Trends and spatial patterns of infill development in Melbourne Metropolitan local government areas
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Keywords: urban consolidation, infill development and GIS
Abstract
Urban consolidation has been featured in Australia for over twenty years as a growth management tool to accommodate an increasing population while reducing urban sprawl and preserving open space on the fringes. Although infill development (also known as dual occupancy) has long been possible, and over the present decade, encouraged under new urban consolidation policy, monitoring of the inevitable changes in residential urban form has not occurred. Thus decision support teams in strategic planning cannot offer detailed advice on the implications of the changed patterns of either changed population densities or changes to access to existing infrastructure and services. We report here the results of applying a data integration framework and tool for systematically detecting infill pattern changes, land parcel by land parcel, first devised and applied to data from the City of Monash. The synthesis presented here refers to infill mapping in different local government areas in the Middle and Outer regions of the Melbourne Metropolitan Area (MMA), including Monash, Knox, Casey, and Whittlesea local government areas. Thus the utility of infill mapping for urban development monitoring and urban planning can be discussed in reference to the MMA as a whole.
1 Introduction

The urban compact planning policy, also known as smart growth (in North America), compact city (in the Netherlands) (de Roo & Schneider, 1998), intensification (in the United Kingdom), and “urban consolidation” or “containment” (in Australia or New Zealand), has been promoted in many countries. Successful implementation of such policies reduces urban sprawl while preserving farmlands and/or designated open spaces on the city fringe and increases the efficiency with which return on investment in existing infrastructures and services is delivered. Thus policies about environmental sustainability can be better supported.

Implementation of urban consolidation planning policy commonly refers to the kind of residential development control administered at the local government area (LGA) land use planning office when appraising development permit applications designed to bring construction of (an) additional dwelling(s) on a particular land parcel. Approvals, resulting in infill development/ residential intensification have been sought regularly for some two decades in many, but especially longer-established suburban LGAs, lacking hitherto undeveloped land parcels. The ensuing population densification brings social, economic and environmental impacts. As previous studies in Australia show, the nature and pattern of social impacts of infill development are spatially and temporally variable (Bunker, Gleeson, Holloway, & Randolph, 2002; Buxton & Tieman, 2004). In the suburban regions dominated by the single dwelling on the “quarter-acre block”, local residents complain that infill development has/will destroy(ed) their streetscapes (Birrell, O’Connor, Rapson, & Healy, 2005). Other outcomes include drainage problems when the stormwater pipe network is over-taxed due to the increased area of effective impervious surface (McMahon et al., 2005; Yoo, 2005). The economic cost of infrastructure provision and transportation in redevelopment of 1000 dwellings in the inner city is found about half price of that needed to support conventional development in the fringe (Trubka, Newman, & Bilsborough, 2008).

The implementation of urban consolidation policies has engendered land-use planning conflicts. The protagonists are the urban developers, the relevant local government authority and the affected neighbourhood residents/rate-payers/voters. Thus the policy falls in and out of favour, here and there. In any case, the strategists behind the policy will need to monitor the rate and mode in which implementation comes to practice. Clearly the identification and monitoring of changes to the infill pattern is part of this. Essentially, this information should be available at a detailed scale because the local planning decisions are made, land parcel by land parcel (Evans & Emilio, 2002).

However, to date, only a few studies characterising the spatial distribution of infill development have emerged. So far, most studies have examined urban consolidation or infill development using an aggregation of the basic census collection spatial unit, such as at the census collection district or aggregations of these spatial units (e.g. LGA by LGA). Many previous research projects have been focused upon the social aspects of urban consolidation, such as housing prices and housing affordability (Bunker et al., 2002; Searle, 2003; Yates, 2001). Improvements in data collection (Holloway & Bunker, 2003), analysis, and interpretation (Chhetri et al., 2008) are recognised as still needed in aid of increased understanding, and improved monitoring and assessment of the effectiveness of the urban compact development policy. Published research results from overseas have shown the necessity and demonstrated the relevance of applying a quantitative approach in urban consolidation policy.
evaluation (Talen, 2003). Adoption of a quantitative approach enables the translation of policy implication into numerical (and mappable) measures, as well as the use of visualisation of temporal and spatial development patterns. Thus communication between stakeholders is facilitated and land-use conflict resolution better served.

