A holistic approach to the evaluation of sustainable housing

Y. Esteban, S. Ang, J. Coulson, U. de Jong, and R. Fuller

School of Architecture and Building
Waterfront Campus, Deakin University
Geelong 3217

ABSTRACT: Residential housing is often evaluated against single or at best a limited number of similar criteria. These include quantifiable indicators such as energy use and its associated greenhouse gas emissions. It might also include material consumption from an embodied energy or resource use perspective. Social factors or qualitative indicators may be evaluated but are rarely placed or juxtaposed alongside these quantifiable indicators. A one-dimensional approach will be limiting because sustainable development includes both environmental and social factors. This paper describes the methodologies that have been developed to assess housing developments against five quite different criteria. These are: energy use, resource use, neighbourhood character, neighbourhood connectedness and diversity. In each case, high and low sustainability practice has been identified so that ranking is possible. These methodologies have then been tested by evaluating a typical precinct (approximately 400 m by 400 m) of a 1970-80s housing development in a suburb of Geelong. The rankings of the particular precinct have then been combined in a visual way to assist in the evaluation of the housing in a more holistic way. The results of this evaluation method are presented, along with a discussion of the strengths and weaknesses of the methodologies. The research is the outcome of collaboration by a cross-disciplinary group of academics within Deakin's School of Architecture and Building.

Conference theme: Sustainability issues
Keywords: Sustainability, housing, multi-criteria, evaluation

INTRODUCTION

Housing development projects on greenfield sites, particularly on the outskirts of our major cities, are the cause of much debate within the community. In many instances, these projects are critiqued within the context of sustainable development. This popular concept is generally recognised to have both ecological and social components, the exact interpretations of which can vary greatly depending on the user. Whatever definition is used, the analysis is often uni-dimensional. For example, the housing may be discussed from the perspectives of social isolation, energy use for travel or for its aesthetics. This shortcoming is understandable because it is difficult to critique housing in a more holistic way. However, a failure to consider housing in a multi-faceted way could easily lead to a development, which while 'sustainable' in one respect, might be quite the reverse in another. Some way of combining evaluations of quite different aspects of a housing development is also required if its various 'components' are to be compared equally. A fair comparison would require a common 'currency'. This paper describes some research that has been undertaken to enable housing developments to be critiqued against five different criteria and then compared. The paper begins with a description of the study site; where and why it was selected and an overview of the general research approach adopted. Some details of the five criteria are then presented using data gathered from the study site. The paper presents some initial results from the research along with some conclusions of its strengths and weakness, and areas for future work.

1. PRECINCT SELECTION AND OVERALL RESEARCH APPROACH

A housing precinct in the suburb of Grovedale, within the City of Greater Geelong, was selected as the study site. The precinct was selected to be representative of a typical housing development in the 1970-80s. The precinct was approximately 0.16 km^2 i.e. approximately 400 m by 400 m. This size was chosen because it is normally regarded as the maximum distance that can be comfortably traversed on foot. The precinct was also selected to be coincidental with an ABS Collection District. Since it was envisaged that ABS data would be used extensively in this study, it was important that the complications of overlapping census districts was avoided. The housing within the precinct was analysed using five different criteria. These were: energy use, resource use, neighbourhood character, neighbourhood connectedness and diversity.

The overall research approach was as follows: for each of the criteria, a methodology was developed which enabled the housing within the study site to be assessed systematically. In some cases, e.g. energy use, a quantitative assessment was possible. In other cases e.g. neighbourhood character, a more qualitative assessment was made. In both types of assessment, however, a system was developed which enabled the housing within the precinct to be ranked. Each of the criteria was represented by several indicators and the housing development was rated using these indicators on a scale of 1 to 5. If the assessment revealed that the development was considered to be best practice for this indicator, then a score of 5 was awarded. If, on the other hand, the development was deemed to be an example of worst practice, then a score of 1 was awarded. To obtain a single figure or ranking for the particular criterion, these rating scores were averaged. In the final step, the ranking for each criterion was transferred to a five-pointed star diagram to enable immediate visualisation of this more holistic assessment of the housing. The main theoretical considerations and details of the individual methodologies adopted for each of the criterion are described in the following sections.

