

# Infill Development and the Distribution of Open Space in Melbourne

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**Abstract:** Melbourne's open space system spans property boundaries over public and private lands, and provides key social and ecological services. With significant population growth predicted over the next 50 years, high levels of infill housing will be required. Increasing house sizes and infill development practices are directly modifying the quantity and quality of private open space in inner and middle belt suburbs. The distribution of public open space in Melbourne is uneven, with most inner municipalities, and 6 of 13 middle municipalities, having a shortage of public open space per capita.

Focusing on public and private open space at ground level, this paper aims to assess how residential infill developments are impacting on open space availability. The method uses rates of detached dwellings and lot size to approximate private open space availability, and rates of recent detached and higher density dwelling construction to indicate infill development in each municipality across metropolitan Melbourne. These rates provide sufficient indicators to assess open space in fully developed inner and middle municipalities with predominantly suburban forms - but not areas with large amounts of high density or greenfields development. The results suggest that infill pressures and open space availability varies significantly throughout Melbourne. Current open space policy mechanisms have not been developed with the capacity to regulate infill development in a way which would allow open space across land uses to provide continuing health, recreational and environmental services to support the growing population.

Key words: Open space, morphology, suburbia, infill development, research design

## Introduction

Open space forms an important part of our urban and suburban environments. Often when we think of open space, the immediate picture is one of city parks or sports reserves; but open space comprises of wider variety of spaces including backyards, parks, plazas, school grounds, sports fields, vacant land, utility and transport easements, nature strips and waterways, and exists on most land uses and property types.

The function of open space in cities has expanded throughout the history of settlement. In Australia, private open spaces, suburban gardens in particular, were initially developed for a degree of self-sufficiency, private leisure and recreation (Timms 2006, Grose 2009). Public open space was developed to provide recreational opportunities and fresh air to those without access to private open space (Lewis 1995). In the mid 20<sup>th</sup> century, parks, sports facilities and school grounds were further developed for public health and community benefit (Lewi 2010, Melbourne Metropolitan Board of Works 1954). While these uses are still vital, open spaces, both public and private, are now expected to provide significantly more functions, particularly with increasing challenges presented from rapid population growth and climate change. Open space provides: ecosystem services (Bolund and Hunhammar 1999), space for biodiversity and contact with nature (Grose 2009, Hall 2010), amenity, recreation and health and wellbeing benefits (Giles-Corti, Broomhall et al. 2005, Pretty, Peacock et al. 2005, Kent and Thompson 2014, Lovell, Wheeler et al. 2014), aesthetic value, environmental comfort and heat island mitigation (Loughnan, Nicholls et al. 2009, Oliveira, Andrade et al. 2011, Christoff 2014).

The distribution, quantity, quality and types of open space in the suburban areas of Australian cities are varied. Pre-existing environmental conditions (Presland 2009) and historical development patterns have created variation in the morphology of cities (Ward Thompson 2002, Silvam, Karuppanan et al. 2012). The geographic availability of open space is affected by historical development practices, but also urban policies, local community responses to infill development and the real estate market through socioeconomic and cultural preferences for different housing types (Bunker, Gleeson et al. 2002, Tice and Randolph 2013). Differences occur in the amount and distribution of public open spaces like parks and reserves, nature strip widths on streets, and the availability of private open space due to differences in lot size, housing density and housing type. These variations in open space in suburban areas means that, for example, greater ecosystem services may be being provided

by open space on private property rather than public open space in one locality, or that a limited amount of private open space means that public open space provides the bulk of the ecosystem services and recreational opportunities in another.

Current regulation and management of open space is complex and often fragmented, and can lead to suboptimal developments of open space, and the green infrastructure it supports, particularly in open space conservation and development on private property (Grose 2009, MacKenzie 2011, Silvam, Karuppannan et al. 2012, Legacy, Pinnegar et al. 2014). Reconceptualising open space as a social-ecological system that crosses land use and property boundaries may enable more integrated housing infill and open space planning for future development within cities.

The purpose of this research is not to calculate a loss of open space, rather the focus is to better understand the proportions of public and private open space in residential areas, and the main pressures which may impact the existing open space in these areas into the future. Methodological issues and scope for further research are also discussed.