In Victoria, the urban development program (UDP) conducted by the Department of Planning & Community Development (DPCD) has, since 2004, involved annual mapping of development tracts (containing 10 or more dwellings) for each of the thirty one LGAs in the Melbourne Metropolitan Area (MMA) (DSE, 2008). Thus, the scale and extent of smaller number of dwellings in infill development sites with fewer than 10 dwellings, for instance as reported to be characteristic of some MMA suburbs (Birrell et al., 2005; Phan et al., 2008), has not been fully documented. In addition, the physical characteristics of urban form, such as building layout and its location relative to the infrastructural network are not examined much. Such a methodological gap in knowledge inhibits our understanding of the relationship between urban consolidation planning policy and practice.

In previous studies by the authors, it is argued that data integration is pre-requisite to documenting the roles of urban planning policies on shaping urban form, especially with reference to the latest Victorian state land use strategic planning policy, Melbourne 2030 (released in October 2002) (Phan et al., 2008, 2009). The objective of this paper is to describe and compare the extent of infill development between four selected Local Government Areas, namely Monash, Knox, Casey and Whittlesea, thereby exemplifying the utility of GIS-based parcel infill mapping and census data for urban development monitoring and urban planning in the MMA.

2 Methodology
2.1 Study areas
Four LGAs in the MMA are selected in this study to understand the extent and scale of new residential development. These are selected to represent:

- a range (Middle and Outer regions in the MMA) of distances from the Melbourne Central Business District (CBD)
- areas subject to densification (population and dwellings) in the 2001-06 period (see Table 2 and Table 3)

Overview of these LGAs is presented as follows.

The City of Knox is an Outer metropolitan municipality located about 25km east of the Melbourne CBD. Its urban environment is surrounded by a variety of significant natural features, including Dandenong Creek to the north and west, the foothills of the Dandenong Ranges to the east, and Lysterfield Park and Churchill National Park to the south. Three Creeks including Blind Creek, Monbulk Creek and Corhanwarrabul Creek provide waterways and stretches of linear parkland through the centre of the municipality (Knox City Council, 2004). The challenge for urban planners and policy makers is to balance housing development with environmental protection of the Dandenong foothills, and preservation of the neighbourhood character of residential suburbs and of the City’s green leafy image (Knox City Council, 2005).

[Insert Figure 1 of study area here]

The City of Whittlesea is about 20km north of the Melbourne CBD. It is surrounded by the Shires of Mitchell and Murrindindi in the north/north-east, the Shire of
Nillumbik in the east, the Cities of Darebin and Banyule in the south/south-east and the City of Hume in the west. Being settled by the European settlers in the early nineteen century, the area provided agricultural products to Melbourne markets as well as water for Melbourne’s first large water storage, the Yan Yean Reservoir. The City features both considerable rural areas and some urbanised areas. It is one of Melbourne’s major growth areas with significant future growth expected (City of Whittlesea, 2006).

The City of Casey (813.3 km$^2$) is one of most rapidly growing regions in the fringe regions of the MMA. Early European settlement occurred in the late 1830’s, at much of the same time as settlement of the Melbourne CBD. Over many years, pastoral activities dominated the local economy. Local urban development referred to neighbouring shires, Cranbourne and Berwick (proclaimed as cities in 1993 and 1994, respectively). The modern extent of the City of Casey refers to a 1994 amalgamation that annexed parts of the former cities of Berwick and Cranbourne, (formed in the late 1860s) and a small part of the City of Knox (City of Casey, 2008). The City of Casey is one of the key growth areas in the MMA. Its population increased by more than 41 thousand persons (22.65%) between 2001 and 2006 (Table 2). In absolute terms, Casey showed the largest Australian inter-censal population growth (2001 and 2006) (DSE, 2007a). The concomitant dwelling number increases are attributed to many factors, some of which are: strong national economy, growth in household incomes, low interest rates, and population growth (DPCD, 2007a). The City of Casey is located in the Southern Region in the MMA. Regional environmental amenity and liveability attributes include proximity to the Dandenong Ranges, bays and beaches, rural areas, and accessibility to the townships and settlements within green wedges and developments such as golf courses (Southern Regional Housing Working Group, 2006).

