Spatial analysis of residential urban form changes: a detailed-geography approach to monitoring results of urban consolidation policy, exemplified for the Melbourne Metropolitan Area.

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Abstract

The study results reported here refer to devising improved ways of monitoring the considerable urban residential form changes that have resulted from implementation of the Victorian urban consolidation policy during the intercensal period 2001-2006. The policy applies to the Melbourne Metropolitan Area (MMA) and was designed (among other things) to de-emphasise urban sprawl while facilitating the construction of new dwellings during a time of rapid population growth. Thus, accommodation has involved not only greenfield land development but also population densification via brownfield and infill (re)development in Local Government Areas (LGAs) that were first populated during earlier city expansion phases when the extent of the metropolitan area was smaller than today. The policy is designed to improve the return on investment in existing infrastructure and services, as well as housing affordability and residential liveability.

Most of the infill has taken place in the suburbs that were zoned/designated greenfield sites four to five decades ago. Here, both strategic (redevelopment around designated activity centres and around principal public transport networks) and dispersed "infill" development have been facilitated in policy implementation. Most of the "infill" is in the form of backyard developments/land-parcel-sub-division or replacement of old housing to make room for two or more new dwellings. The pattern of change due to this indicates that it has evolved as opportunity presented itself in a booming MMA land and property market. This "retro-fit" of extra dwellings is such that the capacity of some extant infrastructural (e.g. the storm water pipe network) and social service (e.g. schools and clinics) assets may be exceeded while that of others (e.g. the transport network) is likely to become better exploited.

In contrast, the liveability and social sustainability of dwellers in newly-developed greenfields is dominated by the lack of access to the public transport network and further distance to public services (i.e. schools and public hospitals). A high level of automobile dependence is imposed on them by the persistence of the traditional urban sprawl approach to land-use planning, even though semi-detached houses and apartments have become included in the dwelling stock, thereby mitigating this tendency somewhat.

In all cases of residential urban form change, the social, institutional and environmental impacts spawn a need for site selection for implementation of targeted mitigation measures. The pre-requisite for this task is detailed residential urban form mapping and monitoring. However, at policy launch, and even after eight years of implementation, the traditional approach to urban growth analysis using spatially-aggregated data had not been complemented by the detailed geographies that would serve the necessary monitoring. Thus geographical variation in the pattern of urban form change across a metropolitan area accommodating nearly four million people and governed by thirty one local government areas (LGAs) is undocumented in terms of the pattern of relative significance of greenfield, brownfield and infill development. Accordingly, both statutory and strategic decision support systems lack data and information that would serve them well.

The lack of adoption of the full power of digital spatial data handling implied by this, is

despite the fact that the various Australian state geographical data coordination committees charged with promoting the analogue-to-digital conversion of public sector mapping were established nearly two decades ago. By way of mitigation, the study reported here is designed to develop a Geographical Information Systems (GIS) parcel-based method for identifying and mapping the extent and location of infill development using various spatial datasets acquired and accessible from local and state government departments. Thus has emerged a method for detailed mapping of not only the pattern changes in the infill development pattern, LGA by LGA, but also the pattern of social impacts, identifiable in terms of census geography. Project results (e.g. as summarised in thematic maps) show that the success of *Melbourne 2030* implementation varies across the MMA. For the study period, the trend was that LGAs offering room for new dwellings by brownfield and infill re-development did not see Activity Centres favoured by infill developers. Accordingly, such data integration and analysis as exemplified by this study will be useful in both strategic and social planning, because in both cases, it is important to monitor the actual outcomes for comparison with policy goals. In addition, those involved in site selection and prioritising for the provision of new or up-graded infrastructure, facilities and amenity can be better informed and, thereby, more effective.

It is shown that the data streams currently accessible to LGA planning departments in the cities dominated by residential areas established four or five decades ago support the application of spatial statistics and modelling in ways that would allow the relative significance of driving forces and of densification impacts to be derived if the necessary data sharing arrangement can be established. Indications from the present study are that dwelling renewals within a 600 to 800 meter zone buffering the railway stations, or 400 meters of activity hubs like Colleges/University, define most of the infill developments, and that this is more marked if the re-developed housing stock is old enough to have been part of the traditional post WWII quarter acre block greenfield developments. Clearly, those interested in predicting future (opportunistic) infill pattern change trends will be planning spatial queries dominated by interest in documenting the condition (including age) of housing stock in the vicinity of transport network nodes.

Adoption for decision support up-grade for further implementation of *Melbourne 2030* may be inspired by this study. However, it requires that the stakeholder representatives (e.g. LGAs, community associations, and state government authorities) can agree to sharing the necessary data maintenance and processing costs. It is argued that there is no longer any reason for the detailed geographies exemplified here to be ignored in urban residential form change monitoring in Melbourne, or any other metropolitan area faced with accommodating population growth while maintaining livability without unmitigated urban sprawl with its continuous call for infrastructure subsidy.

Declaration

Monash University

Monash Research Graduate School

Declaration for thesis based on conjointly published or unpublished work

General Declaration

In accordance with Monash University Doctorate Regulation 17 / Doctor of Philosophy and Master of Philosophy regulations the following declarations are made:

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed:…………………………………………………………………………………….

Date: ………………………………

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The Author's peer-reviewed Publications

Journal Papers

1. PHAN, T., PETERSON, J. & CHANDRA, S. (2008) Urban infill: extent and implications in the City of Monash. *People and Place,* 16**,** 23-31.
2. PHAN, T., PETERSON, J. & CHANDRA, S. (2009a) Residential Intensification In A Suburban Fringe Local Government Area, Casey, Melbourne Metropolitan Area, Australia. *Australasian Journal of Regional Studies,* 15**,** 81-100.

Conference Papers

3. PHAN, T., PETERSON, J. & CHANDRA, S. (2008) Residential intensification on a suburban fringe local government area in the Melbourne Metropolitan Area, Australia. *People, Place and Space: Rethinking Regional Policy Agendas* 30th Nov- 3rd Dec 2008, Adelaide, Australia.
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5. PHAN, T., PETERSON, J. & CHANDRA, S. (2009b) Trends and Spatial patterns of infill development in Melbourne Metropolitan Local Government Areas. *States of Australian Cities* 24th-27th November 2009 The University of Western Australia, Perth.

List of Abbreviations

CBD	Central Business District
DT	Development tract
GIS	Geographical Information Systems
LGA	Local government area
MMA	Melbourne Metropolitan Area
MMBW	Melbourne Metropolitan Board of Works
MMPS	Melbourne Metropolitan Planning Scheme
MRS	Major Redevelopment Sites
PPTN	Principal Public Transport Network
UDP	Urban Development Program
UGB	Urban Growth Boundary
VPP	Victorian Planning Provisions (VPP)

1. INTRODUCTION

1.1. Problem statement

The urban compact planning policy, also known as smart growth (in North America), compact city (in the Netherlands) (de Roo and Schneider, 1998), intensification (in the United Kingdom), and "urban consolidation" or "containment" (in Australia or New Zealand), has been promoted in many countries over the world. This serves to reduce urban sprawl and to preserve farmlands and/or designated open spaces on the city fringe and to bring greater efficiency in use of existing infrastructures and services. Thus environmental sustainability to which many public policies refer becomes more credible. Policy implementation in terms of urban consolidation in residential development is supported by local government area (LGA) land-use planning policy by allowing (an) additional dwelling(s) on already-developed land parcels. This phenomenon, usually named as infill development (a form of residential intensification is occurring within the boundaries of many Australian Local Government Areas (LGAs), especially in the older suburbs, where the availability of vacant land parcels is limited.

Infill development has social, economic and environmental impacts. On the contrary, the pattern of residential urban form change varies from LGA to LGA and time to time (Bunker *et al.*, 2002, Buxton and Tieman, 2004a). In Melbourne, Australia, for instance, residents in long-established suburban areas (commonly exhibiting only a few of any "high-rise" housing complexes) often formally oppose infill development (e.g. through the Victorian Civil and Administrative Tribunal (VCAT): http://www.vcat.vic.gov.au), as they believe that the streetscapes can be destroyed (Birrell *et al.*, 2005b). Other outcomes include drainage problems that arise when the stormwater pipe network is over-taxed due to the increased area of effective impervious surface (McMahon *et al.*, 2005, Yoo, 2005). However, in terms of infrastructure cost, redevelopment of 1000 dwellings in the inner city is reported as costing only half the price as that needed to support conventional development on the fringe (Trubka *et al.*, 2008). Despite these social, environmental and economic impacts, little information about the location and extent of infill development has been assembled (Birrell *et al.*, 2005b). As a result, monitoring of policy implementation is inhibited. For effective monitoring, it is necessary to identify and quantify the location and extent of infill development so that the local impacts of such development can be examined (Bunker *et al.*, 2002, Holloway and Bunker, 2003), and, if necessary, mitigated. Improvements in data collection (Holloway and Bunker, 2003), analysis and interpretation (Chhetri *et al.*, 2008) are still needed in aid of understanding, improved monitoring and better assessment of the effectiveness of the urban compact development policy. Thus, the main pre-requisite of this study is to identify the flow path of spatial data needed for mapping and identifying the location of infill development in Melbourne Metropolitan Area (MMA) (Figure 1.1).

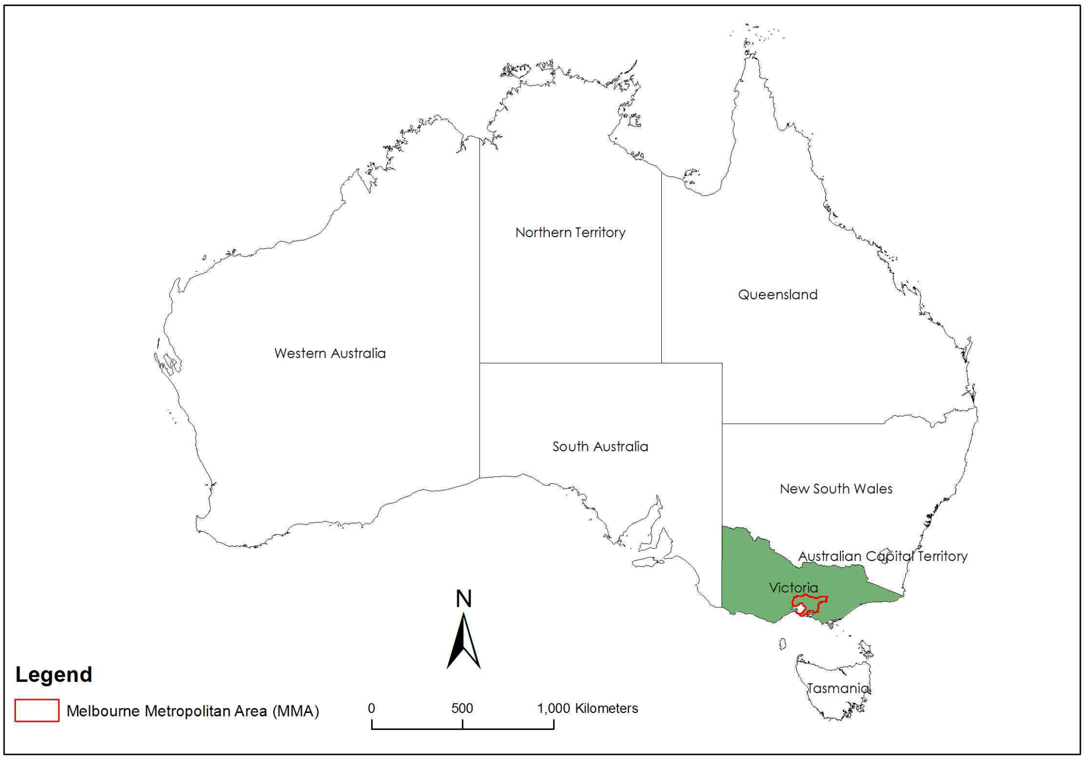


Figure 1.1: Spatial location of the Melbourne Metropolitan Area

Urban consolidation policy comes as a "retrofit" solution to some of the problems that have developed from long pursuit of the rather *laissez-faire* approach to urban planning that has characterised recent neoliberal thinking. Its legacy has seen overstretched calls for ever-more-expensive community infrastructure on the one hand, and popular (somewhat of the not in my backyard (NIMBY) type of) opposition to infill on the other. International and national research has reported that conflicts between urban developers, local government authorities and neighbourhood residents have often arisen (Farris, 2001, Haughey, 2001, Lewis, 1999, Wheeler, 2001). Accordingly, both planners and politicians will appreciate better flows of information via better monitoring of densification patterns when assessing community reactions to densification policy implementation. As a result, the policy and its mode of practice can be formulated and re-formulated to minimise land-use conflict, and maximise compatible densification and use of existing infrastructure, while at the same time facilitating overall growth, especially during times when urban areas are economically expanding and attracting a steadily-growing population of taxpayers. As stated in the Implementing *Melbourne 2030* section (DoI, 2002e, p.169)

> ” While the Strategy itself is a policy framework that will guide decision-making over the long term, ensuring that it remains robust and relevant to public and private decision-makers is an ongoing task –one that will rely on regular monitoring and review of trends, and on feedback as initiatives are implemented.”

From a land supply perspective, identification of the location and extent of major redevelopment projects within already developed areas assists the Victorian Government in monitoring trends in project size, built form, and identification of dwelling yield in the MMA. Such monitoring is needed in measuring the capacity of these established areas to accommodate future housing growth (DSE, 2009b) and thereby, the relative success, LGA by LGA, of the urban consolidation policy can be examined and understood.