### **Open space as a social-ecological system**

The concept of social-ecological systems was developed in the field of ecology in the 1970's (Wilkinson 2012). Social-ecological systems provide an approach to analyse the complexity of open space as being a product of both social (political and economic conditions and social processes) and ecological systems (biophysical conditions and ecological processes) (Redman, Grove et al. 2004, Andersson 2006, Moffatt and Kohler 2008, Elmqvist 2014).

The built environment, including open space can be described as space that has been designated by people for a particular purpose, or a particular setting for human activity (Moffatt and Kohler 2008). Physical space in the built environment at a fundamental level "is based on a transformation of natural conditions, in erecting routes, dwellings etc., and the partitioning of space into functional zones" (de Haan 2005 p. 14-15). The way open space is distributed, developed and managed within the broader built environment is determined by existing environmental patterns and processes including climate, topography and hydrography, geology and soil conditions, ecosystems and prior land use; and though the political and economic conditions of the time (Presland, 2009). The synthesis of these factors provides an open space system that is socially constructed – a social-ecological system.

Open space is continuously being changed and reconstructed, and both social and ecological systems are entwined. Dobbs, Kendal et al. (2013) have demonstrated that the availability of open space and its ownership and management affects the space available to include trees in suburban and urban environments, indicating that the way space is socially constructed and developed affects ecological conditions. In turn, open space, as a part of the built environment provides ecosystem services that are "direct and indirect contributions of ecosystems to human wellbeing" (Elmqvist 2014).

Land use, the focus of this open space research, is an integral part of the social-ecological system of the built environment (Redman, Grove et al. 2004). The broader economic, political and social processes form cultural practices in urban development that shape the availability, allocation and ownership, configuration and management of land, including patterns of open spaces. From an ecosystem function perspective, the configuration of the open space in relation to the built form is important: the size, shape, distribution and connectivity of open spaces, and particularly green open spaces influence biological diversity, that affect the resilience of the system and the ecosystem services that it provides (Andersson 2006). A comprehensive approach incorporating both social and ecological components is required to effectively understand and manage open space in our cities so that it can provide effective ecosystem services that underpin the social health and wellbeing of city inhabitants.

### **Understanding key changes in the distribution of the open space system**

Local, state and federal governments as well as private owners and residents form a matrix of open space land owners and managers. The open space system and the ecosystem services it provides cross boundaries of backyards, streets, parks, vacant lands and other open space types. While

private land ownership might be the smallest individual parcel of land, collectively the land in private ownership makes up a significant proportion of the open space in cities (Kearns, Saward et al. 2014). This indicates that the configuration, distribution and management of open space, both public and private, will be a key determinant of ecosystem service provision in the suburbs.

Consolidation and infill development have been a focus of more recent suburban development, modifying the quantity and quality of private open space in inner and middle belt suburbs by shrinking the availability of private open spaces, and putting pressure on local governments to provide greater amenity and ecosystem services in public open spaces (Grose 2009, Hall 2010). Newton and Glackin (2015) argue that differences in suburban form, location and land parcel size influence the way in which infill development is carried out. Infill housing in the existing suburbs accounts for approximately 35% of new residential development and is mostly low density knock down rebuilds (1:1 replacement) or low yield subdivisions (1:2 or 1:4-6) (Newton and Glackin 2014). From the early 1990's the size of new building floor plans increased an average of 40% for detached houses and 35% for other dwelling types between 1984-5 and 2002-3 (ABS 2005). These trends in increasing housing sizes and densities means that even private open space in low density suburban areas is shrinking, and development is not necessarily occurring in accordance with metropolitan strategic plans (MacKenzie 2011, Tice and Randolph 2013, Wiesel, Pinnegar et al. 2013, Legacy, Pinnegar et al. 2014). The open space in our suburbs is not in a fixed state, but is constantly changing and will be required to change further to meet future needs.

Planning regulations for open space assume that increased housing densities resulting in a reduction of private open space should be compensated for with adequate supplies of public open space to fulfil recreational requirements (Stage Govt Vic 1988 section 18/1A). One of the issues with developing an integrated open space planning approach is how to assess the availability of open space across the open space system. The following method has been developed to provide an indication of open space availability, and uses the Melbourne metropolitan area as a case study.