The City of Monash (81.5km$^2$) is located in the south eastern suburban region of the MMA, between about 13 and 24 kilometres south-east of the Melbourne CBD. The City of Monash is a predominantly residential areas, with considerable amount of industrial, commercial and recreational areas (City of Monash, 2009). The European settled in the area in the 1840s. Its land uses were predominantly grazing, market gardens and orchards. Substantial residential development occurred in the post-war period accompanied by industrial growth. Additionally, considerable housing development occurred around the railway lines during the 1960s and 1970s (City of Monash, 2009). It is expected that future Monash City housing development will be dominated by infill which existing residents are keen to conformable to styles of existing neighbourhoods while inevitably increasing the variety of different housing styles so as to serve the state public policy favouring densification (City of Monash, 2006).

2.2 Data pre-processing

Definition of infill and redevelopment sites is pre-requisite to identifying the data-mining path to their identification such that change monitoring of patterns can take place (Knaap, 2004, p.23). Many terms have been used interchangeably in urban consolidation policy discussion and debates, namely medium density housing, multi unit housing or higher density housing (Buxton & Tieman, 2004). The Department of Infrastructure Municipal Fact Sheets in 1998 define medium density housing as exhibiting more than one dwelling on a lot (Buxton & Tieman, 1999, p.2). Apart from this, in The Good Design Guide document, one dwelling on a lot less than 300m$^2$ was
also defined as belonging to the medium density housing. For mapping and monitoring residential development patterns, the essential analytical input spatial data refers to: the number of demolitions, the number of new units on partially vacant land, and the number of new units on developed land (Knaap, 2004). When these data is unavailable, surrogate datasets, such as building permit approvals and indicators of the number of semi-detached, units and flats have also been used (Bunker et al., 2002; Buxton & Tieman, 2004; Healey & Birrell, 2004).

In terms of the definitions applied by planners in Victoria, Australia in reference to statutory planning rules and the urban consolidation policy, infill development is defined as when:

- a house is demolished and replaced by two or more dwellings, or
- (an) additional dwelling(s) are built on a site that already contains a house, or
- where an existing detached house is demolished and replaced by another detached house (probably one with more bedrooms) (Department of Infrastructure (DOI), 2000).

Thus, as previous studies demonstrated (Phan et al., 2008), infill development sites can be identified by identifying land parcels with no more than one dwelling in a given year (says 2000) but more than one sometime after (says 2006). The progress of infill development can become a part of monitoring the way the urban consolidation policy expresses itself in practice. Mapped at land parcel scale allows customised aggregation (e.g. to LGA) if desired.

Key spatial datasets used in this study include the cadastre; address point, local government planning schemes, the public transport network and road datasets. They are acquired from Victorian Spatial Archive under Monash University license. The steps to identify infill development are described in our previous study (Phan et al., 2008, pp.24-26), thus only key points need to be interpreted in this paper. Data analysis LGA by LGA was facilitated by a mapping tool, Infill, we developed using a Visual Basic Analysis (VBA) language within the ArcGIS environment (ESRI, 2007). It is, at present, customised for comparing the situation in 2000 with that in 2006. User friendly dialogue boxes with drop-down menus are provided. The first selection is for identification of the LGA to be examined (Figure 2). Then the attribute value of planning zones in that LGA for 2000 and 2006 will pop up. For identifying residential infill development, the map of residential zones must be called for. These include Residential zone (R1Z, R2Z, and/or R3Z), low residential zone (LRDZ), and mixed use zone (MUZ). Infill development land parcels are then selected by clicking “Select Infill Sites” box. These selected sites are then validated with on-screen comparison with aerial photos different years from the late 1999 to 2006 and Google Earth version 5.0 images.

