore the case studies show how the BA tool operates in practice and evaluates and assesses the potential of the case study buildings for adaptation and, in this way, contributes to answering the research questions. Best practice in decision-making requires the decision to be reviewed for reliability and validity (Drucker 2001). Naoum (2003) stated there are two types of sampling; random and selected. Random sampling is used when specifics about the characteristics of the sample are not essential, whereas selected sampling is used when specifics about characteristics are essential. This study used selected sampling because of its specific targeting. Fifteen buildings, reflecting typical commercial stock was chosen.

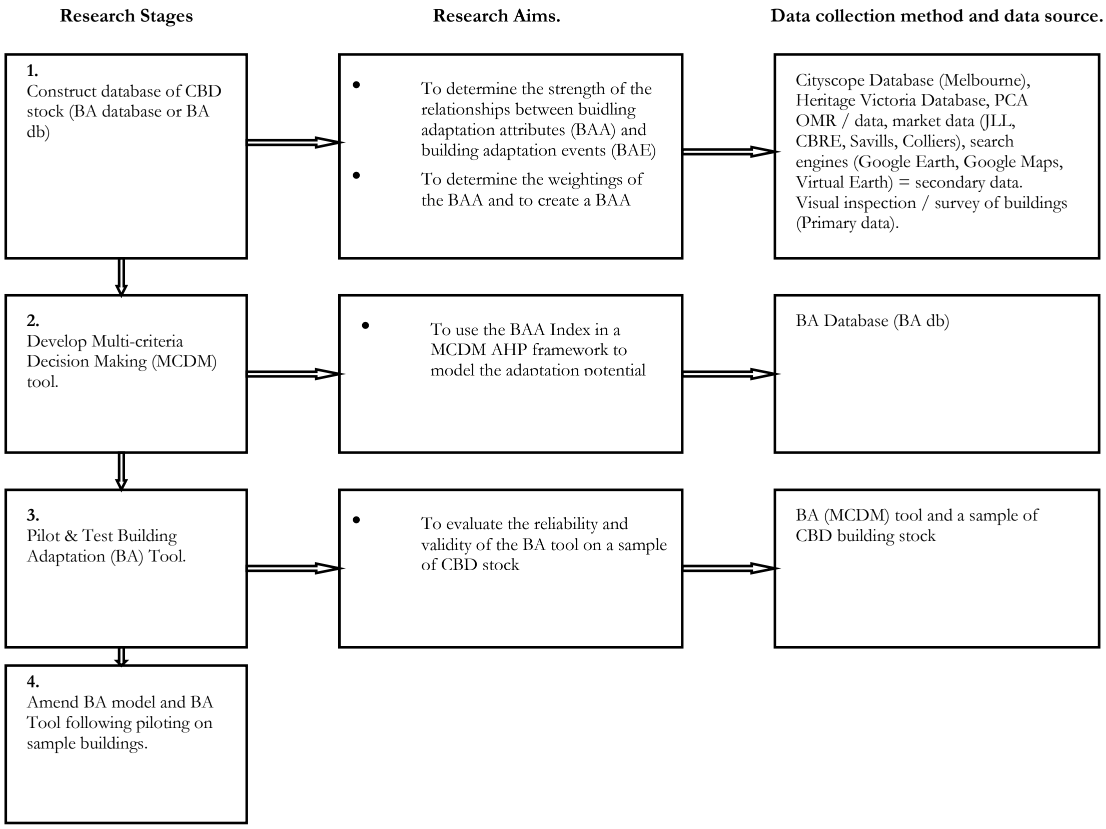
**Stage 4 – Amendment of BA model and BA tool**

Following the application of the MCDM BA Tool to the 15 case study buildings, an assessment of the accuracy, reliability and internal and external validity of the tool is undertaken using a panel of experts, comprising practitioners and stakeholders. Following consultation a list of modifications are devised and changes are made to the BA tool (see figure 4). In summary figure four over illustrates the whole research design in a model form.

**Conclusions & further research**

This paper has identified the sustainability drivers for an increased rate and for targeted building adaptation over time to deliver sustainability targets established by policymakers in Australian cities, specifically Melbourne. In addition, the complexity of decision-making with regards to building adaptation has been explained and the potential building adaptation options outlined. The research design and methodology outlined allows the researcher to fulfil requirements of reliability and internal and external validity for the key attributes for adaptation and weighting of the decision-making criteria. The construction of the BA database allows a unique insight into the building adaptation that has occurred in the Melbourne CBD over time. This paper outlines clearly a framework of the entire research design for the project. The outcomes of this research and the application of the BA Tool will be useful in other urban centres, where the gaol is to increase adaptation to commercial property with a view to reducing greenhouse gas emissions and their respective contribution to global warming and climate change and thus deliver sustainability to some degree.

**Figure 4 Research Method Model.**




*(Source authors)*

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