## **Melbourne**

Historical development patterns mean that the availability of public open space through local parks and reserves, and private open space through distribution and lot size of detached housing at a local scale vary significantly throughout the Melbourne.

In 2012 75% of all Victorians were living in Melbourne, and over the next 50 years Melbourne's population is predicted to almost double from 4.25 million in 2013 to 7.7 million in 2051 (Department of Transport, Planning & Local Infrastructure 2013, ABS 2013). While infill development occurred in parts of Melbourne from the 1950's (O'Hanlon 2010), successive urban consolidation movements have followed most significantly from the 1980's. Regulations encouraged infill developments, allowed broad scale dual subdivision of single detached blocks and encouraged medium and higher density developments near activity centres and public transport (Hamnett and Freestone 2000). In 2011 72.6% of dwellings in Greater Melbourne were detached houses, 11.6% were semi-detached, and 15.3% apartment or unit dwellings (ABS 2013). Most private open space in Melbourne is contained within detached housing lots.

Housing the expanding population is a significant issue; future projections in Plan Melbourne (2013), the latest metropolitan strategic plan, indicate an additional 1,570,000 dwellings are required. The plan states 30% of the allocation should be for higher density apartments, and 35% for medium density townhouses and units; and that 60% of all additional dwellings should be located in established areas, with the majority occurring in middle (67.7%) rather than inner (32.3%) suburbs (Department of Transport, Planning & Local Infrastructure 2013). A report by the Victorian Environmental Assessment Council (VEAC) found that the distribution of public open space is vastly uneven (VEAC 2011). It is standard for municipal councils to aim for a public open space, regardless of size, to be located within a 400m distance (a 5 minute walk) from most residences, as stated in their open space strategies. In general, about two-thirds of residential dwellings across Metropolitan Melbourne achieve this (Mavoa, Koohsari et al. 2014).



**Figure 1:** Melbourne Municipalities (Municipal Association of Victoria 2015)

### **Policy**

Public open space is defined in the Victorian Subdivision Act 1988 as: “land set aside in a plan or land in a plan zoned or reserved under the planning scheme -

- (a) for public recreation or public resort; or
- (b) as parklands; or
- (c) for a similar purpose” (1988 p. 5-6)

While local councils in Melbourne differ in their definitions, most are similar – for example Glen Eira, Bayside & Boroondara City Councils define open space as “publicly owned land that is currently set aside, or has the potential in the future to be set aside primarily for recreation, nature conservation and passive outdoor enjoyment.” (Glen Eira CC 2014 p. 1, Bayside CC 2012 p. 19, Boroondara CC 2013 p. 2). Local council definitions also broaden the scope of what open space is by including additional types of open space, for example most include variations of:

Encumbered open space: Publically owned, can be used for recreation but another use takes precedence. For example, service easements

Publically accessible private open space: Access usually includes membership or fee paying. For example, private golf courses, church grounds, tennis & lawn bowls clubs

Ancillary open space: Other public land that is not set aside for specific open space uses. For example, school grounds, streets and road reserves, railway reserves, public space between buildings

(Glen Eira CC 2014 p. 4-5, Boroondara CC 2013 p. 2).

While these additional public open space land types are acknowledged, they rarely form a part of broader open space strategies as Councils cannot control, or ensure their ongoing open space status or use.

Private open space in policy relates to residential land, and is laid out in the Victorian Planning Scheme and associated residential codes. Private open space is purely defined as recreational and within a specific property boundary (Department of Transport, Planning and Local Infrastructure 2015a, 2015b).

Statutory planning, particularly residential zoning codes have a greater influence over the amount and distribution of private open space in inner and middle municipalities. In Melbourne, current residential zones in the Victorian Planning Scheme include 6 categories, 4 of which are applicable to Melbourne's inner and middle suburbs with higher density zoning close to transit networks. Each municipality has control over where the zones are applied through their local planning schemes.

Mixed Use Zone: High and medium density housing around neighbourhood centres and train stations, no standard maximum building height. Multiple dwellings per lot allowed.