[Insert Figure 2 of Infill Pattern Tool here]

In order to examine the housing development in LGAs, infill development sites are incorporated with the UDP datasets (Figure 3). The UDP datasets include location of Broadhectare and major redevelopment sites in each of thirty one LGAs in the MMA (DSE, 2004). The Broadhectare land is defined as undeveloped land, normally found on the fringe of the MMA, and designated for residential development (DSE, 2004). From the archive for these datasets (reported annually since 2004) a time-series account of such development is available: some of them (in 2005 and 2006) are downloadable in GIS format. Our 2004 dataset was digitised from UDP 2004 maps, which were downloaded from the UDP website (DSE, 2004).
The results are classified into three housing development groups as follows:

- **Dispersed Development**: development within established urban areas, remaining major redevelopment sites not well-located for major public transport, and non-urban residential development. Non urban development is generally located in an around small townships.
- **Strategic Development**: development within 400 meter of designated activity centres (DOI, 2002a, p.8) and of Principal Public Transport Network (PPTN), and 800 meter of railway stations along the PPTN (DSE, 2006). PPTN refers to bus and rail services which are 15 to 30 minute frequency.
- **Greenfield Development**: undeveloped land identified for residential or industrial or commercial development, generally on the fringe of the metropolitan area. In this study, infill development sites or Broadhectare sites are within Growth Areas, but not being designated for strategic development, are classified as Greenfield development.

We choose these classes because under *Melbourne 2030*, it is expected that the Greenfield development and dispersed development will reduce from 38% in 2001 to 31% and 28%, respectively in 2030 whilst strategic development increases from 24% to 41% (DOI, 2002b, p.8). Thus these housing development classes can be used to reveal the different rate and extent of different housing development classes LGA by LGA. The influence of urban consolidation planning policy, *Melbourne 2030*, on such urban form change can then be referred and discussed.

3  **Results of applying the tool**

3.1  **Spatial Location of Infill development and residential intensification**

The outcomes of applying the *Infill* tool to the necessary input data pertaining to Monash City and Casey City and Whittlesea City and Knox City are presented in Figures 4-7. As for our previous study (Phan et al., 2008), the number of dwellings per re-developed land parcel are presented in five classes. By plotting infill development sites, major redevelopment sites and Broadhectare sites from the UDP with transport networks and designated activity centres, the relative location of residential intensification between 2000 and 2006 can be observed. While in cites of Monash and City of Knox, small scale of infill development (2-7 class) is dominant, City of Casey and City of Whittlesea have a considerable number of higher intense infill development (78+ class). In City of Monash, major redevelopment sites are in the highest intense group (78+class) whilst in Cities of Whittlesea or Casey, broadhectare sites are formed in this class. The number of infill development or redevelopment within 400 meter and 800 meter of major and principle activity centres are also seen to vary both intra and inter LGAs. A descriptive summary of each development types is presented in the next section.

3.2  **Scale and extent of residential intensification**

As can be seen from Table 1, Cities of Whittlesea and Casey has the highest percentage of Greenfield development (about 68% of all development), followed by
Knox (14.66%). In contrast, City of Monash has one of the highest proportions (nearly 60%) of dispersed development in the 2000-06 period followed by the Cities of Knox (55.5%), Whittlesea (22%) and Casey (5.43%). The City of Monash ranked the first in strategic development class (41%) whilst City of Whittlesea had a lowest proportion of strategic development sites (9.85%).

4 Discussion and Conclusions

4.1 The utility of GIS in parcel-based infill development mapping and identification

The intercensal period 2001 and 2006 (Table 2) ABS data shows that all four LGAs are growing; a measure of increased demand for dwelling space in the MMA. Given the nature of Victorian government policy about land use planning, accommodation must be partly by infill development. In terms of urban residential form monitoring, some interest will attach to documenting the relative significance of this kind of accommodation in each LGA. This study shows the more detail that can be brought to the analysis, the better the policy-to-practice appraisal can be and the better the decision support that can be offered.

In this study, infill development and residential intensification is examined in terms of land parcel-by-land parcel (2000 cadastre) dwelling number increases between 2000 and 2006. This is different from the approach of Buxton and Tieman (2004, p.41), in which intensification or densification was identified from the development permit records. This is a very direct but expensive and time-consuming approach because the permit records are not easily accessible.