2. ENERGY USE

How and where we live are the key determinants of residential energy use. In 2007-8, the sector was responsible for 7.4% of the country's energy consumption (ABARE, 2010). In 2008, the sector consumed 402 PJ and this is expected to rise by 16% by 2020 (DEHWA, 2008). Houses are getting bigger, household size is getting smaller and we are building houses on sites with poor, if any, public transport, forcing occupants to drive their cars further. The car is the most energy consuming household appliance but usually energy for car use is considered separately from the residential sector. In housing development design, however, serious consideration of location is essential if real residential sector energy use is to be contained. In order to reduce the amount of calculations required, a typical house within the precinct was selected, following an on-site inspection of the precinct, and this house was analysed. The methodology used to determine the energy use due to the size, style and the location of the house was as follows. The heating and cooling energy was determined using published Nationwide House Energy Rating Scheme figures for various housing types (AGO, 1999). The embodied energy of the house was calculated using the method suggested by Fuller and Treloar (2004), where typical houses of various eras were analysed using an approximation method. Gross floor area was multiplied by an embodied energy coefficient (GJ/m^2). ABS data provides a breakdown of the mode of transport used for work travel. This data is collated by the mode of travel under various categories and sub-categories. In order to simplify the data and also make it comparable with other studies e.g. Fuller and Crawford (2011), car and public transport usage only were used to determine an average method of work travel in this study. The relationship between the operational, embodied and travel energy per annum for a resident in the typical house of the precinct is shown in Figure 1.

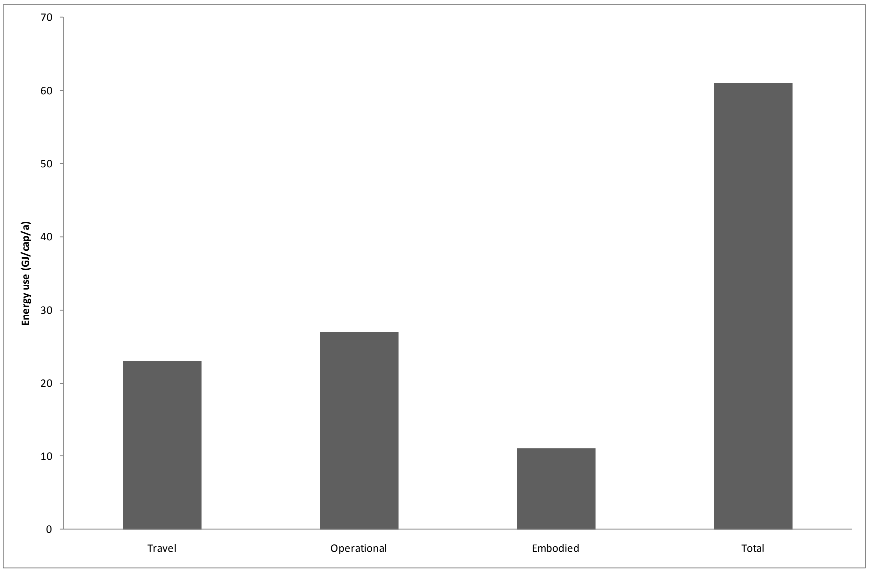

Figure 1: Travel, operational and embodied energy use per capita per annum for Grovedale house

To rate the operational, embodied and travel energy for a resident in the selected house in the precinct, an upper and lower level of energy use for each energy component was determined. The total range of energy use defined by these limits was then divided in to five sub-levels. To determine the lowest range of operational energy use i.e. the highest ranking, it has been assumed that a house can be designed that requires no heating or cooling by external sources. Similarly, it is assumed that someone could deliberately choose to live close enough to their place of work so that they could ride a bicycle or walk to work. In both of these cases, energy use would be zero. In the case of embodied energy, however, identifying 'best practice' is more problematic. A house constructed of renewable/reused or recycled building materials could theoretically be low in embodied energy, but some energy would still be used in either harvesting and/or processing the materials. Fuller et al. (2009) determined that a 1950s weatherboard house had an embodied energy of 9.2 GJ m^{-2}. Assuming a further 50% reduction is possible, a figure of 4.6 GJ m^{-2} has been assumed in this study. The upper range i.e. lowest ranking of the three indicators was determined as follows: for operational energy use, the highest combined heating and cooling energy requirement for a detached house (857.4 MJ m^{-2}), as predicted by the NatHERS program (AGO, 1999), has been assumed. All travel is assumed to be by car and an embodied energy coefficient of 15 GJ m^{-2} has been used (Fuller and Crawford, 2011). Table 1 summarizes the ranking ranges for operational, embodied and travel energy. The overall energy ranking for the Grovedale house is 2, being the average of its three individual rankings in Table 1.