Residential Growth Zone Schedule 1: Medium density housing near activity areas and train stations, maximum building height 13.5m, or 4 storeys. Multiple dwellings per lot allowed.

General Residential Zone Schedule 1: Single dwellings and some medium density housing in residential areas, maximum building height 9m. Multiple dwellings per lot allowed.

Neighbourhood Residential Zone Schedule 1: Single dwellings and some dual occupancies, in residential areas with 80% single dwellings or significant neighbourhood, landscape or environmental character, maximum 8m building height. 2 dwellings per lot allowed.

(Department of Transport, Planning and Local Infrastructure 2015b)

The basic standard of open space for new dwellings (all infill development) is 80m<sup>2</sup> or 20% of the lot area, whichever is lesser, with a minimum of 40m<sup>2</sup> of open space - of which 25m<sup>2</sup> must be useable with a minimum width of 3m. 20% of a block must have a permeable surface according to the basic Residential Development Standards in areas where other codes don't apply (Department of Transport, Planning and Local Infrastructure 2015a, Department of Environment, Land, Water and Planning 2015). The standards do not take into account existing public open spaces or adjacent lot sizes, but councils can apply overlays that modify the standard, for example altering setback requirements or building heights. Some councils also lessen or increase minimum open space requirements.

## Research Methods

The 26 city councils in the Melbourne metropolitan area (Fig 1) have been included in this study. The research methods included two steps:

- A review of open space provision and housing infill literature, including open space regulatory frameworks
- A quantitative analysis of open space by municipality using key factors influencing the availability of open space: amount of public open space, amount and types of residential dwellings, average lot sizes and residential development since 1990, and projected population growth.

The quantitative analysis uses a rate of public open space per population, the availability of open space is calculated relative to the population density. Similarly, private open space is not directly calculated, residential dwelling type and lot size have been used to approximate private open space availability. This is possible because of the uniformity of suburbs in Australia, with approximately 70% of dwellings being detached. In general, for detached dwelling lots, larger lot sizes provide a greater amount of private open space, and as the lot size decreases, so does the amount of private open space; and dual occupancy, villa unit or townhouse developments have reduced amounts of open space again. Apartment buildings can significantly vary in the amounts of open space at ground level provided, and as such, lot sizes of apartment buildings are not being quantified. This analysis focuses on private and public open space at ground level in residential areas, not other land use types or zones.

Residential development since 1990 is being used to assess infill, as this is shortly after the urban consolidation policies of the 1980's came into effect; and it is also in the time period where house sizes started to increase. This means that suburban development from 1990 was more likely to include multiple dwellings on a lot and larger house replacement, as well as higher density housing – all of which reduce the amount of private open space.

### ***Data***

Two georeferenced datasets were used in this investigation, metropolitan Melbourne rates data from 2012 obtained from the Victorian Office of the Valuer General which contains lot size, type of property and date of building construction at a property parcel level; and the Victorian Environmental Assessment Commission's (VEAC) public open space dataset compiled in 2011, the first comprehensive audit of public open space undertaken in the Melbourne Metropolitan area. This data set includes public open space on crown, public authority and local council land (VEAC 2011 p.32). VEAC classified land types as conservation, natural/semi natural, parks and gardens, organised recreational, services and utilities, civic squares and promenades and recreation corridors (VEAC 2011 p. 36). VEAC's Metropolitan Melbourne investigation calculated the amounts of all these public open space types per 1000 people in each municipality; those rates have been used here. These rates have been used as a social-spatial measure, in line with the social-ecological systems approach to this research.

Each city council within the Melbourne metropolitan area was assessed using rates of public open space, rates of detached dwellings, average lot size (Table 1) and dwellings constructed since 1990, both in total and the percentage of detached dwellings (Table 2). Projected population growth has also been included using data from the report, Victoria in the Future (2014) to determine the population increase (%) from 2011 to 2031 (Table 1).

### ***Limitations***

The classifications of units, villa units and apartments don't adequately describe the open space configuration, for example, shared or private open space descriptions. Whilst the VEAC open space data is the most up to date municipal wide audit of public open space, it does not record other open space types which may be publically accessible, but not publically owned or zoned for public use. Private open spaces, like private golf courses are similarly not included. While these spaces may not be accessible for use, they are still a part of the broader open space system and contribute ecosystem services. Address checks revealed that some dwellings classified as detached did not fit within the standard typology of a single dwelling on a lot with associated private open space, for example, a dwelling above a shop with associated land at the rear of the dwelling.