By using land parcel as a spatial unit for mapping and analysis in this study, the extent and location of infill development can be identified at a much more detailed scale than by using the traditional aggregated (e.g. census collection unit; ~230 dwellings at a time (ABS, 2006)) data. Our Infill tool facilitates systematic identification of dispersed infill development in the established urban areas. Integrated with broad hectare land development and major site redevelopment (as reported annually from the UDP) the data offers urban planners and decision makers a chance to understand and monitor the trends and patterns of different densification types. As presented in Table 1, densification patterns and types varied from one LGA to another. The exemplification presented here represents a range of MMA LGA types in terms of urban residential form. Documentation of such geographical variations in urban residential form can be explained in terms of market demand on the one hand and response to urban consolidation policy on the other. Data accumulated from monitoring the pattern changes, would be deployed not only in decision support for up-dating the policy, but also in predicting the potential for infrastructure/facility failure due to a need for up-grade to meet increased demand (e.g. on facilities and on network infrastructure: e.g. storm water, sewerage, and transport).

Non-LGA sources maintain and supply much of the data from which were made the infill maps (Figures 4-7). Routine application of the approach developed for the research reported here would require data custodians to agree to share and maintain the data needed to sustain the data flows that support the mapping approach. Incentives include the chance to share the other application of the data, such as visualisation.
4.2 The utility of the infill pattern map for proximity analysis in urban planning policy monitoring and evaluation

From spatial analysis of infill development patterns vis a vis principal public transport networks and activity centres it is seen that infill development is more likely to be randomly scattered in relation to facilities and services in those LGAs that lack greenfield development sites. On the other hand, the new settlement patterns in LGAs with extensively re-zoned Greenfields seem to be settled well ahead of the provision of facilities. The high value of Greenfield development in Casey and Whittlesea indicates that much residential development has taken place beyond 400 and 800 metre walking distance to public transport networks and activity centre buffer zones mentioned in the Melbourne 2030 planning policy. This suggests that plans for improvements of public transport networks and services especially in the fringe areas need to be advanced or formulated or re-formulated: they will surely refer to upgrading of bus routes and bus stops and/or upgrading to service frequency.

4.3 The utility of infill pattern mapping with census data for understanding housing development and socio-economic issues arising from densification

In comparison to census data analysis, the added information value provided by the detail in the infill allows urban growth monitoring to be conducted at an inter-LGA and intra-LGA level of analysis. Table 3 shows that both the number of detached dwellings and, attached dwellings and flats (i.e. medium density dwellings) in the City of Knox grew positively by 1500 and nearly 2000 dwellings, respectively, in the last intercensal period. In the City of Monash there was decline in the total number of detached dwellings whilst the number of medium density dwellings increased by 3000 in the same period. It is noticed that for the fringe cities of Casey and Whittlesea (in the East and the North respectively) there was a bigger increase the number of dwellings, detached dwellings (12,000 and 4,000, respectively) compared to growth in medium density dwellings. To illustrate diversity in response to the urban consolidation policies, and as Figures 4 to 7 show, residential intensification in Monash is predominantly as dispersed infill development (i.e. adventitious re-development, residential land parcel by land) whereas for the other three LGAs, especially Whittlesea, residential development is by larger incremental the size according to land use re-zoning of large land parcels. It is clear from these Figures and Table 1 that on the MMA fringe, it is Greenfield development that is still dominant. Thus, on the periphery today, we see some parallels in the pattern of housing development that applied in the Knox City between 1996 and 2001 when housing growth accounted for 42% (Greenfield sites) and 38% (existing residential land parcels) of total new housing development in the Knox City (Knox City Council, 2005).

Access-to-facilities analysis in Casey and Whittlesea reveals that the dominant urban consolidation response pattern in the MMA fringe cities is Greenfield development. This also suggests that the need for transportation infrastructure and services are not yet adequately provided in the new development areas. According to the census datasets, in the journey-to-work experience for ratepayers in Casey and Whittlesea is dominated by personal automobile use, whilst for Monash or Knox city ratepayers trains, buses and the footpath network seem to relatively accessible. On the other hand, recent research results (Wood et al. (2008)) found that the cost of detached dwellings in the fringe cities, which are not necessarily close to public transport
networks or Principal Activity Centre, rendered them more immediately affordable for low-income families.