Table 1: Rating levels for operational, embodied and operational energy (GJ/a/cap)
(Grovedale rating in grey)

Ranking	1	2	3	4	5
Operational	65-52	52-39	39-26	26-13	13-0
Embodied	17.1-14.0	13..9-10.9	10.8-7.7	7.6-4.6	<4.6
Travel	24.2-19.4	19.3-14.5	14.4-9.7	9.6-4.8	4.7-0

3. RESOURCE USE

This part of the evaluation calculates the impact of resource use in the built environment due to the changing fabric of suburban development. The scale and density of dwellings influences the consumption of global resources and is significant in terms of evaluating sustainable habitation. This aspect of the study is considered from two principal perspectives. Firstly, the economic, functional and aesthetic requirements of habitation determine dwelling size, scale and elaboration. This influences material selection and determines material quantities for domestic spatial enclosure and utility. Secondly, the infrastructure of suburban development is initially imposed on the landscape to establish legal title for residential property. This translates into physical dimensions of individual building sites as well as road reserves and other land usage (parkland, schools and businesses) required to facilitate inhabitation. This contributes to dwelling density as well as influencing the quantity of materials needed to complete the infrastructure.

The methodologies used to determine the house size, material use and dwelling density of houses were as follows. The typical house in the precinct was modelled using AutoCAD Revit to incorporate principal construction materials for structure and enclosure. This allowed direct extraction of data from the model in terms of dwelling footprint and the ratio of material volume to floor area delivered. This is an indicator of resource consumption for population potential (number of inhabitants per dwelling) and amenity. Analysis of GIS information allowed direct measurement of land use according to dwelling site area as a percentage of the total precinct area. This can then be compared to the efficiency of infrastructure space for access (road reserve) and amenity (parkland, schools, recreation reserves). Tables 2 and 3 respectively show the material and land usage for the selected house in the Grovedale precinct. The selected house has a floor area of 165 m^2 and a volume of 56.2 m^3 resulting in volume to floor area ratio of 0.34. The ratio of renewable* to non-renewable building materials is 0.09.

Table 2: Volume of material used (m^3)

Timber*	5.20
Concrete	21.51
Masonry	23.77
Plaster	5.53
Steel	0.00
Glass	0.18
Aluminium	0.00

Table 3: Land usage data

House site area (m^2)	752
House floor area (m^2)	165
No. of houses in precinct	192
Precinct area (m^2)	203200
Total house site area : Precinct area	0.71
Total building area : Precinct area	0.16
Precinct area per house site (m^2)	1058

Five indicators were selected to analyse the two principal concerns for the chosen house and precinct. Spatial Enclosure Efficiency assesses the resources used to achieve a unit of floor area. The Renewable Material Proportion reflects the volume of renewable/recycled materials to total material used. It assumes that a house can be designed that requires only light timber cladding with effective insulation that can be largely comprised of renewable materials. The Precinct Building Footprint (total house site area : precinct area) expresses building resource density and dispersal within the precinct as an indicator of the sprawl of urban development and the loss of land available as a resource for other purposes. House Site Proportion indicates the capacity of a site to accommodate an efficient plan and maximise available floor area for habitation from the volume of resources used in building. This is balanced against the reduced infrastructure required for narrow site frontages through less roads and length of services. The Land Use Efficiency (precinct area per house site ratio) expresses the infrastructure resource implications of providing a useable site within the precinct. The greater the density of house sites within a given range for low-density development, the lower the infrastructure needs to service the capacity for habitation. This issue is complex and is interconnected with broader sustainability issues for land use such as amenity in urban habitation as well as biodiversity, and the modification or exclusion of habitat for other species. The indicators and rating ranges are summarised in Table 4 below, with the Grovedale results indicated in grey tone. The overall ranking is the calculated average of 2.6.