Information needed to sustain such monitoring refers to urban form residential pattern changes at a scale as detailed as at the land parcel level (Chapin *et al.*, 2008, Hasse and Kornbluh, 2004) because many local planning decisions are made based on land parcel boundaries (Evans and Emilio, 2002, Moudon and Hubner, 2000). For instance, land subdivision or approval of building permits takes place land parcel by land parcel. However, to date, there have been few attempts to characterise the spatial distribution of infill development. It is acknowledged that efforts to monitor outcomes of planning for growth management in metropolitan regions suffers from inadequate evaluation methodologies (Carlson and Dierwechter, 2007) and scarcity of information needed undertake these studies (Talen, 1996a, Weitz and Moore, 1998). Historically, there was a lack of evaluation and monitoring of planning policy in Victoria, Australia. This can be partly attributable to the lack of requirement for plan monitoring and review (McLoughlin, 1992), or a failure to frame plans in reference to theory (Reade, 1987). Monitoring and evaluating the effectiveness of the implementation of dual occupancy policy[1] in Victoria is not much evident after decades of dual occupancy implementation (Mitchell, 1999b). Few social impact studies of the latest state-wide strategic urban consolidation planning policy in Australia have been reported (Randolph, 2006). In fact, research on the influence of the strategic urban planning policy favouring densification in Australian Metropolitan Areas of Brisbane, Sydney and Melbourne commenced only recently (Randolph, 2006).

Some information about infill development has been available for some time (e.g. Breheny, 1997, Eccles, 1991) and some dates from more recent times (e.g. see Ancell and Thompson-Fawcett, 2008, Lilley, 2006, Vallance *et al.*, 2005). All including the more recent information is qualitative rather than quantitative in nature. Moreover, the input data for these previous analyses is aggregated, census collection district (CCD) by CCD, or even more aggregated (e.g. LGA by LGA). Internationally, previous researchers have shown the necessity and demonstrated the applicability of adopting a quantitative approach to urban plan evaluation in general (Talen, 1996a, Talen, 2003) as well as to urban consolidation plan/policy evaluation in particular (e.g. Burton, 2000). Such a quantitative approach enables the translation of policy implications into numeric measures, which, together with the use of visualisation of temporal and spatial development patterns facilitates communication in aid of consensus building and conflict resolution among stakeholders. Quantitative methods can be used in plan evaluation, which involves comparison between the plan's blueprint and reality. Thus information about impacts, success and pitfalls of any particular planning implementation can be assembled (Brody and Highfield, 2005).

Closer monitoring is seen to be advantageous once it is recognised that there are many factors that influence the spatial distribution of infill development. These include the availability of potential infill sites (Landis *et al.*, 2005), the willingness of residents to move into infill development dwellings, the willingness of investors and developers to build infill development dwellings (Birrell *et al.*, 2005b), and the planning policies and their implementation from and by the state and local authorities that are responsible for their administration (Bengston *et al.*, 2004, Buxton and Tieman, 2004a). Many international studies have examined relationships between these factors and residential

[1] Dual occupancy refers to the development of two separate dwellings on a single allotment. It was initially formulated by the Victorian Ministry of Housing in the late 1970s as a housing option and policy under the Victorian urban consolidation policy (Mitchell, 1999)

development patterns (e.g. Hu and Lo, 2007, Landis and Zhang, 1998a, Shen and Zhang, 2007, Smersh *et al.*, 2003). They are part of the social, economic and environmental impact assessments of urban growth policies in general or urban consolidation polices in particular. They are designed to provide valuable information for decision support systems. However, up-to-date and quantifiable information on the spatial distribution and the relationship between each factor and infill development is not yet available for the MMA (DSE, 2008). So far, most research results available in planning decision support and urban studies relate to the social aspects of urban consolidation, such as housing prices and housing affordability (Bunker *et al.*, 2002, Searle, 2003, Yates, 2001). The physical characteristics of urban form, such as building layout and its relative location with infrastructural networks are no more than superficially examined. This knowledge and information gap refers to both methodology and an understanding of the relationship between urban consolidation planning policy and practice. The modern information technology offers the potential for improvement of information flows to decision support teams monitoring the impact of MMA urban consolidation policy implementation, and thus the extent to which any policy to practice gap is held open by failure to adopt new monitoring methods might be identified.

The potential to monitor the details of infill patterns is appealing because the monitoring data that would accrue would not only provide better information to each LGA land-use planning office but also serve to support an analysis seeking to establish the relative significance, LGA by LGA, of the infill component of urban consolidation. Clearly this implies a need for parallel assessment of the relatively less complex and more easily monitored residential urban form changes contributed by greenfield land development and brownfield (re)development.

1.2. Aims and Objectives

This chapter has so far offered a summary of the need for a systematic approach to monitoring spatial distribution of infill development via reference to a more detailed geography (the land parcel scale, LGA by LGA) than assembled before now. It is recognised that such a detailed geography would give better support than hitherto available for monitoring the relationship between state-wide urban consolidation policy and its implementation with regard to infill development patterns. From this, a number of research questions arise:

- Can infill development pattern changes be mapped on demand at the land parcel scale?
- How can infill development patterns be quantified and visualised?
- To what extent do the infill development pattern changes of the intercensal period (2001 to 2006) reflect the intent of *Melbourne 2030* urban compact city policy regarding the need for such development to maximise proximity of workers to public transport networks and activity centres?
- How can we assess if growth management and improved quality of life for residents (as envisaged by implementation of compact city policy) been achieved?
- Can the determinants of infill development patterns between 2000 and 2006, and their relative significance, be identified?
- What are the social, environmental and policy implications of the changed urban residential form that has evolved as a result of infill development?

Accordingly, this study must aim **to explore relationships between urban consolidation theory, policy, and practice of the compact city using the MMA as a case in point**. Rather than identifying the merits and demerits of urban compact policy, this study demonstrates the merits of applying an integrated approach to data gathering, analysing and modelling for improving decision support and presentation. Three objectives are defined to address research questions.

1. *Melbourne 2030* sets specific targets for residential development types: greenfield development, dispersed development and strategic development by 2030. However, the methodology to be applied for achieving these targets is as yet unknown (Birrell *et al.*, 2005b). Information about the extent and location of infill development is also limited (Birrell *et al.*, 2005b). Systematic and detailed mapping of infill development is needed for local impact assessment and land capability analysis (DPCD, 2009a, Holloway and Bunker, 2003). Thus, objective one of this thesis is *to develop a GIS-based land parcel framework for automatic and systematic identification of residential intensification that can be applied for all local government areas (LGAs) in the MMA, which will produce outputs that can be used further for quantifying spatial patterns and spatial modelling.*

2. It has been recognised that urban planning policy evaluation and monitoring should be undertaken regularly if the extent to which existing policies meet established goals is to be determined (Wilson and Song, 2009). In fact, regular monitoring and review of development trends are parts of the *Melbourne 2030* implementation process (DoI, 2002e, p.169). More than one hundred activity centres were designated in the MMA and it is expected that new development would be in or within these activity centres or public transport network. Some previous research has examined the residential intensification in four LGAs in the inner MMA (Buxton and Tieman, 2004a), and population changes and dwelling development in the MMA at each CCD in the MMA (DPCD, 2007b, DPCD, 2008). Information about residential intensification in the middle and outer Regions in the MMA is too limited and undocumented to be useful. Therefore, the second objective of this thesis is *to evaluate the conformity of development patterns to state planning policy (Melbourne 2030) objectives regarding to development vis-à-vis activity centres and liveability for the residents.*
3. Although barriers of infill development have been intensively identified internationally and nationally (Alves, 2004, Birrell *et al.*, 2005b, Farris, 2001, Lewis, 1999), the infill development determining factors have been little quantified. In 2005, Birrell *et al.* suspected that the development of infill development was a function of "opportunistic" activity by land re-developers selecting properties that come to market according to land parcel size and age of property improvements. This explanation is untested and so determinants of the pattern of infill re-development are yet to be identified. Therefore, the third objective of this thesis is to *explore, quantify and examine the drivers of urban form changes: infill development using spatial statistics and spatial modelling*.

1.3. The Contribution and Innovation of this study

First, this study will provide a novel approach to identify residential subdivision patterns in different LGAs in the MMA, covering both middle (greenfield developments of three to five decades ago) and outer regions (recent or current greenfield regions) of the MMA. Identification of patterns and impact analyses of urban consolidation have been conducted for selected regions in both Sydney and Melbourne (Buxton and Scheurer, 2005, Holloway and Bunker, 2003), but hitherto a systematic and automated process of identification and analysis for the whole metropolitan region is not available.

Hence, the study not only provides a methodological innovation but also a new and practical contribution to urban form change monitoring task. In practical terms, detailed identification of urban consolidation patterns reveals the effectiveness of current practice in bringing the state strategic planning initiative: urban consolidation policy to implementation, LGA by LGA. The findings from this research will inform local urban planners and local community members about infill development trends in each LGA. Subsequently, it facilitates the amendment of planning policy to achieve desired goals as well as to facilitate communication and discussion between stakeholders in balancing between growth and social liveability. Additionally, although it is the MMA that forms the study focus, the data integration derived for the mapping and analysis can be applicable for other regions in both Australia and overseas, for which population densification under a policy de-emphasising urban sprawl is being seriously implemented. Application will be more appealing as the necessary spatial data infrastructure becomes more detailed (accuracy issues intrude in these terms) and more regularly maintained.

Secondly, the study develops an infill development detection tool to speed up the process of data analysis as well as to facilitate communication of results through deployment of a user friendly interface with easy-to-use functionality. Thus the population of naïve GIS users among decision support staff can be increased and spatial information made better use of. Thus it can be expected that adoption of the proto-type tool developed in this study will enhance the planning and management process in urban consolidation implementation.

Thirdly, the output from infill pattern mapping is used in spatial analysis to document the changes in the urban form distribution characteristics and relationships between urban form components. This is the unique aspect of this study compared with the previous and comparatively aggregated, descriptive and qualitative studies about urban consolidation in Australia. This is also the first study using spatial statistics to quantify the pattern of infill development. Using City of Monash data, the utility of regression analysis is exemplified in providing a quantitative approach to assessment of the relative significance of identified determinants of infill development, with special reference to the extent and contribution of land parcel size and age of housing stock, land parcel by land parcel.

1.4. Outline of the nature of following chapters

Chapter 2 presents an overview of urban planning theory, with particular reference to urban compact city theory, in twentieth centuries. In setting a research context, this chapter includes a review of previous studies about urban compact policy, their implementation and quantitative approach in urban planning monitoring and evaluation. A critical review of previous studies about urban form and impact analysis of urban form changes is also included. It is followed by a description of the data collection and analytical approach taken for each of the three objectives defined in Chapter 1. Chapter 3 presents an overview of the study area: its location, demographic characteristics, development patterns and governance. Subsequent chapters (4, 5, and 6) are devoted to meeting the main objectives by ways of describing project data collections and analyses. Chapter 7 presents a conclusion, discussion and prospects for future research.

2. CHAPTER 2: URBAN CONSOLIDATION: ITS PLANNING THEORY LINEAGE

2.1 Introduction

Many urban and regional planning theories, e.g. ranging between the comprehensive planning, and the technical and operational approaches, not to mention, the radical democracy and political environmentalism and neo-liberalism perspectives, have been proposed over the last two centuries. According to Hall (1992), the focus of urban planning has shifted four times as each generation of urban planners has identified and dealt with the key urban problems of their times. In parallel, urban planning tools and performance measures have been evolving. Currently, it is recognised that urban planners need to take a holistic approach to steering urbanisation toward sustainable development (Hall and Pfeiffer, 2000). In these terms, urban consolidation planning is important.

In examining the relationship between planning theory and urban consolidation, planning and practice, three major areas of interest have been identified: (i) theory behind urban consolidation policy formulation, (ii) urban consolidation planning in practice, and (iii) methods to identify the location, extent and scale of urban consolidation, and to compare the practice of urban consolidation and planning policy objectives. A review of the literature pertaining to all three can help to (i) increase our understanding of urban consolidation, both in terms of theory and practice, (ii) address the gaps of knowledge in urban consolidation policy evaluation and monitoring, and (iii) formulate appropriate research approaches to address the gaps.

Section 2.2 of this Chapter begins with an acknowledgement of the importance of the debate about the merits and demerits of "urban sprawl" versus compact urban forms. It is followed by an introduction to the nature of urban consolidation practice in Melbourne (section 2.3). The utility of GIS in urban land use planning is first discussed in section 2.4, followed by a review of various methods used in exploration and quantification of urban consolidation patterns and impacts. The rationale of the research agenda is presented in sections 2.5 to 2.7. Finally, the research design as a framework for thesis structure is described in section 2.8.

2.2 Urban consolidation: a policy for diminishing the momentum of urban sprawl

A topical land use planning debate over the last twenty years refers to the relative merits of the "sprawl" and "compact" urban forms (Camagni *et al.*, 2002). The "compact" urban form was suggested to mitigate the effects of earlier-imposed "urban sprawl", which are reported in many metropolitan areas of the United States (Burchfield *et al.*, 2006, Talen, 2003), in Europe (Gennaio *et al.*, 2009), and in Australia (Birrell *et al.*, 2005a). It is designed to encourage moderation in resource consumption, the better use of infrastructure and services, and the recycling and reuse of resources. It has been found that different terms have been used to promote this approach, region by region, culture by culture, and from time to time. A review of the evolution and meaning of the various terms is presented in the next section.

2.2.1 Neotraditional town planning: New urbanism

The "neotraditional town planning" approaches emerged when planners and architects sought better urban forms based on existing physical site qualities (Nasar 2003, cited in Jabareen, 2006). The most popular approach among "neotraditional town planners" is the new urbanism of the 1990s, a design-based strategy referring to traditional urban forms, and advocating redesign of regions, neighbourhoods, and buildings (CNU p.32, cited in Song and Knaap, 2003) in order to curb suburban sprawl, to address "inner-city decline, and to build and rebuild neighbourhoods and cities" (Jabareen, 2006, p.43). At the same time, the new urbanists advocate (1) mixing housing types so that they can be afforded by a range of income and household structures, (2) providing higher dwelling density, and (3) providing more convenient public transit via, bicycles paths and pedestrian-friendly street networks so as to reduce automobile use. The focus of urban design in this new urbanism approach in the 1990s refers to concepts that were popular before the 1950s. However urban design before then focused on construction of new infrastructure and services for future development. In contrast, those advocating the new urbanism approach do not necessarily mandate infrastructure construction. Instead they aim for improved social interaction and revitalisation of both already developed and new areas.