### ***Reliability***

At a metropolitan scale, the results indicate this method is useful to identify areas which may be facing greater or lesser open space pressures due to existing public open space, lot sizes and housing development, but alternative methods and data will need to be utilised for a detailed analysis across land use and ownership types. These data and methods are sufficient for providing indications of open space availability within inner and middle municipalities with strong existing suburban forms, but are less useful for areas with greater amounts of higher density housing, or non-suburban morphology like the City of Melbourne. Similarly, on the city fringes, these results do not differentiate between infill and greenfields developments.

While other methods may be able to accurately quantify the extent of open space, this method has been developed as a relatively quick way to indicate open space availability and development impacts on open space without the requirement of specialist software and coding, or georeferenced aerial imagery.

## Results

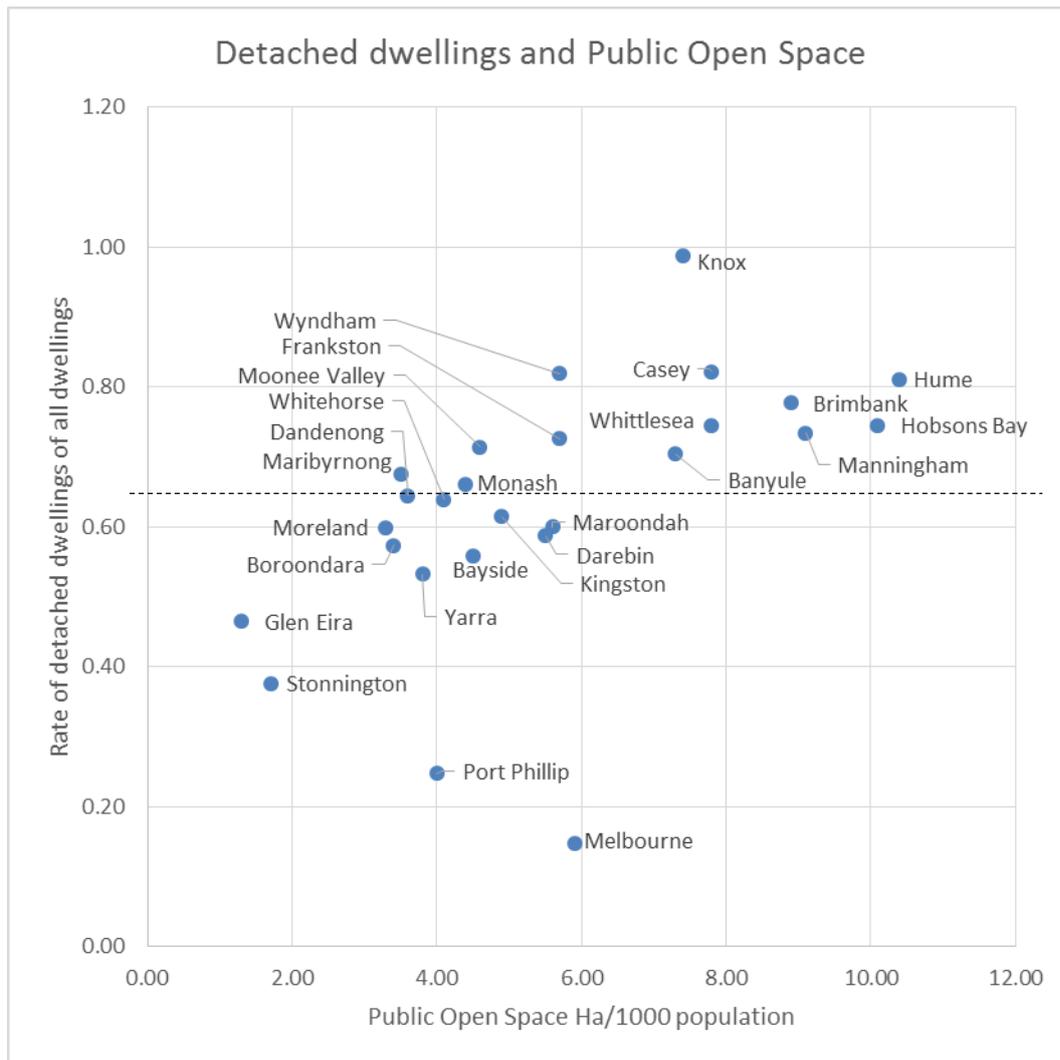
The results have been categorised by distance from the CBD: while there is overlap; inner municipalities mostly located within 5-7km of the CBD, middle municipalities within 7-20km, and outer municipalities mostly over 20km. Growth municipalities are new greenfields developments on the outskirts of the city, classified as such by the State Government of Victoria.