Table 4: Resource Use Indicators and Rating Scale

	Rating				
Indicator	**1**	**2**	**3**	**4**	**5**
Spatial Enclosure Efficiency (material volume / house floor area)	> 0.5	< 0.5	< 0.4	< 0.3	< 0.2
Renewable Material Proportion (renewable material volume / total material volume)	< 0.1	> 0.1	> 0.3	> 0.5	>0.7
Precinct Building Footprint (house floor area x no. houses / precinct area)	< 0.1	> 0.1	> 0.2	> 0.3	> 0.4
House Site Proportion (site frontage / site depth)	< 0.15 or > 0.95	< 0.25 or > 0.85	< 0.35 or > 0.75	< 0.45 or > 0.55	> 0.45 and < 0.55
Land Use Efficiency (site area / precinct area per site)	< 0.5	> 0.5	> 0.6	> 0.7	> 0.8

4. NEIGHBOURHOOD CHARACTER

Research on neighbourhood character is thin compared with the substantial literature on conceptions of place. Defining neighbourhood character is not a simple task because character is not easily reducible to a collection of elements. Definitions of neighbourhood character are often 'an assemblage of built form elements' though 'place-identity is strongly territorialized' (Woodcock et al, 2009; Dovey and Woodcock, 2011). Green (2010:2) argues that character of a place is 'an experiential phenomena' - physical features plus experiential perceptual phenomenon. Relationships between the built and the natural environments are critical to neighbourhood character, which touches on scale and height, as well as surface articulation of architecture and materials used, and the amount and type of vegetation in the landscape. Green (2010:5) suggests that 'we are talking about aesthetics' coupled with meaning, about place attachment. Woodcock et al. (2009:19) argue that neighbourhood character is 'profoundly social', that it is 'fundamentally about the way built form mediates relations between neighbours and the ways such forms and practices give rise to a "sense of place"'. While recognising that 'neighbourhood character involves many complex and inter-related elements', this study tries to answer the question 'how do buildings and landscape interact?' (Planisphere, 2010:13) by examining the built form and its relationship to topography and vegetation to gain a whole picture.

Six physical/landscape indicators have been developed from the City of Greater Geelong's *Housing Diversity Strategy* (COGG 2007) and other neighbourhood character studies in order to establish the physical neighbourhood character of the selected precincts. The six indicators are: (1) style of public infrastructure and urban design; (2) allotment sizes; (3) building setbacks; (4) building footprint (5) building type/design; (6) vegetation. Observations were made from walking the streets in the study area, plus on-the-ground photos, supplemented by aerial photos from NEARMAP.com. Together these provided qualitative data for precinct description and analysis.

Table 5 describes the six indicators with their different values. The higher the number, the greater the positive contribution to neighbourhood character in each indicator. The grey columns signify the scores the suburb of Grovedale has received. Observations of Grovedale's public infrastructure and urban design show that there is little consistency in appearance, with concrete footpaths in one street and none in another; overall the streets are curved with no clear orientation, there are some courts and grassed nature strips. Observations of allotment sizes show that the blocks are approximately 750 m^2 in size; some have wide and short dimensions while others have narrow frontage and are wedge shaped. Observations of building setbacks show that these are generally consistent from street frontage, yet perception varies as some properties run their front lawn to the street curb while others have erected a fence on their boundary. Setbacks between houses are well defined, generally by paling fences. Observations of building footprint show that all original buildings have reasonable front gardens and various backyards depending on their location in the court. Though it is difficult to see backyards, our estimate (confirmed by the aerial photos) is that the footprint takes up about 40% of the allotment space. Observations of building types and designs show that the neighbourhood comprises single storey detached dwellings of similar height and bulk with garages that are relatively unobtrusive beside the dwellings. Most of the houses are 1970s brick veneered with a mix of hipped roofs, some flat roofs, and some 1980s with bagged brick and attic lights. One house has been 'gentrified' into a new look (mimicking models designed for adjoining new neighbourhoods). The aerial view shows a variety of houses, all unique according to their roofscapes. Lastly, observations of vegetation show that there is no consistent street tree planting, and there is a mix between established large shrubs (e.g. Bottle Brush tree) and trees, scattered at random. A number of properties have some large trees (eucalypts), which provide shade and habitat for birds. There is a mixed diversity of established trees and shrubs, flowers and lawns. Various levels of maintenance were evident, some manicured and others quite rambling.

As discussed above, it is hard to define neighbourhood character and it is even harder to determine what a "good" neighbourhood character might comprise. It is clear that neighbourhood character will change according to the contextual situation in which a neighbourhood is located, and whether, for example, it is a suburban environment with low density housing or an urban environment with high density housing or a coastal area with a fragile environment.