Secondly, a “transit-oriented development” or “transit-oriented design” (TOD) is another type of development based on the neotraditional form of urban development (Jabareen, 2006). The TOD model promotes development and intensification close to transit nodes, thereby reducing automobile use (Jabareen, 2006, Newman, 2007).

Thirdly, the “urban village” concept emerged in the United States and in the United Kingdom in the early and the late 1980s, respectively (Jabareen, 2006). An urban village is a new settlement on the greenfields, or brownfields as a redevelopment. It is characterised by high density, mixed use (for instance in terms of housing tenures, ages and social groups), and high quality development priority for pedestrians. The urban village model seeks to respond to urban problems that emerged into the post-industrialisation during the 1980s, namely traffic congestion, pollution, infrastructure costs and quality of life. It aims to improve convenience, efficiency, beauty and community connectivity (Jabareen, 2006).

2.2.2 Urban containment

According to Pendall *et al.* (2002), the term “urban containment” dates at least to 1973, when Hall *et al.* (1973) released their book on the British post-war planning system, *The Containment of Urban England*. The urban containment policy imposes geographical constraints on urban growth to contain sprawl and prevent the outward urban expansion (Pendall *et al.*, 2004), such that farmlands can be preserved and open spaces provided for urban residents (Millward, 2006). Thus, is promoted urban consolidation and a more efficient use of city infrastructure. The main “push” factor of the urban containment policy is more open space provision while its major “pull” factor is cost-effective infrastructure (Pendall *et al.*, 2004). To bring planning policies in practice, urban planning tools are implemented (Pendall *et al.*, 2004):

1. An Urban Growth Boundary (UGB): is a line between urbanisation and rural lands. Its implementation is usually imposed through application of regulatory controls, such as zoning; and

2. The imposition of a "Greenbelt"[2]: usually this term refers to an area within a boundary drawn fairly tightly around a city or urban region in a way that planners intend to be very difficult to change.

The UGBs and Greenbelts are deliberately designated to accommodate projected housing and associated open space demands within a defined time period (i.e. 20-30 years). They are revisited periodically in case change might be necessary (Pendall *et al.*, 2004). The UGB tools have been implemented in both developed and developing metropolitan areas (Millward, 2006) as well as at city and county levels (Dawkins and Nelson, 2002, Pendall *et al.*, 2004). The UGB of Portland, Oregon is an example of the application of regional land use planning tools designed to assist in reshaping the metropolitan area into a higher-density, more compact and transit-oriented city. In contrast, the UGB of Boulder County, Colorado is an example of implementation of a city-wide policy for imposing tight growth restrictions so as to slow down the rate of urban sprawl (Jabareen, 2006). In California, the adoption of containment policies, for instance, locally limits the number of housing units produced and/or applies constraints on housing supply (Dawkins and Nelson, 2002). Likewise, the objectives and goals of applying greenbelt land development tools vary by country. For example, the urban containment policies in the United States aim to avoid leapfrog development[3] whereas those in the United Kingdom or in Korea contain the leapfrog development in the form of new satellite cities beyond the greenbelts (Pendall *et al.*, 2004). Urban containment policies have been implemented in the United Kingdom for over fifty years, and in Korea for over twenty years (Dawkins and Nelson, 2002).

If the urban containment policies are designed to be a key to regulation of needed city growth, they are considered as growth management programs (Pendall *et al.*, 2004). Under this definition, the UGB tool is a type of growth management program. When management programs attempt to balance growth with environmental, economic and social development, they are generally named as of the "smart growth" policy kind (Jabareen, 2006). The "smart growth" concept featured during 1997 United States media accounts of the debate over "smart growth" legislation in Maryland (Daniels,

[2] In the recent Victorian strategic urban land use plan, *Melbourne 2030*, green wedge was used instead of greenbelt.

[3] Leapfrog development can be referred to development which is far beyond the metropolitan fringe, thus it fragmented farmland or natural lands (Pendall *et al.* 2004, p.22)

2001, p.274). In practice, “smart growth” programs concern and promote the concepts of compactness (e.g. applied as infill development in established areas and as higher-than-hitherto density settlement in new land development areas), mixed land use, and their subsequent cost savings (Jabareen, 2006). Apart from the implementation of the UGB, “smart growth” programs might include environmentally and pedestrian friendly street design and mixed-use zoning (Jabareen, 2006), of a kind that sees it regarded as leading to relatively similar outcomes to those from implementation of the TOD concept as discussed above.

2.2.3 Compact city

The *compact city* or *compactness* model was proposed as a tool for betterment of cities by Dantzing and Saaty in 1973 (Jabareen, 2006). The merits of higher density were earlier espoused in proposed city plans, such as those by Ebenezer Howard in the late nineteenth century (Hall, 1992). Its vision is to enhance the quality of life but not at the expense of the “next generation” (Jabareen, 2006). In general terms, and as stated by Tsai (2005), compactness involves the concentration of urban development. Compact urban development is used to denote planned urban infill in already urbanised areas (Jenks *et al.*, 1996), as well as redevelopment of brownfields and revitalisation of central city areas (Roo and Miller, 2000). Compactness promotes more effective use of public transport and more environmental conservation (Dieleman *et al.*, 1999). The concept relates to making the most of metropolitan infrastructure so that the transport network can become even more compatible with land use patterns, inherited as well as imposed and proposed.

Overall, it is clear from the evolution of the ideas described above that terms used in explaining the merits of compact urban forms changed as the planning concepts superseded one another in prominence. “New urbanism” or “smart growth” emerged in the United States while “compact city” as support for “greenbelts” and/or green wedges were proposed in the UK and Australasia. Several points in common can be identified:

- First, they emerged as a proposed solution to problems recognised when it was realised that there were environmental, social and economic costs associated with urban sprawl.

- Secondly, they are seen to offer a conceptual framework within which residential urban form can evolve with high-density dwelling patterns, within mixed-use zones such that there can be connectivity between housing and job locations. Hence, they aim to lead to a reduction in land consumption, more efficient uses of existing infrastructure and services, and a reduction in travelling by cars. Quality of life for residents is believed, therefore, to be better in terms of access to infrastructure and employment opportunities while retaining environmental conservation and heritage protection.

In practice, urban planning policy has long included some of these concepts in one form or another. For example, the compact city policy in the Netherlands over the last 30 years includes the urban containment component (Dieleman *et al.*, 1999). Meanwhile, the *Melbourne 2030* policy (Victoria, Australia) includes a number of designated activity centres (i.e. TOD), green wedge and the UGB (Figure 2.1), as well as the urban containment and the compact city components. *Melbourne 2030* Initiatives 2.4.1 to 2.4.4 state that the legislation planning controls in the green wedges ensure the long-term protection of environmentally significant areas, natural resource-based uses and rural landscape (DoI, 2002e). Figure 2.1 shows the spatial extent of green wedges in the MMA in relation to existing urban area and designated growth areas in *Melbourne 2030*.

Figure 2.1: Spatial extent of green wedges (DoI, 2002e, p.34). Twelve green wedges are designed outside the urban growth boundary to protect important non-urban uses: conservation areas, recreation, agriculture, airports, sewage treatment and quarries (DoI, 2002e).

In the next section, an overview of MMA urban consolidation policy is presented. One of the main tasks of urban planners is to monitor and evaluate the progress of urban planning implementation objectives and outcomes. Therefore, in order to set the context for this study and highlight the gap in current monitoring and evaluating of *Melbourne 2030*, a summary of urban consolidation research in the MMA is also presented.

2.3 Urban consolidation policy and practice in Melbourne

Urban consolidation or intensification[4] of urban development has been integrated in urban planning policies in major Australian cities for over 20 years (Searle, 2003). Initially, in Melbourne, the urban compact form was recommended and preferred by

[4] The term is normally used in the UK. In Australia it serves the urban containment concept and refers to urban consolidation. The latest strategic urban planning policy (DoI 2002), higher density development is used.

those responsible for addressing urban planning problems especially those associated with ongoing urban expansion and urban sprawl on the MMA fringe. In 1971, the Victorian Government urban land use planning policy was designed to contain suburbia into a number of “corridors” (McLoughlin, 1991). However, between the late 1970s and early 1980s, urban policy tended to keep the CBD as the dominant node while moving retail and office activities into some fourteen or fifteen “district centres” (McLoughlin, 1991). By 1987, increased densities were again preferred by policy makers. Later, increased housing choice and housing affordability became dominant planning themes (Morris, 2003, Yates, 2001).

2.3.1 Conceptual basis of urban consolidation

Although urban consolidation has been of interest to Victorian politicians and bureaucrats (not to mention researchers and general public) for over twenty years, there is no consensus and consistency in the definition of “urban consolidation”. In 1991, indeed, McLoughlin was able to assert that it was the lack of any definitions of urban consolidation that triggered the urban consolidation debate (McLoughlin, 1991). While some people referred to urban consolidation as a process to accommodate increased population and/or dwelling numbers (Williams, 1999), others might relate it to new development in the already urbanised region rather than on the fringe greenfields.

It is essential to define the “urban consolidation” term so that decision makers and community members can communicate and discuss the extent to which urban consolidation can be incorporated in planning policy. Success in gaining public acceptance of urban consolidation implementation might be enough to aid smooth implementation. In terms of communication, Buxton and Tieman (1999) reported that two terms: “medium density housing” and “multi-unit developments” were used interchangeably in the Victorian public and media debates in the 1990s. Table 2.1 summarises the interpretation of “medium density housing” from different research groups in Victoria up to 2008. As can be seen in Table 2.1, instead of using “medium density housing”, the Victorian Government used the term “higher density” development. Table 2.1 also reveals that land parcel subdivision into less 10 dwelling sites cannot be directly identified from the current data collections. In other words, smaller infill development project (subdivided into fewer than 10 dwellings) are, at present, unmapped and unidentified.

Table 2.1: Definition of Medium Density Housing by different Victorian Departments over time (Buxton and Tieman, 1999, p.9, DSE, 2004, DSE, 2006b, DSE, 2009c)

Department	Document	Medium Density Housing definition	Data and Methods
Department of Infrastructure	From Doughnut City to Café Society (1998)	More than one house on an ordinary block or any form of attached housing, such as townhouses, apartments of flats	No existing database
Department of Infrastructure	The Municipal Fact Sheets April 1998	Above definition; and Building code of Australia Class 1a(ii) and 2 buildings. This includes row houses, terrace, town or villa hoses and flats and apartments, but excludes "more than one [detached] house on an ordinary block	ABS data Aggregated into Census Collection Districts (CCD)
Australian Bureau of Statistics (ABS)		No definition Classify building type as: • Detached • Other residential buildings	
Victorian State Government	The Good Design Guide	• Two or more dwellings on a site, other than moveable dwelling units or high rise apartments; • One dwelling on a lot less than $300m^2$ • Residential buildings such as boarding houses	No dataset
The Building Commission (BCC)	Monthly building permit approvals	No definition Classify building type as: • Domestic building type: detached and attached • Residential building work: flats, apartments, aged accommodation, and boarding houses	Monthly dataset Unable to differentiate detached and attached housing
Victorian State Government	Melbourne 2030 (2002)	Change to "higher density" term	Collected and analysed by DPCD
Department of Planning and Community Development (DPCD)	Annual Urban Development Report between 2004 and 2009	Urban consolidation includes three components (DSE, 2008): • Infill development i.e. subdivision of land parcels at higher densities (e.g. Figure 2.1) • Development in vacant land parcel; and • Redevelopment of brownfields (e.g. old schools or factories) for housing	Broadhectare and major redevelopment projects of **10 dwellings or more** Small scale development e.g. backyard infill development is not identified.

In the early 1990s, in order to increase dwelling density, Burke (1991) suggested that medium density developments can be achieved in two ways, firstly, by multi-unit housing where a number of attached dwellings are built under a single title but with separate dwelling units on individual strata titles. The second way is by small lot subdivision where a single dwelling is placed on one allotment that is considerably smaller that the typical 750 square metre land parcel (Burke, 1991).

According to Buxton and Tieman (2005) and Morris (2003), intensification can be achieved by:

1. identifying suitable locations, such as those near public transport routes or on redevelopment sites
2. incremental dispersed market-led redevelopment of existing housing lots and building conversion in a city
3. increasing urban densities in planning approvals for development on the urban fringe

In practice, "suitable locations" for intensification include:

1. vacant lots within the existing urban areas (named as "*infill development*"),
2. uneconomic land values land parcels, such as old industrial or commercial sites (named as "*brownfield development*") (DPCD, 2009c, Landis *et al.*, 2005, Steinacker, 2003) that have lost value under current zoning and have greater value after rezoning
3. and vacant lots on the urban fringe that can be developed with higher density housing (named as "*greenfield development*") (Boffa Miskell Limited and Jerram Tocker Barron Architects Limited, 2007).