Rates of public open space of hectare per 1000 people (VEAC 2011) were assessed with the percentage of detached dwellings for each municipality (Figure 2). Across Melbourne, the median percentage of detached dwellings per municipality was 65%. For public open space, VEAC calculates that less than 6 Ha/1000 people is low. The average detached dwelling lot size calculated was 663m<sup>2</sup> across Melbourne. Lots under 300m<sup>2</sup> are considered small (Metropolitan Planning Authority 2014), but lots below 450m<sup>2</sup> can still result in fairly low ratios of private open space inadequate to accommodate sizable tree growth (Hall 2010). Rate of dwellings constructed from 1990 were calculated, the average being 33% of dwellings in each municipality, and the percentage of detached dwellings constructed from 1990 were also recorded. These results provide an indication of the availability of open space on private residential land and public open space. The amount of space available is one determinant of the recreational and environmental contributions open space makes to the built environment.

**Table 1:** Public open space, residential dwellings, percentage of detached dwellings and their lot sizes, projected population increases per municipality

Council	Public open space Ha per 1000 population	Average detached dwelling lot size M <sup>2</sup>	Number of residential dwellings	Number of detached dwellings	% of detached dwellings	Projected % population increase 2011-2031
<b>Inner</b>						
Maribyrnong	3.50	408	31569	21317	68	57.05
Melbourne	5.90	735	57720	8547	15	117.86
Port Phillip	4.00	273	56650	14008	25	38.85
Stonnington	1.70	562	48879	18407	38	33.47
Yarra	3.80	247	37481	19943	53	45.88
<b>Middle</b>						
Banyule	7.30	814	48346	34053	70	15.69
Bayside	4.50	693	38458	21485	56	17.07
Boroondara	3.40	732	66223	37979	57	17.18
Darebin	5.50	573	59049	34656	59	31.28
Glen Eira	1.30	649	57070	26550	47	18.88
Hobsons Bay	10.10	529	36004	26831	75	22.20
Kingston	4.90	620	60490	37184	61	21.44
Manningham	9.10	1212	43538	31962	73	17.04
Monash	4.40	715	67405	44501	66	17.60
Moonee Valley	4.60	548	47012	33566	71	28.34
Moreland	3.30	473	64315	38524	60	37.48
<b>Outer</b>						
Brimbank	8.90	630	67740	52659	78	15.04
Frankston	5.70	789	54059	39225	73	18.10
Greater Dandenong	3.60	621	50737	32710	64	33.33
Maroondah	5.60	878	42741	25638	60	20.22
Knox	7.40	835	56840	56096	99	14.88
Whitehorse	4.10	708	62256	39813	64	19.68
<b>Growth</b>						
Casey	7.80	671	91957	75519	82	65.44
Hume	10.40	1088	60475	49031	81	67.13
Whittlesea	7.80	630	64411	47992	75	99.33
Wyndham	5.70	619	69226	56697	82	45.88

Sources: Office of the Victorian Valuer General (2012), Victorian Environmental Assessment Commission (2011), Department Transport, Planning and Local Infrastructure (2014)



**Figure 2:** Public open space and rate of detached dwellings (median .65). Sources: Office of the Victorian Valuer General (2012), Victorian Environmental Assessment Commission (2011).