In this attempt to evaluate the neighbourhood character of the Geelong suburb of Grovedale, we have tried to bridge between the desire to maintain a low density environment with abundance of vegetation and greenery on one hand, and the need to aspire to a sustainable suburban housing model on the other. The six indicators must be seen not as six separated indicators but as an integrated matrix in which each of the indicators is influenced by and influences all other indicators. For example, public infrastructure and urban design influences allotment size and orientation, which, in turn, influences vegetation and sun access. In the six indicators Grovedale scored 24 out of possible 30, which is 80% out of 100%, giving an average ranking of 4.0. This score shows that Grovedale has been quite successful in bridging between achieving a good neighbourhood character and sustainable housing. In other words, the neighbourhood has been able to combine both social sustainability and environmental sustainability through its built form and its relationship to topography and vegetation. While recognising the limitations of this approach, this initial attempt to evaluate the neighbourhood character of Grovedale provides a starting point for the conceptualisation and evaluation of neighbourhood character.

Table 5: Criteria for neighbourhood character with Grovedale scores highlighted in grey.

Criteria	1	2	3	4	5
Public infrastructure and urban design	No consistency of streetscape pattern; no consideration of urban design; no clear orientation of streets; no communal spaces	Poor consistency of streetscape pattern; little consideration of urban design; little orientation; very few communal spaces	Moderate - consistency of streetscape pattern; moderate consideration of urban design; little orientation; few communal spaces	Moderate + consistency of streetscape pattern; reasonable consideration of urban design; some orientation; some communal spaces	Consistency of streetscape pattern; high consideration of urban design; clear orientation of streets; variety of communal spaces
Allotment sizes (m^2)	≥350	≥450	≥550	≥750	≥1000
Building setbacks	No setbacks; no space between dwellings; very high front fences.	No consistency in setbacks and spacing, and front fencing height	Inconsistent setbacks and spacing, inconsistent front fencing height	Moderate consistency in setbacks and spacing, consistency in front fencing height	Similar full setbacks; spacing between dwellings; unified height of front fences
Building footprint (%)	<100	<85	<70	<55	<40
Building type/design	Total uniformity or chaotic mixture of buildings; import of external materials, styles and heritage influences	Inconsistent mix and scales, imported and local materials and styles	Moderate uniformity, some mixture between materials and styles	Some variety of buildings; using local material, styles and heritage influences	Planned variety of buildings; using local material, styles and heritage influences
Vegetation	No trees – 0-10% coverage	Very few trees – 10-20% coverage, scattered effect	Few trees – 20-30% coverage; street planting ad hoc	Some trees – 30-40% coverage	Mature trees – >40% coverage in street plantings and in private gardens

5. NEIGHBOURHOOD CONNECTIVITY

Boyce et al. (2009) identify housing choice, mobility, connectedness to the outside world, social cohesiveness and inclusiveness as key elements for sustainable communities. Their study highlights the benefits of understanding neighbourhood community infrastructure by analysing street morphology and residents' mobility. This present study has analysed the distance relationships between areas of housing and existing community infrastructure facilities utilizing the indicators presented by the City of Greater Geelong in their Sustainable Communities Strategy (CoGG, 2010). Nine key local indicators for sustainable communities were utilised in the mapping process in this study. The indicators consisted six main facility types: (1) community centres, (2) kindergartens and childcare centres, (3) general practitioners, (4) community libraries, (5) maternal and child health facilities, (6) aged care facilities, and three network-based facilities: (1) public transport, (2) public open space, and (3) retail and convenience shopping.

The geographic location of community indicators was tested for accessibility using two key benchmarks; accessibility by foot assuming a comfortable walking distance of 400 m; and accessibility by public transport assuming a walking catchment of 400 m from any transport stop. A rating system was applied to the 'performance' of each indicator. The rating system is based on a percentage scale that corresponds to a 'score' from 1 (0 to 20% accessibility) to 5 (80 to

100% accessibility), with the corresponding figures in 20% increments in between. Table 6 shows the results for both the walking and public transport connectivity mapping across Grovedale and Figure 2 shows the comparative indicator scores on star diagrams for the two types of accessibility. Connectivity to community infrastructure is fundamentally based on the proportion of the community that either lives within a 400 m walking distance of each of the indicators, or alternatively within 400 m of a public transport stop which is in turn within 400 m of the indicators. The average of the ratings (i.e. the ranking) of Grovedale's connectivity to community infrastructure has therefore been calculated to be 3.1.

Table 6: Connectivity results for Grovedale, showing the percentage (%) of population within 400 m of community infrastructure.