From a fine scale as at the land parcel level, infill development can be perceived as:

1. demolition of old stand-alone house and redevelopment with multi dwelling units or town-houses (Figure 2.2a and Figure 2.2c)
2. building multiple town-houses in a vacant land parcel, which are detached (Figure 2.2b) or attached (Figure 2.2d)
3. building (a) house(s) on the undeveloped land (e.g. garden) on a land parcel on which stands an already-existing house

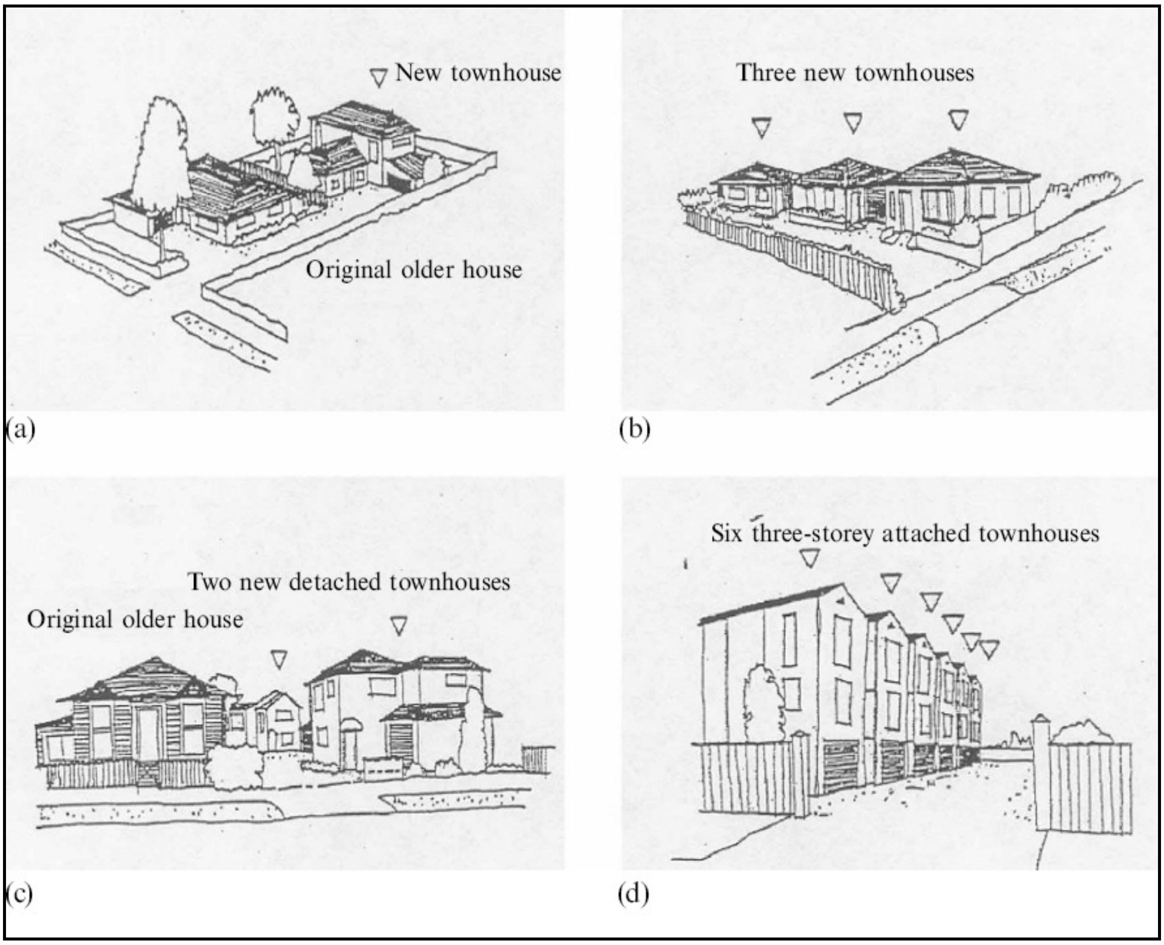
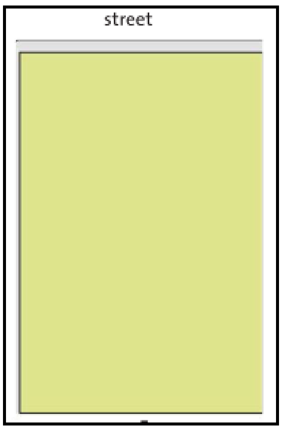
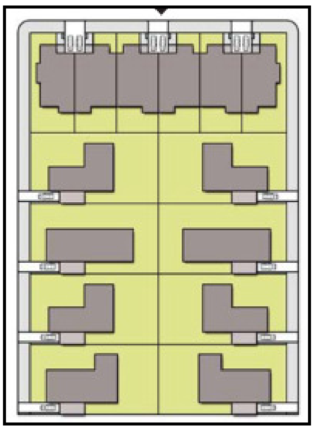


Figure 2.2: Conceptual diagram of infill development (Vallance *et al.*, 2005, p.720). A new townhouse is built next to current old house (a), three new townhouses built on vacant land (b), redevelopment of old house into two new detached townhouses (c) and the development of six three-storey attached townhouses in a vacant land

Figure 2.3 shows that greenfield development can provide a variety of housing development types and sizes.



Greenfield development site



A mix of housing types and sizes

Figure 2.3: Example of greenfield development ,which includes subdivisions into attached units and detached houses (Boffa Miskell Limited and Jerram Tocker Barron Architects Limited, 2007, p.5)

It is also worthwhile to note that in formulating the *Melbourne 2030* policy, the Victorian Government forsook the term "medium density development" for "higher density housing", the latter being defined as "housing units on a given area of land that are more numerous than the average in the surrounding locality" (DoI, 2002e, p.182). Accordingly, the design of any monitoring method of higher density housing needs to include a parameter that captures change in the pattern of "housing units", which can be quantified or compared between improved or developed sites and neighbourhood sites. Thus it is land-parcel scale mapping that is called for.

2.3.2 Current states of monitoring of urban consolidation planning policy implementation

Many scholars have argued that there is a gap between the rhetorical aspirations of new urbanism (Jabareen, 2006), and compact city policy (Birrell *et al.*, 2005a) and their outcomes in practice, these being only revealed by detail study, e.g. (Burton, 2000).

The Victorian Department of Planning & Community Development (DPCD) is responsible for regular monitoring of residential and industrial land supply and development in both Metropolitan and Regional Victoria. Since 2004, DPCD has prepared the Urban Development Program (UDP) Annual Report, reporting the location and process of major redevelopment in brownfields and the land development (land parcel subdivision) in the greenfields (DSE, 2004, DSE, 2008, DSE, 2009b). These are the land development sites that provide at least twenty dwellings per project (UDP 2004) or at least ten dwellings per project (since UDP 2005) (DSE, 2008). Since 2006, the UDP has identified the location of projects with 5-9 dwellings (UDP 2006) but has not reported this data type in its annual report (DSE, 2008, DSE, 2009c), and so the data has not been made available. As for suburban infill development, it is only estimates that have been offered. As Birrell *et al.* (2005b) argued, although the Victorian authorities predicted the proportion of infill development would reach 35% of new residential development by 2030, no documentation of this figure was offered. As mentioned in Chapter 1, this type of development has environmental, social and economic implications. Accordingly, it is necessary to identify, quantify and monitor its extent and changes.

Birrell *et al.* (2005b) attempted to map 2003-04 infill development around two City of Monash Activity Centres by overlaying a pair of time-series cadastral datasets. Field validation showed that this approach gave overestimation of infill development due to the delay in cadastral update. Additionally, in areas where cadastral boundaries are not updated, the utility of using address points from the address point spatial database (DSE, 2007c) for identifying the presence of dwellings was not attempted by these authors. Such a tedious time-consuming (manual) approach to mapping is clearly not cost-effective for either local government or state-wide scale of study.

In Australia, only two significant studies attempted to map land parcel scale urban consolidation pattern change. The first was a study of three LGAs in Sydney by Holloway and Bunker (2003) and the second was of four inner MMA LGAs by Buxton and Tieman (2005). Buxton and Tieman (2005) used annual dwelling approval data (1988-89 to 2002-03), five-year interval dwelling stocks (1991, 1996, and 2001), local planning registers (1997-98), and building approval data from the Victorian Building commission (2002-03). While the first two datasets were quantified and compared between four municipalities in terms of number of dwellings and proportion of dwelling changes, the latter two datasets allowed examination of the relative spatial location of medium density development to the public transportation network. Buxton and Tieman (2005) present the analysis in terms of the number and percentage of permit approvals within 400 metres of railway stations, and tram and bus routes in two periods: 1997-98 and 2002-03. The results are presented using descriptive analysis. Studies of factors relating to urban consolidation practice refer more to generalised than to detailed analysis. Any correlation between urban consolidation patterns and the spatial location of their public transport networks or to the proximity of designated activity centres is sparsely examined. Previous research about urban consolidation impacts on the urban form and amenity of suburban regions is also of limited scope.

It is also noted that the building approval data does not provide information about the status of any land parcel being developed. Thus the use of approval data might overestimate the number of new house developments. Ideally, land use attributes should be available for each land parcel, for instance, being vacant or improved (detached house, attached units or townhouse). Such a detailed land use database (in 2008) is currently being developed for Victoria (Per. Communication with Elizabeth Morse-

McNabb on 29 April 2009). At local government level, in the City of Monash, for instance, land use attributes are stored, however time-series land use is not preserved (Per. Communication with Steve Truman on 27 November 2009). There is inconsistency in the record of land use attributes. Whilst “house” is classified by building materials, “flat” is differentiated by ownership/tenure as set by the Valuer General (Per. Communication with Steve Truman on 2 March 2009). In this thesis, as presented in Chapter 4, residential land parcels are defined by using land use planning zones.

It is clear from Table 2.1 and from the above discussion that the assembly of spatial datasets suitable for integration and mapping of infill monitoring has not been demonstrated to Victorian decision makers. Thus the change in urban residential form pattern resulting from infill development (medium density housing or higher density development other than in the brownfield and greenfield land developments) cannot be monitored at the present time. To address this gap and achieve Objective 1, Chapter 4 offers an integrated approach, using a range of moderately accessible spatial datasets that could be made accessible for each local government area in the MMA so that urban consolidation patterns could be mapped, monitored and interpreted without major reorganisation of the regulation system.

2.4 Urban consolidation mapping, monitoring and evaluation

The next section will review how the practice of urban compact city or urban consolidation policy can be identified, monitored and evaluated. This aims to achieve the study Objectives. Two branches of literature are directly relevant to the study, including:

- the adoption of GIS in decision support for urban land use planning
- the quantitative measurement of development patterns and its use for the evaluation of the effects of policies governing development on development patterns before and after the implementation of the development policy

2.4.1 The advent of the Geographical Information System in decision support for planning

The GIS is a system that can store, edit, analyse, share and display geographic information. GIS tools facilitate digital representation of spatial phenomena or events in a way that supports analysis of spatially related data (Dueker 1987, cited in Levine *et al.*, 1989). Initially developed in the 1960s as a tool for spatial querying and thematic mapping, GIS has evolved to incorporate other advanced functionalities, such as spatial analysis, network analysis, image processing, global positioning system (GPS), and geo-coding. The input information can be assembled and processed as either or both vector and raster datasets (see Figure 2.4).

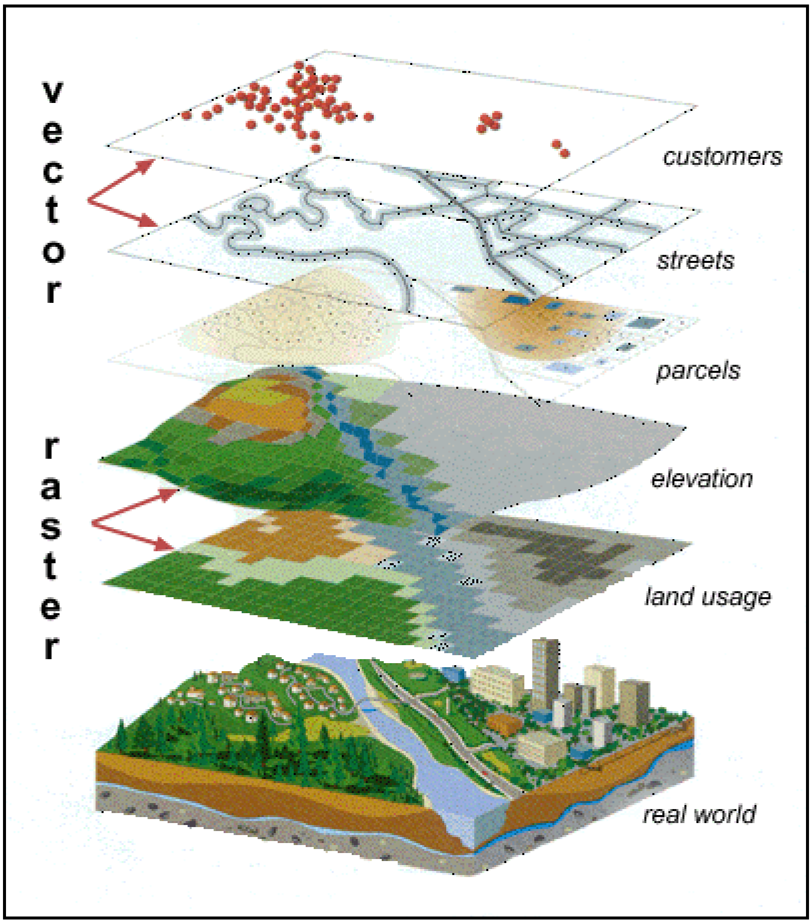


Figure 2.4: Examples of vector and raster datasets (Escobar *et al.*, 2000). In GIS software products, such as ESRI ArcGIS, vector or raster datasets are called layers. They can be overlaid for visualisation to represent the landscape or arrangement of different phenomenon/events in the real world or integrated in spatial analysis and modelling.

As indicated in Table 2.2, the integration of different spatial datasets in GIS provides a higher level functionality for planning as compared with traditional paper maps or computer cartography. While the level of communication in these three systems is high, the functionality of planning has gradually increased as systems have evolved from traditional maps and computer cartography to GIS. The advancement of GIS functionalities and complexity is due to the advancement of technology, especially during the 1990s and 2000s. Many commercial GIS softwares have developed user-oriented GIS technology (Malczewski, 2004). GIS can be improved for modelling, either via the up-grade of embedded programs or by export of the data by transformation for application in other software tools. Thus a sequence of spatial data handling improvements has emerged.

Table 2.2: The Functionality of Spatial Information Systems in Planning (Kliskey, 1995, p.19)

Ability of different spatial information systems to provide functionality for planning (ranging from high-low)		Spatial Information Systems		
		Traditional Maps	Computer Cartography	GIS
Functionality of planning	Communication	High	High	High
	Inventory	Moderate	High	High
	Monitoring	Low	Moderate	High
	Modelling/ Analysis	Low	Low	High

There are many ways to collect geographic data including:

- surveying using a global navigation satellite system (GNSS) (e.g. global positioning system positioning: GPS), or a total station (for feature/asset inventory),
- on-screen digitising of scanned image data so that the patterns on paper maps can be transferred to digital form, and
- remote sensing and aerial photography.