**Table 2:** Dwelling construction from 1990

<b>Council</b>	<b>Number of dwellings constructed from 1990</b>	<b>% dwellings constructed post 1990</b>	<b>Number of detached dwellings built from 1990</b>	<b>% detached dwellings constructed from 1990</b>
<b>Inner</b>				
Maribyrnong	9404	30	4996	53
Melbourne	35926	62	2308	06
Port Phillip	18402	32	2073	11
Stonnington	10948	22	2756	25
Yarra	8803	23	2347	27
<i>Total</i>	83483 (16.8%)			Median: 25%
<b>Middle</b>				
Banyule	12190	25	5520	45
Bayside	11399	30	4483	39
Boroondara	14574	22	6317	43
Darebin	13647	23	2924	21
Glen Eira	12862	23	2521	20
Hobsons Bay	12660	35	8369	66
Kingston	17606	29	9434	54
Manningham	11880	27	5066	43
Monash	17350	26	4833	28
Moonee Valley	10637	23	6284	59
Moreland	15353	24	5839	38
<i>Total</i>	150158 (30.3%)			Median: 43%
<b>Outer</b>				
Brimbank	26172	39	18195	70
Frankston	19009	35	11958	63
Greater Dandenong	9605	19	3609	38
Maroondah	12557	29	5345	43
Knox	17826	31	17809	100
Whitehorse	14317	23	4159	29
<i>Total</i>	99486 (20%)			Median: 53%
<b>Growth</b>				
Casey	56643	62	49753	88
Hume	29646	49	24372	82
Whittlesea	31517	49	24408	77
Wyndham	45398	66	41203	91
<i>Total</i>	163204 (32.9%)			Median: 85%

Sources: Office of the Victorian Valuer General (2012), Victorian Environmental Assessment Commission (2011),

## Discussion

The City of Melbourne has been excluded from this discussion. Melbourne, being the municipality encompassing the CDB, has significant tracts of parklands and areas of very high housing density,

ringed by lower density suburbs. The method of analysis has not been able to adequately capture these variations in spatial arrangements.

### **Inner municipalities**

All inner municipalities have low rates of public open space, and have significant population growth projections above 45%; the average across non-growth or CBD municipalities is 25%. Stonnington has significantly reduced rates of both public open space and detached housing; larger lot sizes mean that private open spaces potentially contribute a significant amount to the open space system, but are more likely to undergo infill development. Glen Eira, a middle municipality shows similar patterns. Maribyrnong, with closer to average rates of detached housing and lot sizes, has more balanced ratios of private and public open space; limited as it is with a low rate of public open space and smaller lot sizes. Private open space in Yarra and Port Phillip make less of a contribution to the open space system, with very small lot sizes, particularly in Port Phillip with very low rates of detached housing.

For Maribyrnong, low density 1:1 housing replacement (presumably with larger footprints) and lot subdivision may be impacting on the distribution of private open space more than other inner municipalities. Yarra, Port Phillip and Stonnington already have higher ratios of higher density housing. For these municipalities, the private open space configurations and contributions in higher density developments will be more integral to managing the overall open space system.

### **Middle municipalities**

Hobson's Bay, Moonee Valley and Kingston all have higher rates of detached dwellings being built than other housing types, indicating that low density infill is impacting on the distribution of private open space. This will affect the open space system more in Moonee Valley and Kingston with lower levels of public open space. Banyule and Manningham each have greater rates of public open space, a greater proportion of higher density dwellings and lower population growth projections in these municipalities may not result in significant additional pressures on the public open space system; though their large lot sizes could accommodate more intensive housing developments. Moreland, Boroondara and Bayside, with low levels of public open space, also face increasingly restricted and fragmented areas of private open space as a mix of detached and higher density dwellings have been constructed.

Recent development in Whitehorse, Monash and Darebin has been higher density dwellings; which may be severely limiting the availability of private open space in certain areas. Public open space in these municipalities may be contributing more to the overall open space system. Significant population growth is expected in all middle municipalities, but it is highest in Moreland, Moonee Valley and Darebin which will put pressure on their limited public open spaces.