	Community centre	Library	Maternal/ child health	Child care/ kinder	G.P.	Aged care	Public transport	Public open space	Retail centre
Walking connectivity	4.1	3.1	4.4	22	15	15	86	54	24
Public transport connectivity	86	43	86	75	74	86	n.a.	52	86
Indicator score	3	2	3	3	3	3	5	3	3

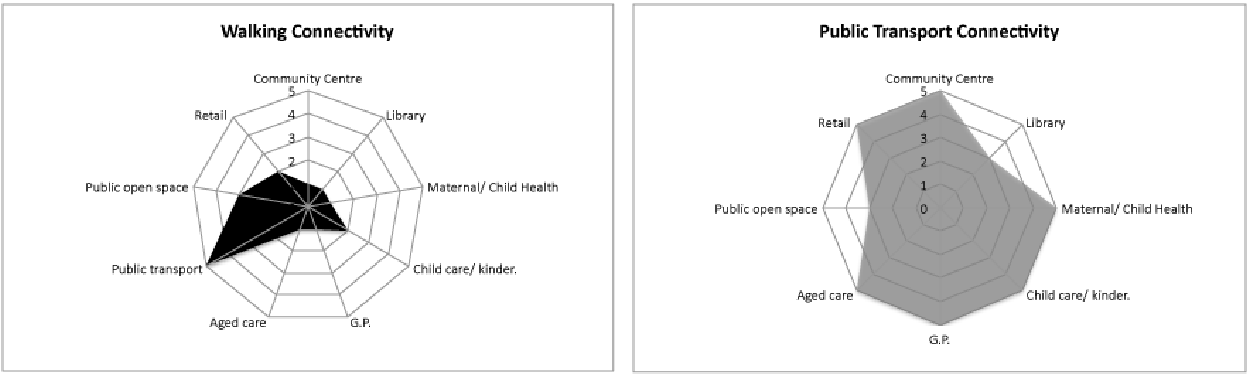

Figure 2: Comparative indicator score results for walking and public transport connectivity in Grovedale.

Relatively-low ratings across most node-based indicators (community centres, libraries, maternal and child health, child care and kindergartens and general practitioners) point towards either a lack of community services in the suburb or a concentration of services within a limited geographic area. From a walkability point of view therefore, the 400 m catchment zone around community nodes appears to be capturing only a fraction of its potential audience. The results therefore show the need for support from an efficient public transport network in order to be deemed physically well 'connected'. A higher proportion of longer streets with less connecting streets may have led to less residents being 'connected' by foot to most of the community indicators. The larger community indicators of public transport, public open space and retail centres returned the highest rankings. This may be due to their dispersion throughout the suburb, and therefore being more accessible at the local scale. This is particularly true of public open space and public transport, which are geographically located in network form, rather than a nodal or singular point of activity. The results show a significant difference between walking and public transport connectivity. Whilst public transport is deemed to be successfully efficient in Grovedale, the results may differ across other suburbs where there is less community infrastructure or the street layout and pattern differs.

6. DIVERSITY

Fainstein (2005) found diversity to have a variety of meanings in urban literature. Amongst urban designers it refers to mixing building types; among planners it may mean mixed uses or class and racial-ethnic heterogeneity; for sociologists and cultural analysts it primarily takes on the latter meaning. The whole idea of diversity is central to urban and future city planning and the evaluation of a multi-dimensional social mix as an approach to ascertain neighbourhood context diversity is directly linked to it (Talen 2006). Several methodologies for defining housing diversity and sense-of-place have driven and continue to be driven by city councils and local government agencies in the past decades (e.g. COGG 2007; 2010).

The methodology used in this research focussed on population diversity as a key consideration of sustainable housing development. A range of socio-demographic variables which contribute directly to the definitions and extent of equitable and diverse housing was extracted from the Suburb-level Community Profile Census for the selected precinct in Grovedale (ABS 2006). Seven community profile indicators were used: (1) education; (2) family composition; (3) dwelling structure typology; (4) tenure of dwelling structure; (5) age; (6) gross weekly household income; and (7) birthplace. The approach used was to compare the actual number of any particular 'diversity' indicator in Grovedale with the "ideal" number of that indicator, determined by the percentage of the same indicator in Melbourne. The rationale is that it is impossible to have a greater level of diversity that that achieved in the State capital. A comparison of the "ideal" number with the actual number in the precinct shows the level of diversity for that particular indicator. If the actual number exceeds the "ideal", it implies that in the given category there is adequate representation of diversity i.e. 100% of the given category. A rating of 1 to 5 was then developed where 1 represented zero or nil (0%) diversity and 5 represented maximum or perfect (100%) diversity. Intermediate ratings were proportionately distributed between the two extremes (Table 7).