As time goes by, the latter is seen to offer more and more value. Basically, remote sensing involves the process of mapping, by classifying and identifying objects of interest as represented in images that are captured remotely from space-borne and air-borne sensors. The image data market supports collection of geographic data in time series. Scale of capture varies according to mapping theme. The models of application range from, synoptic (even global) visions of earth sources (Lillesand and Kiefer, 1994) to detailed imagery of small areas, such as a block of houses. The image data market is such that the pixel arrays of which the products are composed can later be transferred, processed in GIS software and integrated with other geographic datasets (both aspatial and spatial) in GIS.

The planners interest in GIS and other geospatial technologies such as remote sensing and GPS derives from the spatial nature of urban phenomena and from the interdisciplinary nature of urban planning (Nedovic-Budic, 2000). Taking an applied science approach, planning is fundamentally a sequence of rational and technical procedures (Hall, 1974). Central to this scientific approach to mapping is the instrumental rationality of the positivist paradigm. From this perspective, GIS is seen as a data-centered information technology that provides tools for deriving information from databases to be used in a value-free process of rational planning. The underlying assumption derived from the positivist paradigm is that there is a direct relationship between the data processing capability and information availability on one hand, and the quality of planning on the other.

GIS users deploy many applications designed to support natural resource management and planning. The datasets refer to expertise across a range of disciplines, for instance land use suitability analysis or development of decision support systems to archaeology, hydrology, or business analysis. Planners who adopt GIS can use and apply geographical information technologies in all aspects of a planning process that include data collection and storage, data analysis and presentation, planning and/or policy making, communication with the public and decision makers, and planning and/or policy implementation and administration: see Nedovic-Budic (2000). Figure 2.5 shows an integrated role of GIS as a decision support tool to provide a spatial framework for data gathering, collecting, evaluating and decision making.

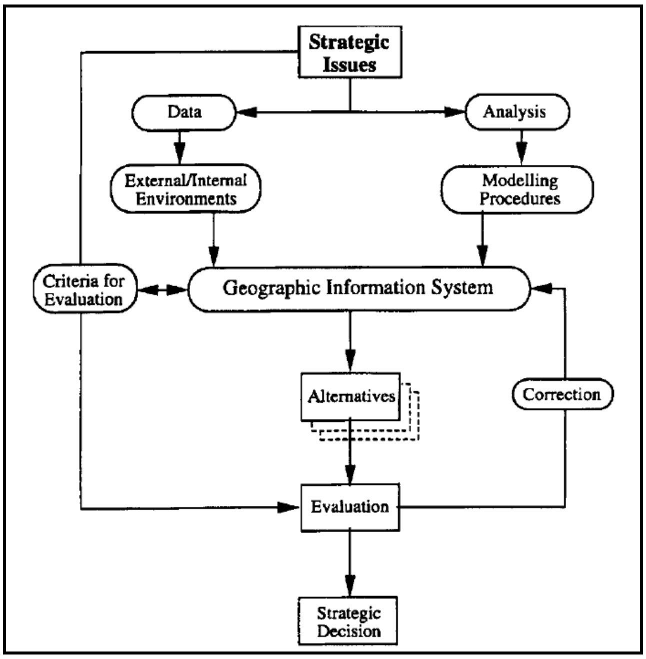


Figure 2.5: The Role of GIS in planning process (Kliskey, 1995, p.20)

GIS technology is most widely and commonly used in comprehensive planning, zoning, land use inventories, land use suitability assessment (Malczewski, 2004), and socio-demographic analysis. In Australia, due to the availability of census data from the Australian Bureau of Statistics (ABS), socio-demographic analysis is mainly deployed for mapping the distribution and attributes of not only people but also housing. The value of maps in understanding and communicating planning issues is well recognised and appreciated. As Balodis (1986, p.215) states,

> …[one] cannot make a spatial decision without appropriate information. Statistics, computer generated models, scientific or technical reports more often than not, are cumbersome and meaningless to a legislator or decision maker, whereas a "good" map like a well-written narrative, should supply the readily understandable spatial information essential to the process of decision making.

Furthermore, urban and regional planners in decision support mode require access to a range of information sets, ranging from social, economic, cultural, environmental management and planning. It is the integrating of geographical datasets (both spatial and attribute ones) that establishes GIS as a highly useful planning and decision support tool. The data power is exemplified by successful application in modelling urban growth patterns and processes (Sui, 1998) as well as by its application for hypothesis testing, and scenario analysis in decision making (Malczewski, 2006). These functionalities and capabilities allow a far richer set of questions to be posed and a considerably broader range of problems to be addressed than would be possible in conventional information systems, which involve only attribute data, or in computer-mapping systems designed only for handling spatial data without georeferencing[5] (Kliskey, 1995). As presented in Table 2.2, while GIS and other spatial information systems share some domains, traditional maps on the one hand and their computer cartographic versions on the other, are relatively equal in contributing to "communication" in planning. However adoption of GIS offers additional advantages over the others for supporting monitoring to modelling and other analysis capabilities. Research has demonstrated that integration of remote sensing, and GIS allows the patterns and processes of urban growth expansion to be understood and monitored better than ever before (Herold *et al.*, 2003, Herold *et al.*, 2001). As Kliskey (1995, p.22) believes:

> "At a minimum, the application of GIS should enable the resource manager to conduct exploratory spatial analysis.., while in an optimal setting, GIS offers the possibility of supporting a sophisticated decision-support system…"

This section has discussed the roles and utility of GIS in urban planning studies. Next, quantitative approaches in urban consolidation policy evaluation are reviewed.

2.4.2 The Quantitative approach in urban consolidation policy monitoring and evaluation: its new role

Although urban consolidation theorists predict many socio-economic and environmental benefits for future urban development from appropriate implementation, empirical studies are still needed to validate such claims (Burton, 2000). Such studies would probably reinforce claims that the information handling that would be required for such appropriate implementation is relevant not only for policy monitoring and evaluation, but also for impact assessment. Oliveira and Pinho (2009, p.36) state four supporting points of planning practice evaluation as it:

- legitimises planning before citizens, providing sustained appraisals on planning products, procedures and results, through the whole planning process
- helps politicians and planners in complex processes of decision making

[5] Georeferencing is a process to assign geographical locations of layers on or near the earth's surface (ESRI 2007 Georeferencing Help)

- tracks the course planning proposals, promoting an effective planning dynamic, then suggestions for changes or reviews in planning products and processes are supported by the results of evaluation exercises, and
- enables the construction of planning process based on a continuous learning process.

For guidance, it is worth noting that both qualitative and quantitative research has been conducted in urban consolidation theory, planning and practice (e.g. Bunker *et al.*, 2002, Burton, 2000, Burton, 2002, Randolph, 2006, Vallance *et al.*, 2005). However, and as stated in Chapter 1, this thesis takes a more quantitative view in designing the major research approach. Accordingly, a review of the range of quantitative approaches available is appropriate.

Quantitative analysis can be used to identify and distinguish urban form types , thus contributing to measurement of policy success (Song and Knaap, 2007). However, studies offering quantitative assessments of implementation success in planning are comparatively rare (Talen, 1996b). Whilst quantitative information is usually perceived as a means to provide an "objective" and reliable basis for measuring program effectiveness and examining the progress of achievement of planning policy objectives and outcomes, the performance indicators deployed can constrain the effectiveness of this approach because they assume (Judd and Randolph, 2006):

- more clarity and specificity of planning policy objectives than is usually present. This has been cited as one of the main barriers for undertaking planning policy evaluation
- the process of spatial data acquisition and accessibility relates to planning policy implementation boundaries that are changing

Deployment of GIS, in pursuing a quantitative approach in urban consolidation policy monitoring and evaluation can include reference to maps, urban form indicators (often derived from digital spatial data handling and modelling), spatial modelling and application of spatial statistics techniques. The next section presents a summary of how these techniques have been used and applied in urban studies in general and urban consolidation research in particular. Cited mostly will be previous studies about the implementation, operation, monitoring and evaluation of "new urbanism", or "urban containment", or "compact city" policies in the United States, United Kingdom, and Australia. The review focuses on (1) how urban form: sprawl vs. compactness can be identified, distinguished and monitored and (2) how dimension of urban form: density, mixed-use and connectivity be can be measured and evaluated, and (3) how factors or driving forces of urban form can be visualised, quantified and explored. The review looks at the scale of analysis, type of data used, and key findings. By way of summary, the strength and weaknesses of these studies in terms of the present aims and objectives are identified and discussed.

2.4.2.1 Thematic Mapping

Thematic mapping is a key to application of spatial modelling for planning purposes. In particular, time-series thematic mapping of urban land attributes reveals the pattern of residential urban form change. For example, Holloway & Bunker (2003) geo-coded development permits in each of four Sydney municipalities and overlaid them with other spatial datasets: municipality boundaries, street layers and railway station layers. The maps revealed that urban consolidation developed with proximity to highways and railway stations. A similar exercise was undertaken in Melbourne by Buxton and Tieman (2004b). Both studies used graduated colour maps. As previously discussed in section 2.4.1, an appropriately composed and presented thematic map of attributes and resolution fit for purpose can be useful for exploration, analysis and communication among stakeholders.

2.4.2.2 Trend Analysis

To characterise and examine planning policy outcomes, research has been normally designed to compare development pattern over time. In other words, spatial-temporal research has been generally found in urban planning policy monitoring and evaluation. For example, in a study of housing choices made by residents in Sydney and Melbourne, Yates (2001) examined, by regions, the changes of dwelling stocks between 1986 and 1996 in inner, middle, and outer Sydney and Melbourne in terms of number of bedrooms in each dwelling, dwelling types, tenures and income. Likewise, Randolph (2006) studied the changes in the relative significance of single houses and multi-unit dwellings in Sydney, Brisbane and Melbourne between 1981 and 2001, for instance by tenure and dwelling size. Although in these studies many demographic attributes are examined with changes in urban form changes, the spatial location characteristics of urban form, for example with regarding to existing infrastructure and services are not central to outcomes. In other words, the detailed accessibility and connectivity dimensions of urban form changes are rarely investigated. Other studies undertaken for the MMA have not much considered this aspect. The accessibility of development approval data in the four Inner LGAs studied by Buxton and Tieman (2004b) only look at the proportion of development within 400 and 800 meter buffer of railway stations and public transport networks (including bus and trams). The accessibility from each new dwelling to existing infrastructures and services, such as hospitals or schools has not been examined.

Chhetri *et al.*(2008) examine changes in net residential dwelling density in the MMA inside the UGB. This analysis of cadastral datasets in 2001 and 2006 and dwelling numbers in each 1km grid cell is at a coarse scale of analysis (1km), and so exemplifies a way of data handling at the metropolitan scale. As such, it does not support comparison of urban consolidation between municipalities: it is not offering the finer scale of urban form change at land parcel scale. The study focuses on changes in distribution and extent of single houses rather than other types of medium density housing development (i.e. semi-detached houses and multi-units and dwellings in apartments). As such, significant factors explaining the nature of the pattern of urban consolidation might be under-examined. Correlation analysis between dwelling density in 2001 and 2006, and proximities to Melbourne CBD, and Principal and Major Activity Centres were statistically examined using ANOVA test. The autocorrelation Index (Moran score) was calculated, and it was found that dwelling density patterns were spatially correlated. In commenting on the apparent decline in densification 2001-2006 indicated by the analysis of the coarse grid data, Chhetri *et al.* (2008) suggested a need for further analysis to confirm this conclusion especially given the lack of incorporation of medium density housing development or multi dwellings in the database. In Chapter 4, a land-parcel based approach is developed and presented so that higher density development in terms of both single housing and multiple dwellings is identified and mapped. Thus, outcomes from methods exemplified in Chapter 4 can be used as additional data to address Chhetri *et al.* (2008)'s suggestion.

While a coarse scale analysis such as the 1km grid (Chhetri *et al.*, 2008), or the census collection district (for instance by Randolph, 2006, Randolph *et al.*, 2005) is useful and feasible for the metropolitan area comparative analysis, land-parcel based analysis is needed to characterise urban sprawl or urban compactness changes at subdivision level (Chapin *et al.*, 2008, Hasse and Kornbluh, 2004). Additionally, because many land-use policies are enforced through regulation and other mechanisms designed for influencing how individual property parcels are used, the land-parcel based approach for evaluating implementation of land use plans and regulations offers advantages over previous applications of GIS analysis necessarily conducted at coarser spatial resolution (Moudon and Hubner, 2000). A further discussion about the need to examine detail geography for examination of relationships between urban consolidation theory, planning and practice is presented in section 2.5.

2.4.2.3 Outcome Measures for Urban consolidation policy

In section 2.2, it is shown that urban consolidation theory offers a conceptual framework within which urban form can evolve with high density dwelling patterns, within mixed-use zones, and high accessibility to employment sites and infrastructures and services. Therefore, in the following section, important factors of urban consolidation: urban density and accessibility are reviewed. These factors are incorporated and highlighted in initiatives and principles of *Melbourne 2030*. The review is focused on how previous studies determine these factors and their utility in urban planning monitoring and evaluation. It sets a context for a discussion of methods used in this study when applied to the MMA.

2.4.2.3.1 Urban density

Density, defined as the ratio of people or dwelling units to land area, is an important aspect of sustainable urban form (Jabareen, 2006) because it influences energy consumption, materials uses, housing land consumption and call for urban infrastructure (Walker and Rees, 1997). According to Buxton and Scheurer (2005), the urban land area needs to be clearly defined before urban density is calculated. They reviewed the concept of net and gross land density used by different urban planners in Melbourne in the 1990s. They found that different terms have been used for total land area when determining urban density, either including or excluding local parks, public streets, or schools (Figure 2.6). Using gross residential density[6], as previous defined by Cardew in 1996, Buxton and Scheurer (2005) undertook scenario analysis to determine the savings of land consumption from increased gross residential density. According to Buxton and Scheurer (2005), in the Growth Areas in the MMA, if gross residential density increases from 10 dwellings per hectare to 15 dwellings per hectare, 33% land savings can be achieved. These findings highlight the importance of gross residential density on land use consumption savings and thus it should be monitored so that urban planners can have information on the progress of compact city planning policy outcomes' achievement.