In this paper, we used orthophoto mosaics (between 1999 and 2006) to validate the mapped infill development pattern as derived from data integration using the relevant street address files. However, the comparatively low resolution (~ 2meters) of the 2001 mosaic imposed some ambiguities when enumerating the number of dwelling(s) on some of the land parcels. Another limitation of our approach refers to identification of infill development sites in established urban areas. As defined in section 2.2, the mapping of infill or re-development between 2000 and 2006 refer to the base-line land cover pattern, land parcel by land parcel, provided by the 2000 cadastre overlain on the relevant orthophoto map. Data integration using street address files would show that if a residential land parcel was vacant in 2000, it will be assumed to have a single dwelling on it and so if there is a single dwelling depicted on the 2006 ortho-photo mosaic it will not be counted as a new dwelling. However, the ortho-mosaics are snap-shots. It can be assumed that any vacant residential land parcel that is vacant is soon likely to change status in these terms. We found that in a suburban LGA like City of Monash, there were only a few circumstances that land-cover change detection showed that it was a single house depicted on the 2006 photo occupied a vacant 2000 land parcel, as depicted on the air-photo mosaic of that year. We found that such changes were more likely to be seen from analysis of changing patterns in fringe/outer LGAs like the City of Whittlesea, but, again, once land-use re-zoning to residential use takes place, building (and additions to the street address files) are soon to follow.

From this study, exemplification is available for use in monitoring compact city infill development and the pattern of validity in claims that it will promote a more efficient use of land and community infra-structure in existing residential areas, and as a result, environmental sustainability is enhanced while accommodating the need to house a growing population without adding to urban sprawl and the violation of (locally, much valued) green wedges. Our results may be used in furthering debate about such matters, and as background information for review of both strategic and statutory planning as applied to further the policy and mitigate the effect of unplanned outcomes. Future work might include social surveys in areas of infill development (for example as in a case study by Eccles, 1991) to understand the social profiles of infill development houses in ways that will help people decide whether infill housing is for them. In addition, it is probable that image data processing could be automated in object-oriented mapping to speed up the validation process, thus adding incentive for the approach pioneered here to be routinely adopted during in development permit application appraisal as well as urban form change monitoring.

It can also be mentioned that data derived from monitoring residential urban form change adds scope for deployment not only of visualisation techniques configured to promote consensus building among stakeholders, but of spatial statistics (Cuthbert & Anderson, 2005; Paez & Scott, 2004) in the search for mapping the relative significance of drivers of infill and/or re-development.

5 Acknowledgements
The authors would like to thank Faculty of Arts and Monash Graduate Research School, Monash University for financial support of this project. We thank Centre for GIS, School of Geography & Environmental Science, Monash University for
providing necessary facilities and datasets. Also, great thanks to staff at Victorian Spatial Data Infrastructure, Department of Sustainability and Environment and GIS Officers in Melbourne Local Government Councils for granting access to data and for their help in understanding the data lineage and structure.

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- Google Earth images

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- Activity centres
- Principal Public Transport Network

Proximity analysis
- Residential Intensification
  - Greenfields
  - Strategic development sites
  - Dispersed Development

Urban Development Program (2004-2007)
- Broadhectare
- Major redevelopment sites

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Table 1: Summary of residential intensification in four LGAs between 2000-06

<table>
<thead>
<tr>
<th>Classes</th>
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<th>Knox</th>
<th>Casey</th>
<th>Whittlesea</th>
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<td></td>
<td>Total</td>
<td>Total</td>
<td>Total</td>
<td>Total</td>
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Table 2: Summary of total population (estimated population) in 2001 and 2006 in different Local Government Areas

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Table 3: Summary of dwelling types in each LGAs in 2001 and 2006

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Source: City of Monash, Whittlesea, Knox, & Casey, Community profile

6 References


National Biennial Conference of the Spatial Sciences Institute, September, Melbourne.