Table 7: Calculation of Grovedale data and Melbourne data

Profile indicators	Melbourne data	Ideal Grovedale	% Ideal Grovedale	Diversity ranking
Educational Level	974,684	153	58	3.3
Family Composition	938,488	151	95	4.8
Dwelling Typology	1,283,041	192	34	2.4
Tenure	1,165,847	185	76	4.0
Age	3,592,592	502	96	4.8
Income	1,140,128	168	78	4.1
Birthplace	3,592,591	479	47	2.9

These indicators present a tangible and "visible" way to quantify diversity (Figure 3). While the scope and the sample study are quite limited, it presents a working method for quantifying and rating diversity to produce an overall snapshot of housing and population diversity. The results show that Grovedale has performed quite well, since four out of the seven indicators are rated 4 or higher (family composition, tenure, age and income). The two lowest rated indicators are dwelling typology (2.4) and birthplace (2.9). The ranking for overall diversity in Grovedale is assumed to be the average score of all the indicators assessed and is therefore 3.8.

7. RESULTS AND DISCUSSION

The rankings determined in the previous sections can now be visualised together (Figure 4) and this representation can be used to quickly understand the strengths and weakness of a housing development in terms of its sustainability.

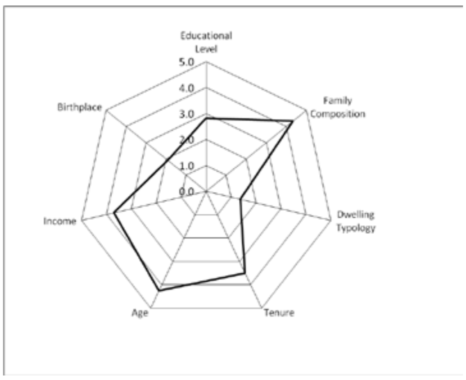

Figure 3: Diversity rating comparison

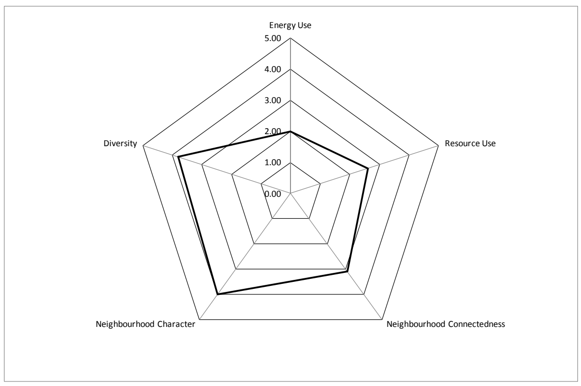

Figure 4: Visualisation of the rankings of sustainability criteria for Grovedale

Figure 4 shows that the Grovedale precinct performs quite poorly in terms of resource and energy use. On the other hand, its performance in terms of diversity and neighbourhood character is reasonable. Neighbourhood connectedness could arguably be improved. If the sustainability of the precinct was to be increased, the provision of more public transport could simultaneously improve the ranking of the energy use and neighbourhood connectedness criteria. While the analysis of only one precinct has been described in this paper, the research team has applied the technique to two other precincts in the Geelong region. These two other precincts are also representative of other eras. Juxtaposing the star diagrams for each era provides insights into the strengths and weaknesses of different types of housing development over time. These insights can be used in the design of new housing developments or to improve the sustainability of existing ones.

CONCLUSIONS

This paper has described the methodologies used to analyse five criteria selected to be important considerations of any sustainable housing development. Using these methodologies, each criterion has been ranked on a scale of 1 to 5 for its 'sustainability'; the lower score (1) representing a poor outcome and the higher score (5) representing a good outcome. It is recognized that there is some subjectivity in the choice of criteria, the indicators and their rating. It is also acknowledged that some criteria and indicators can be in conflict with one another. However, the authors contend that the exercise has value and potential use in improving the sustainability of present and future housing developments. The strength of this early pilot study has demonstrated longer term value of the application of a holistic approach involving a multi-dimensional investigation of five criteria related to sustainable housing developments. Further refinement and testing of the method and widening the sample size of the examples are envisaged as part of future research directions.

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