Land uses contained in definition	1 Residential lots only (both single and strata-titled)	2 Land uses contained in (1) plus: public streets and pedestrian/cycle access ways	3 Land uses contained in (2) plus: local parks, local community facilities, primary schools, local commercial facilities	4 Land uses contained in (3) plus: share of arterial roads and dedicated public transport routes, regional parks, regional community and commercial facilities, secondary schools, mixed-use and business areas[a]	5 All urban uses within continuously developed urban area
McLoughlin (1991)			Net residential density	Gross residential density	Overall urban density
Loder and Bayly *et al.* (1993)	Site density[b]	Net dwelling density[c]	Neighbourhood dwelling density		Urban centre dwelling density[d]
Cardew (1996)	Site density	Net residential density	Gross residential density	Release area density	Metropolitan area density

[a]McLoughlin uses the term 'medium-sized local parks', Cardew uses the term 'regional parks', referring to open space that extends beyond the scale of an individual subdivision.

[b]Loder and Bayly advise taking separate site density measures for single and strata-titled parts of residential areas.

[c]Only includes roads that provide legal access to lots.

[d]ABS metropolitan area definitions are used, which include a proportion of rural land at the urban fringe.

Figure 2.6: Summary of Urban Density Concept (Buxton and Scheurer, 2007, p.9)

A substantial discussion about urban density in different Australian metropolitan cities is found in Roberts (2007). He presents six dimensions of urban density: demographic, spatial, mass, utility, time space and perceived urban density. Roberts (2007) also uses indicators to assess the impacts of urban density changes on urban built environment, as well as economic, governance, natural and social systems. Roberts (2007) measures urban density in terms of population density, built-up density, and dwelling density for

[6] In Figure 2.6 the to determine gross residential density, Cardew (1996) defined land uses as residential lots plus public streets, pedestrian/cycle access ways, local parks, local community facilities, primary schools, and local commercial facilities

all Australian cities and territorial statistical divisions between 1991 and 2001. Roberts (2007) finds that population density of Australian cities is declining while their urban footprints are increasing. Because the latest urban consolidation policies in state-wide strategic plans in Melbourne, Sydney and Brisbane were released after 2001, such analysis was limited in regard to examination of the influences of recent urban consolidation policies (e.g. *Melbourne 2030*) on changes in urban density. Additionally, the analysis of dwelling density changes on the fringes relied on the estimates released in those strategic plans; hence, the analysis lacks inclusion of evidence of actual policy in practice. Other dimensions of the compact city, such as accessibility by public transportation are not examined by Roberts (2007).

2.4.2.3.2 Accessibility

In terms of both sustainability and efficiency, it is necessary and desirable to understand the location of new residential developments or subdivisions relative to existing infrastructure and services. Social sustainability refers to the social equity and liveability of residential areas and community sustainability (Bramley *et al.*, 2009, Burton, 2000). This maintenance of equitable access to community services and amenity is a necessary land use and community planning objective. For example, low income workers, and their family members, need ready access to the public transport services for travelling to work or leisure, or to schools and open space areas. This accessibility together with social interaction, safety and local environment quality would influence both directly and indirectly the well-being of the residents (Bramley *et al.*, 2009). Lack of accessibility in these terms has been shown to indicate failure in planning control of urban sprawl (e.g. Hasse and Kornbluh, 2004).

Traditionally, accessibility has been most used in transport research. Four different models of measuring accessibility are normally discussed among researchers. They were reviewed in Talen (1998) and Talen and Anselin (1998). These models include:

1. gravity model
2. average distance between each origin and all facilities
3. minimum distance from an origin to the nearest facility, and
4. the number of facilities within n metres of the origin, for example, residents' households

These models differ in terms of datasets called upon, and the complexity in calculating the particular distance metric called for in the underlying algorithm. For instance, the minimum distance model offers the option to measure a shortest Euclidean (straight) distance, the shortest street network distance, or a distance along a route designed to minimize travel cost. The data assembly should also capture the barriers in the surfaces by travel speed, topography or other landscape features. Talen (1998) argues that in planning application, indicators need to be simply analysed for urban planners, thus she recommends the minimum distance model in Euclidean distance mode. However, in studies of travel accessibility by public transport, designed to capture the influences of frequency of service for the range of public transport modes and accessibility levels of Gold Coast residents, travel time distance using network modelling is called for (Pitot *et al.*, 2005). Accessibility analysis is also used in health research, such as to measure access to different types of food. Access to major supermarkets was used as an indicator for access to a healthy diet and fast food outlet as an indicator for access to unhealthy food. Thus the authors could examine the relationship between residents and their access to healthy and unhealthy food (Burns and Inglis, 2007). At a finer scale of analysis (household level), Omer (2006) used a minimum distance model with some modification to measure accessibility of residents in the City of Tel Aviv to urban park services. Combining with socio-economic datasets, Omer (2006) examined the differential accessibility of residents based on their income and national-ethnic identity. This provides useful information for decision makers in regards to allocation of local urban services, spatial equity practice and discourse. Likewise, accessibility to services of residents of public housing in Montreal was studied by Apparicio and Seguin (2006). They used network distance to measure street distance from dwellings to location of services to evaluate the accessibility of residents in public housing to different urban facilities and services. However, there is no similar attempt undertaken in the MMA. Thus to address this gap and achieve the Objective 2, accessibility of new dwelling development to existing infrastructures and services is examined using both Euclidean distance and network distance.

Buxton and Scheurer (2005) examined eleven new development sites in the MMA Growth Areas. They used a number of new urbanism design indicators to assess the current trends of subdivisions in the green fields, such as weighted ranking of number of intersections nearby new dwelling development, lot size diversity, single lot with solar orientation and dwelling density. Thus, urban design in recent subdivided lots could be described and implications of urban consolidation policy on new development were discussed. In other overseas study, to examine the “new urbanism” factors in infill developments in Cleveland, Ohio, USA, Talen (2003) used five urban morphology parameters, including: (1) enclosure (the distance from street to front and back house), (2) lost space: parking areas, undefined open spaces and vacant lots, (3) public space: defined and undefined open space, (4) spatial suitability, (5) proximity, such as to retail. These metrics enabled the author to explore differential urban form in Cleveland.

Urban form indicators have been used for planning policy evaluation. To understand and examine the success of recent Government policies to control urban sprawl and increase progress toward compact cities in the Liverpool, UK conurbation, Couch and Karecha (2006) used three indicators: (1) retention of Green Belts Land, (2) proportion of new dwellings built on previously developed land, and (3) the density and type of new dwellings. By measuring these indicators, the authors found that UK compact city policies are well implemented locally and nationally.

In studying the influences of planning policies to minimise dispersed rural residential development in biodiversity conservation, Compas (2007) used four landscape metrics/indicators to examine 1973-2004 changes, to residential urban form due to regulated subdivision, both major (multi-dwelling) and minor. These metrics revealed the following information:

1. major subdivisions became more clustered and less land consumptive
2. minor subdivisions became more dispersed and more land consumptive
3. distances from existing development decreased for major subdivisions, and
4. an increasing number of parcels were developed near or within riparian areas

2.4.2.3.3 Mixed land use

Mixed land use indicates the presence of different land use types, such as residential, industrial, commercial (Jabareen, 2006), schools, and public services, such as local parks on the defined areas, such as the activity centres. Due to the scope of this research on residential land use development and subdivision, the mixed land use component is not examined in greatly detail.

In section 2.4.2.3, it has been shown that international studies conducted in USA and Europe (e.g. Compas, 2007, Couch and Karecha, 2006) have incorporated many urban form indicators including both housing density and accessibility to public services (i.e. riparian areas) to examine the influence of planning policy in curbing urban sprawl and preserving rural conservation land consumption. However, in the MMA, previous study by Robert (2007) only examined urban density for the temporal scale of between 1991 and 2001. Therefore, the influence and impacts of *Melbourne 2030* on new development patterns were not examined. Only study in the MMA (Buxton and Scheurer, 2005) starts to use urban form indicators to examine development trends in eleven development tracts in Growth Areas on the fringe of the MMA. Therefore, in Chapter 5, apart from some of these urban form indicators, such as gross housing density or the proportion of intersections and cul-de-sacs in each development tract, other urban form development factors are introduced, such as the total of impervious surface area per new housing development. The use of socio-economic data from Census in this Chapter demonstrates an integrated analytical approach to examine the influence and impacts of *Melbourne 2030* on new development patterns.

2.4.2.4 Spatial statistics

A quantitative measure that describes the spatial pattern of land-parcel development will facilitate further analysis of trends in land development. For example, a given City of Monash land parcel pattern represents the status of land parcel development and subdivision for the date to which the input data refers. From time series assemblies of similar data, the evolution of the pattern may be deduced. The attributes of the entities mapped will be part of the input data analysed in the search for explanations involving consideration of cause and effect. Whether or not the pattern changes influence later changes in a chain of cause and effect during urban intensification needs to be examined. Application of well-documented statistical techniques can strengthen hypothesis generation, and testing. In fulfilling Objective 3 (in understanding and examining the contributing factors of urban infill development) Chapter 6 firstly applies Kernel density estimation to visualise the relative location of urban infill development and designated activity centres and railway routes, and then Univariate and Bivariate K functions to quantify the spatial patterns of infill development with activity centres and railway stations. These analytical techniques are described in the following sections.

2.4.2.4.1 Kernel density estimation

The kernel density estimation (KDE) is a spatial statistical technique that measures variation in the mean value or intensity of a process in space (O'Sullivan and Unwin, 2010, Xie and Yan, 2008). Kernel density offers a more sophisticated and accurate approach to modelling sprawl than normal density calculation (Openshaw, 1995, cited in Carlson & Dierwechter 2007), hence offering means for both visual and critical interpretations of the effectiveness of the UGB or smart growth policy in reducing urban sprawl. KDE has been used to monitor the urban development before and after implementation of the UGB in Washington state, USA (Carlson and Dierwechter, 2007), and to elucidate understanding of the development process in Canada (Cuthbert and Anderson, 2002a).

The KDE is a spatial statistical technique in exploratory spatial data analysis (ESDA) that measures the variation in the mean value or intensity of a process in space. Calculating kernel density of annual building permits in Pierce County, Washington, Carlson & Dierwechter (2007) showed that residential permits were more clustered inside the UGB than before the implementation of the UGB in 1995. This information is very useful for planning practitioners and managers seeking to understand the implementation and practice of planning policy outcomes. Thus the gap between planning policy and practice may be bridged. In another study in Canada, by using KDE for time-series datasets of residential and commercial land parcels between 1970 and 1996, Cuthbert and Anderson (2002a) found that the urban form of Halifax-Dartmouth was due to a combination of infill, contiguous and leap-frog sprawl development. This provides insight in urban development patterns. A detail description of how KDE is estimated will presented in Chapter 6, section 6.3.1.

2.4.2.4.2 Univariate and Bivariate K function

The univariate and bivariate K functions can be used to analyse spatial patterns over a different range of spatial scales. The univariate K function is an explicit test for spatial dependence or clustering among different events. In case of residential development at land parcel scale, the univariate K function is defined as the expected number of parcels within distance *h* of a randomly selected parcel, divided by the overall intensity of parcels, which is denoted as K(*h*) (Rowlingson and Diggle, 1993). A detail description of how K function is estimated will presented in Chapter 6, sections 6.3.2 and 6.3.3.

Cuthbert and Anderson (2002b) used these two approaches to elucidate the nature of spatial clustering of new residential land parcels around newly-zoned commercial land parcels. Thus, the nature of spatial relationships between residential zones and commercial (employment) planning zones can be revealed. The clustering of land parcels may be such that metropolis-wide clustering and perhaps even multi-nucleation has taken place. Thus Cuthbert and Anderson could document the changing urban form of the Halifax-Dartmouth region, Canada in ways that allow the implications of changing form to be better identified.

Although ESDA techniques, such as KDE, and univariate and bivariate K-functions, have long been used by ecologists, biologists and health scientists quantifying the spatial distribution of species or fast-food restaurants (Austin *et al.*, 2005b), application in urban analysis or in residential development mapping has not been often attempted. Apart from a study by Cuthbert and Anderson (2002b), Lee (2002) also used spatial statistics to study time-series of residential development in Geauga County, Ohio of the United States from before 1900 to 2000. Using Join-Count spatial statistics, Lee (2002) formulated models to describe the process of urbanisation over time in different townships and villages. Thus, Lee (2002) quantified three growth patterns occurring in the county: old intensely developed areas, mature developed areas and young developing areas.

2.4.2.5 GIS-based modelling

Although deployment of ESDA methods, for instance kernel density or spatial statistics, has been shown to assist in exploring and characterising the spatial distribution of land development, it is the GIS-based explanatory model that can assist to understand the relationship between multiple variables, including biophysical and socio-economic factors on patterns of infill development. For land-use change modelling studies or urban growth related research, many variables have been incorporated: they include neighbourhood characteristics, resident income, state, regional and local planning controls and incentives (Shen and Zhang, 2007). Different models have been used to examine the relationship among determining factors of urban growth, and on pattern of urban growth. They include the cellular automata model (He *et al.*, 2006), and the regression model (Irwin and Bockstael, 2004, Smersh *et al.*, 2003). The choice of model is dictated by the nature and purpose of the study. While statistical models, such as regression models, are usually used in empirical or explanatory studies; other approaches such as that based upon deployment of a cellular automata model are used to simulate the process of urban growth or land use change. This approach assumes the probability that a cell will change status is greatly affected by its interaction with neighbourhood cells which are changing (or not) (For more information about statistical and cellular automata models, see Irwin and Geoghegan, 2001).

From the discussion in section 2.4, it is shown that researchers seeking to identify, characterise, quantify and examine pattern and process in urban consolidation have tested the utility of a range of approaches. Researchers familiar with the merits and demerits of the various approaches will choose according to fitness-for-purpose considerations. Accordingly, the next section presents rationales of studying infill development at land parcel scale using an integrated approach deploying trend analysis, spatial metrics, spatial statistics and spatial modelling.