### **Outer Municipalities**

Frankston, Brimbank and Knox all had above average rates of dwellings built from 1990, and high proportions of detached dwelling construction in that period, probably due to low density greenfields developments on the city fringes. Maroondah had slightly above average dwelling construction rates, and a higher proportion of higher density housing, but large blocks and significant public open space. Dandenong had a low dwelling construction, and also low percentage of detached housing, indicating moderate development of higher density dwellings. These results indicate that the outer suburbs have a strongly suburban morphology with private and public open space contributing equally to the open space system (with the exception of Dandenong), there is perhaps a greater capacity for infill development in these areas. Dandenong, however has the greatest population growth projections.

### **Growth Municipalities**

Growth municipalities are located on the fringes of the city; all the developments in these areas are greenfields. These results demonstrate that newer housing developments tend to have smaller lot sizes than older city fringe developments, restricting the availability of public open space agreeing with findings from Hall (2010) and Grose (2009). Public open space in these areas are developed to make significant contributions to the open space system. As these areas have not been fully developed, new developments will include new public open spaces.

## **Current policy implications**

Basic residential development standards mean that smaller lots don't need to provide as much private open space. In areas with predominantly smaller lots, or areas with significant proportions of the General or Residential Growth zones which allow for greater subdivision, the open space allocations are such that there may be wide tracts of residential land which when fully developed, will be unable to support trees with significant tree canopy sizes - with widths reduced to 3m, no single private open space area will be large enough to accommodate them. In contrast, some municipalities with larger lot sizes may have greater capacity for infill development whilst maintaining higher levels of open space, but current zoning prevents development. Coutts, Beringer et al. (2010) state that open space like parks with significant amounts of vegetation can provide a cooling effect on downwind areas, similarly, suburban areas with private open spaces with significant vegetation would enable similar localized cooling effects. For the open space system to deliver these and other ecosystem service benefits, open space, both public and private needs to be more evenly distributed across the suburban landscape. Population projections show higher growth will be focused on municipalities with low existing rates of public open space, and where in some cases, private open spaces currently make a significant contribution to the open space system.

This analysis of open space indicates that distribution is uneven, a predicament which will be exacerbated as higher density residential zones are applied around public transport routes and activity centres in clusters or tracts, and low density zones overlaying much of the greater suburban area. Neither take into account availability of nearby public or surrounding adjacent private open spaces. Conceptualizing open space as a social-ecological system may provide a basis for policy to readdress more stringent requirements of private open space in higher density developments, and consider the open space ramifications of residential zoning on the full open space system. In established suburban areas, public open spaces are fairly fixed within the existing morphology; acquisition or disposal of open space is difficult, land may not be available where additional public open space is required, land prices may be unaffordable for local governments and community support may be limited. Even if public space is distributed to provide recreational requirements for increased housing densities, for open space to reduce the urban heat island effect and to assist with storm water runoff, it needs to be considered in terms of ecosystem service provision at a localised level. From this point of view, while public parks and reserves may be able to provide adequate provision for health and recreation and can provide important ecosystem services, they most likely will not be able to replace private open space; but a mixture of public open space, private open space and public streetscapes may. Future open space planning will require an integrated approach across all land uses to be able to provide a socially and environmentally functional system that can incorporate population growth pressures and changing climatic conditions.

## **Conclusion**

This paper presented a basic analysis of the varying distributions of private and public open space across Melbourne. At a metropolitan scale, rates of detached housing, lot size and infill development trends provide sufficient indications of the types of open space pressures facing the inner and middle municipalities in Melbourne. Australian cities have significant proportions of open space spread over all land uses, but consolidation and infill policies are changing the distribution, functionality and use of public and private open space. While infill development is required to house significant future population growth, strategies need to be developed that fully incorporate the social and environmental services provided by open space across all land uses. Assessing the availability of all open space is required to enable this planning to occur. Further research is required into the spatial distribution of public open space, infill development and private lot sizes to assess open space availability at a more localized scale. Qualitative research into social and cultural processes of infill development and open space use and management should also be included to further understand open space as a social-ecological system; and will form the next stage of this research.

## **Acknowledgements**

The author would like to thank her PhD supervisors Peter Newton, Kath Hulse and Stephen Glackin, and the anonymous referees for their suggestions. This PhD research is a part of the Visions and Pathways 2040 project <http://www.visionsandpathways.com/>, funded through the Cooperative Research Centre for Low Carbon Living <http://www.lowcarbonlivingcrc.com.au/>.

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