2.5 Research Rationale- spatial distribution of infill development at land parcel scale

Given the enforcement of land use planning policy, both the location and extent of medium density developments in the inner cities (including four LGAs) of the MMA are known to have evolved with a rate and scale dictated by economic cycles: spatial variability in style is therefore to be expected in the residential urban form pattern changes (Buxton and Tieman, 2005). Previous studies of the residential urban form change have used aggregated data (for instance in CCD level or LGA spatial level) (Randolph, 2006, Roberts, 2007, Yates, 2001, DPCD, 2007) and so infill development, which in some LGAs is a major component of urban residential form change is not identified. Thus credible analysis of spatial inter-relationships between infill densification patterns and local infrastructures and services, not to mention the associated social costs is not supported. Additionally unidentified is a metropolitan scale LGA by LGA, appraisal of the relative significance of the modes of housing and their pattern changes as they evolve to accommodate the steadily increasing population.

Accordingly, the nature of changed characteristics of the MMA either before or after the urban consolidation policies were promulgated is yet to be documented. The best current available analysis of resident development around MMA activity centre and redevelopment sites is that of the dwelling approvals data. These data, are collected CCDs by CCDs (DPCD, 2007b). There are many drawbacks when using CCDs to monitor resident development activity, namely (DPCD, 2007b):

- the boundaries of the CCDs do not accord with areas identified in *Melbourne 2030*; therefore it is difficult to identify residential development in or outside the sphere of influence of the activity centres
- the boundaries of the CCDs will be subject to change as the population number change, therefore it does not provide a consistent framework for time series monitoring
- the dwelling approval does not always indicate the construction and completion status of dwellings

In addition, available results of previous analysis are generally presented in tabular form. Thus the location of urban form and pattern is not readily available to decision makers and stakeholders, and such location data as is provided, would not support detailed visualisation. Detailed datasets, such as would support land parcel level of mapping, have been called for so that monitoring and management of urban development can take place at the local (DPCD, 2009a). Phan *et al.* (2008) have demonstrated the scope for adopting detailed mapping of infill development (see Chapter 4).

Other attempts to provide such detail (finer) scale of temporal and also spatial data have recently been undertaken; however they have been limited to manual infill detection (Birrell *et al.*, 2005b), descriptive analysis of urban consolidation patterns in three municipalities in the Sydney metropolitan area (Holloway and Bunker, 2003), and comparative analysis of urban consolidation patterns for only a limited number of inner municipalities in Melbourne (Buxton and Tieman, 2004b).

Documentation of the spatial pattern of urban residential MMA infill development in different LGAs, especially in the middle and outer Regions, will help urban planners, policy makers and urban modellers to better understand and efficiently manage the pattern of development. Better understanding of the pattern of infill development must improve those aspects of operational and strategic planning designed to ensure maintenance of services and infrastructure in the face of growing and changing dwelling development and population. Data about infill development is also relevant to analysis of other aspects of densification policy implementation, for instance whether the net density within the urban areas is increasing to achieve the goal of urban consolidation policy in the face of land consumption in the (expanding the UGB) fringe. The infill changes are therefore part of monitoring so that the need for information supporting further assessment review and outcomes measurement as already called for (Buxton *et al.*, 2006) can be better supported.

2.6 Research Rationale- evaluation of the effect and success of urban compact policy

It is urgent for urban planners to find appropriate management tools to accommodate urban growth while addressing other challenges such as climate change, housing affordability and transport efficiency. Plan evaluation is a complex but most necessary exercise (Baer, 1997, Brody *et al.*, 2006). Planners must adopt an evidence-based approach in promoting urban compact policy (Wilson and Song, 2009) and to do this it is necessary to conduct empirical studies to document and elucidate the effects and impacts of planning policy on development patterns (Burton, 2000, Talen, 1996a, Wilson and Song, 2009).

Melbourne 2030 was introduced and implemented in November 2002 (DoI, 2002e). Empirical studies on its impacts socially, environmentally and economically have started (Randolph, 2006). Therefore, it is indeed necessary to further examine the impacts of *Melbourne 2030* and investigate if outcomes or practice reflect urban planning policy's objectives and directions.

2.7 Research rationale- the contributing factors of infill development

Although barriers of infill development have been intensively identified internationally and nationally (Alves, 2004, Birrell *et al.*, 2005b, Farris, 2001, Lewis, 1999), the determining factors on infill development have been little quantified. In 2005, Birrell *et* *al.* suspected that the development of infill development was due to “opportunistic” land parcel size and the age of housing development.

As reviewed in the above section, previous Australian studies have not incorporated both biophysical and social economic factors in urban consolidation study. Spatial models of use in identifying the factors driving urban form changes under urban consolidation policy will need to incorporate these variables. Identification of driving factors will improve the information flows available to policy makers during times when update or amendment of planning policy is being considered as a result of assessment of data gathered during the monitoring process.

2.8 Research design

This section describes the overall methodology to answer the study questions and achieve its three objectives.

2.8.1 Spatial datasets

Datasets used in previous international and national studies have been assembled so that the trends and patterns of urban intensification or urban consolidation, and population density can be identified. For instance, it is reported that for the first time, the United States Bureau of the Census, is by analysis of data about population growth producing data that readily reveals infill, as measured for the nation’s urban areas (Cox, 2009), building density, building permits, utility hookups and intersection of street network density (Borchert, 1961, Foust and Theo, 2008). Previous studies about urban consolidation, urban containment and growth management have been mainly supported by the following kind of datasets:

- Quarterly building approval (ABS) (Birrell *et al.*, 2005b, Buxton and Tieman, 2004b)
- Building Commissions (Buxton and Tieman, 2004b)
- Local government building permit datasets (e.g. in Sydney (Holloway and Bunker, 2003), or cities in USA: Maryland (Wiley, 2007), or Austin (Sui 2005)
- Field survey i.e. dual occupancy street survey (Eccles, 1991)

In this study, the range of spatial datasets of use is shown to cover wider range of data custodians. In examining the scope for integrating different spatial datasets for urban consolidation mapping and monitoring, the utility of the following datasets had to be tested and demonstrated. These include:

- Planning schemes in 2001 and 2006
- Address point in 2006 and 2008
- Aerial photos, dated ranges from 1999 to 2007
- Property datasets/cadastres
- Road network
- Railway routes and stations
- Principal public transport Network
- Activity Centre locations
- Schools
- Hospitals
- Broadhectare and Major Development sites (UDP 2003 to 2008)
- Local council report map archives
- Australian Bureau of Statistics (ABS)

2.8.2 Choice of time-series range

As stated in Chapter 1, the aim of this study is to explore the relationship between urban compact policy, *Melbourne 2030* (released in 2002), and its practice using data that spans the intercensal period between 2000 and 2006. Thus data from the late 2000 (shortly before the *Melbourne 2030* policy was promulgated) to the late 2006 (when the new rules had applied until the end of the census period that began soon after the policy encouraged population densification) is appropriate for exemplifying the scope for deploying data integration in documenting the impact of urban densification policy in the MMA during this period when land developers could plan their activities under the new rules/ incentives and development permit appraisal authorities could interpret them in the same terms. A more formal account of the reasons for the choice of the study period (2000-2006) includes:

- its average population annual growth rate of 1.3 percent, which is higher than that of 1.1 and 0.6 percent in 1996-2001 and 1991-1996, respectively (DSE, 2007a); meaning that dwelling development could increase to accommodate the population growth. All 31 MMA LGAs show a positive average population growth in the 2001-2006 period (DSE, 2007a)

- the period covers the time before and after the implementation of the recent Victorian state strategic planning policy, *Melbourne 2030*, so that implications for urban planning policy can be discussed from the residential urban form changes documented
- the period covers two census dates: 2001 and 2006, so that many socio-economic factors from the ABS can be incorporated and integrated in the analysis
- previous studies (Birrell *et al.*, 2005b, Buxton and Tieman, 1999, Buxton and Tieman, 2004b, Mitchell, 1999b) are old enough for the appraisals they offer to be re-visited

While some studies report urban growth year by year, this study examines changes in urban consolidation patterns over the six year period. In so far as smoothing of the data trends is useful (Smersh *et al.*, 2003) the six-year study period offers scope for this.

2.8.3 Methodological approach

As stated in Chapter 1, this thesis aims to explore relationships between urban compact city planning concepts and their translation into policy, and between policy and its practice in the MMA. A fine-scale analysis (land parcel level of detail) is applied. The project is designed to explore and illustrate the utility of the quantitative and analytical tools, particularly the use of GIS to identify the patterns of compactness, characterise and quantify them, and undertake impact analysis. Hence geographical outcomes from implementation of *Melbourne 2030* can be revealed municipality by municipality. As a result, the scope for monitoring (and, perhaps evolving/improving) of the impact and effectiveness of current planning policies and the decision making process that evolved to bring them to practice can be identified.

Figure 2.7 presents an overview of the thesis structure. It includes seven Chapters. After describing the study area and justifying the choice of case studies in Chapter 3, study results are presented in Chapter 4 to Chapter 6. In Chapter 4, a GIS-based land parcel approach is developed and presented for identifying and mapping infill development. The method is developed within GIS commercial software: ArcGIS, version 9.2 (ESRI, 2007), so that embedded functionalities in ArcGIS can used. Outputs are presented in thematic mapping and descriptive summary form. The utility of spatial dataset handling, manipulating and analysis in supporting the interpretation of urban infill development patterns in four selected LGAs in the MMA is also exemplified.

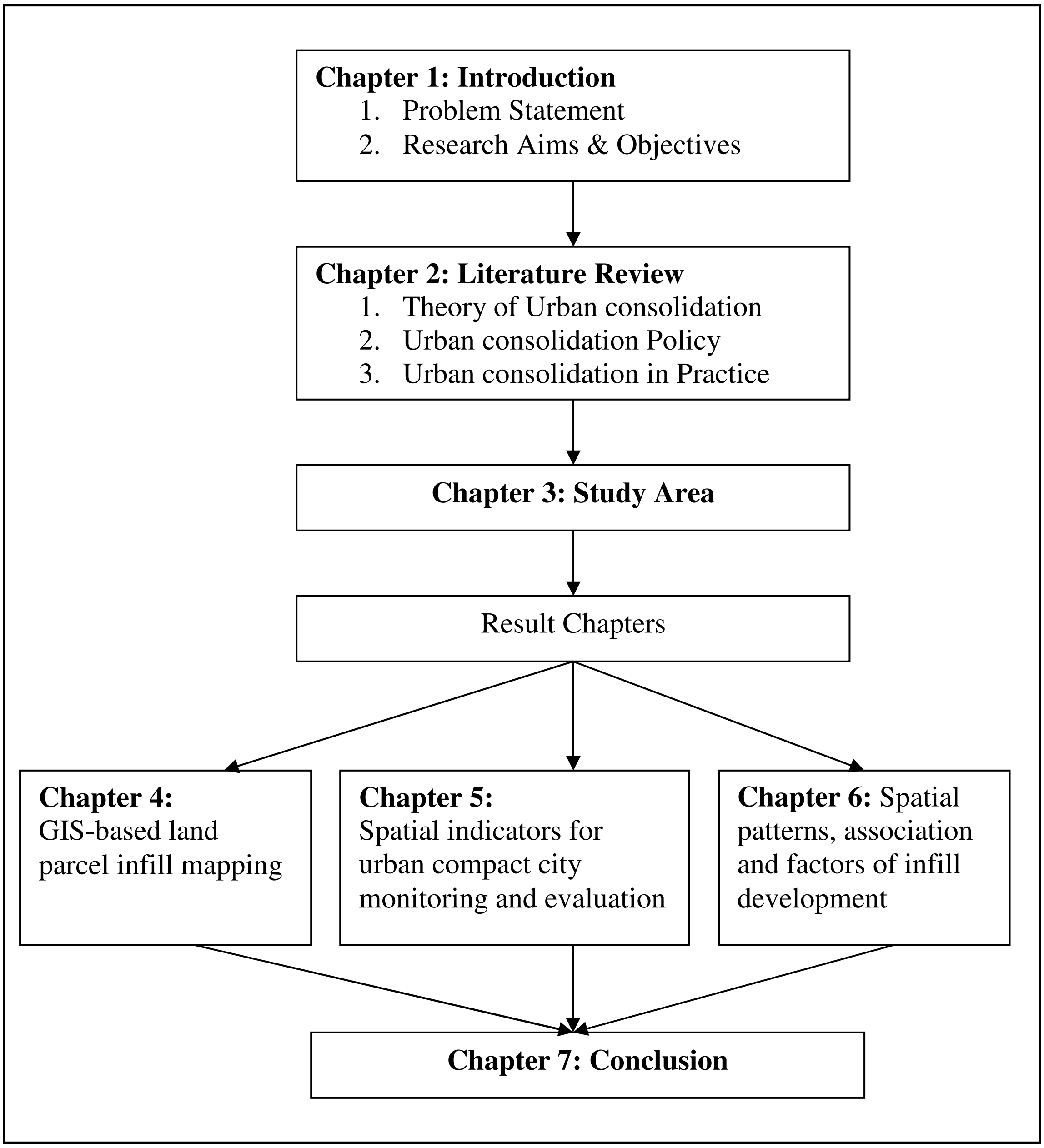


Figure 2.7: Overview of the thesis Structure

In Chapter 5, two urban form indicators designed to assist *Melbourne 2030* implementation monitoring and evaluating are presented. Outputs from Chapter 4 are integrated with spatial datasets to represent brownfield and greenfield development, which are accessed from DPCD, to derive housing development indicators: dispersed development, strategic development and greenfield development. These groups are defined in *Melbourne 2030*. Then, accessibility from each new development in these housing development classes to schools and hospitals are determined using both Euclidean and network distance. Four development tracts, one in each LGA, are further examined in urban design attributes: housing development density, the number of cul-de-sac, and the proportion of impervious surface area. Socio-economic census data is also incorporated, so that the influence and local impacts of *Melbourne 2030* on new development can be discussed and interpreted in geodemographic terms.

In Chapter 6, three techniques are used to assist interpreting, understanding and examining the contributing factors of infill development in the City of Monash. First, KDE is used to visualise the spatial patterns of infill development with existing infrastructures and services. Particular interest refers to railway stations and designated activity centres. Secondly, univariate and bivariate K-Functions are used to quantify the spatial patterns of infill development with spatial patterns of railway stations and activity centres. Thirdly, a linear regression model is developed and analysed using *Ordinary Linear Regression* (OLS) Tool in ArcGIS 9.3 (ESRI, 2008). This aims to examine the influence of land use planning overlay, ages of land estates, land parcel areas and perimeters, proximity to schools, railway stations and activity centres, and population changes on the intensity of infill development in each CCD in City of Monash.

2.9 Summary

In this Chapter, it is argued from the appraisal of previous studies that there are many approaches and methods available to those intent on quantifying and measuring urban form changes. Such studies may provide information to help decision makers to monitor these changes in relation to public policy objectives. In prospect, it is argued that spatial statistics and spatial models can also be used to integrate urban form, physical, demographics and policy variables in an analytical framework designed to enhance understanding of the process of urban development: the emergent pattern of development, its drivers, and impacts. The deployment of archived datasets has improved in both spatial and temporal scales , thus enabling analysts to look at the human geography at a finer scale (Clifton *et al.*, 2008). Though methodology and data archives have been widely developed and updated, their application in practice is, apparently, somewhat rare. Within the MMA context, it has been found that there is a lack of research to examine the influences of urban planning policy and the impacts of urban development. This is especially in regards to urban consolidation (Randolph, 2006, Phan *et al.* 2008). Hence, the scope for research refers not only to demonstrating the strength and utility of data collection and innovative analytical approaches but also the nature of information flows deployed in decision support.

The spatial information strategies referred to here were, established in Victoria, Australia since 1993, for improvement in acquisition, management and applications of spatial information used in both public and private sectors of the economy (DSE, 2007b). Since then, many digital spatial information products, (for instance, online planning services and cadastral maps) have been in use in planning and management in Victoria. Therefore, it has become possible to study urban form and development pattern changes over time through the integration of spatial datasets and urban models. It is argued here that integration of spatial data for urban growth analysis offers a planning support system path for capturing urban form change in Victoria in a greater detail than ever before.

3. CHAPTER 3: STUDY AREA

3.1 Introduction

In offering an overview of the study area (physical location and general trend of its urban growth (Figure 3.1 and Figure 3.6) and development and its urban planning policies), this chapter sets a context for explaining the approach evolved for analysis of residential urban development in the MMA.

3.2 Physical characteristics

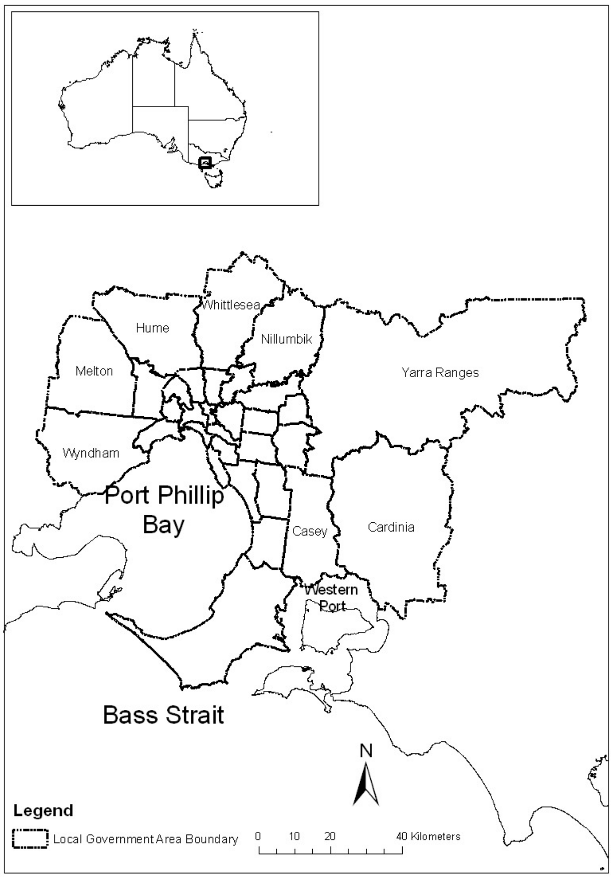


Figure 3.1: Location of the Local Government Areas that constitute the Melbourne Metropolitan Area (MMA)

The MMA (Figure 3.1) is defined by the spatial administrative boundary of the outer most of the 31 MMA LGAs. The MMA covers a region of about 8,835 km^2 (DSE, 2006a). From reference to Figure 3.2, Figure 3.3 and Figure 3.4 it can be seen that the higher land to the north and east is better watered and forested than the basaltic plains to the west.

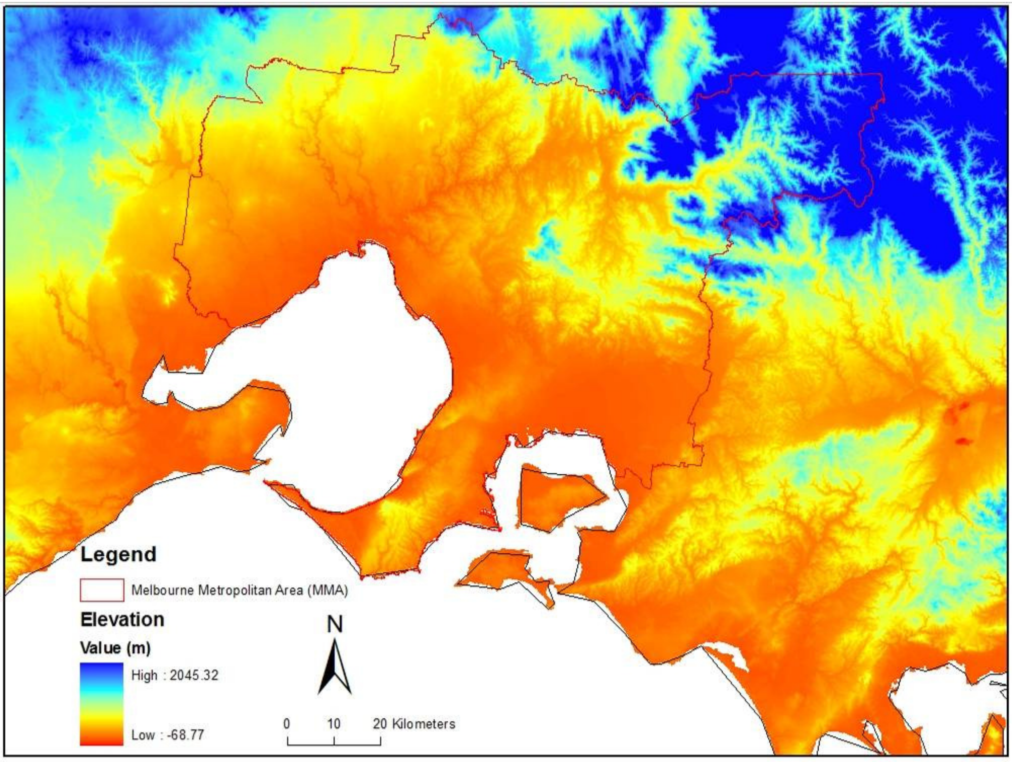


Figure 3.2: Topographic map of the Melbourne Metropolitan Area (Elevation layer is acquired from DSE, Vicmap Elevation product, 20 metre resolution)

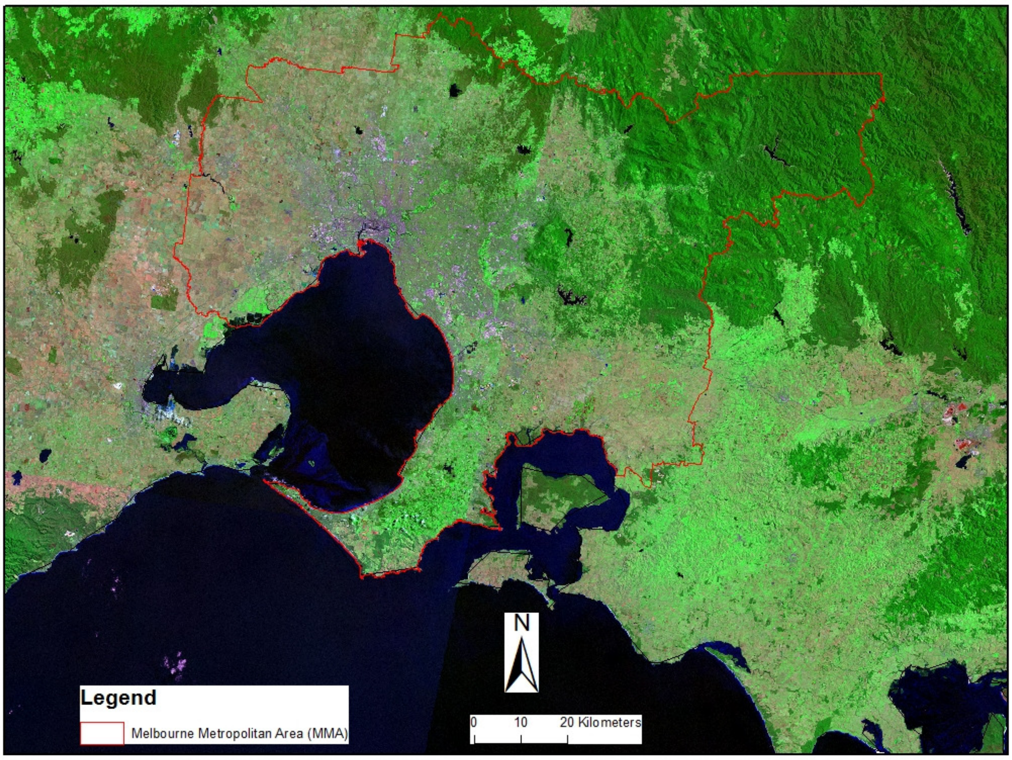


Figure 3.3: Land cover map of the Melbourne Metropolitan Area. The map presents a combination of band 2, 4, and 7 of Landsat 7, in which green colour presents the areas of vegetation (in the north east region of the MMA) as compared to the brownish areas of bared soils and basaltic soils in the southern east and west regions, respectively of the MMA. (Landsat image is acquired from ACRES Landsat Mosaic of Australia, 2000)

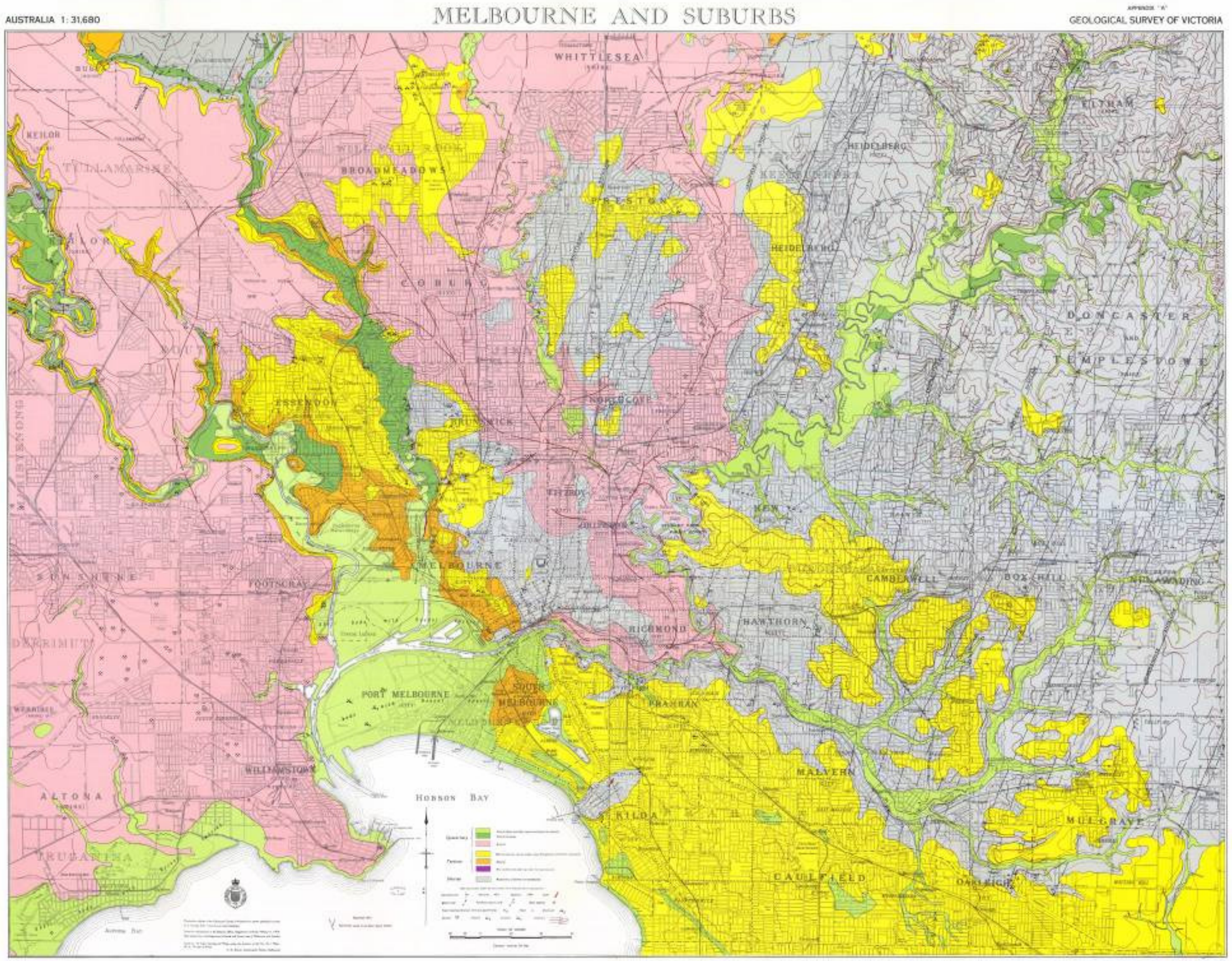


Figure 3.4: Geological map in the Melbourne region, published in 1959 (Department of Primary Industries Earth Resources Online Store, accessed 24 February 2011, http://dpistore.efirst.com.au/categories.asp?cID=58)

Planners have combined the themes of these figures as seen in Figure 3.5.

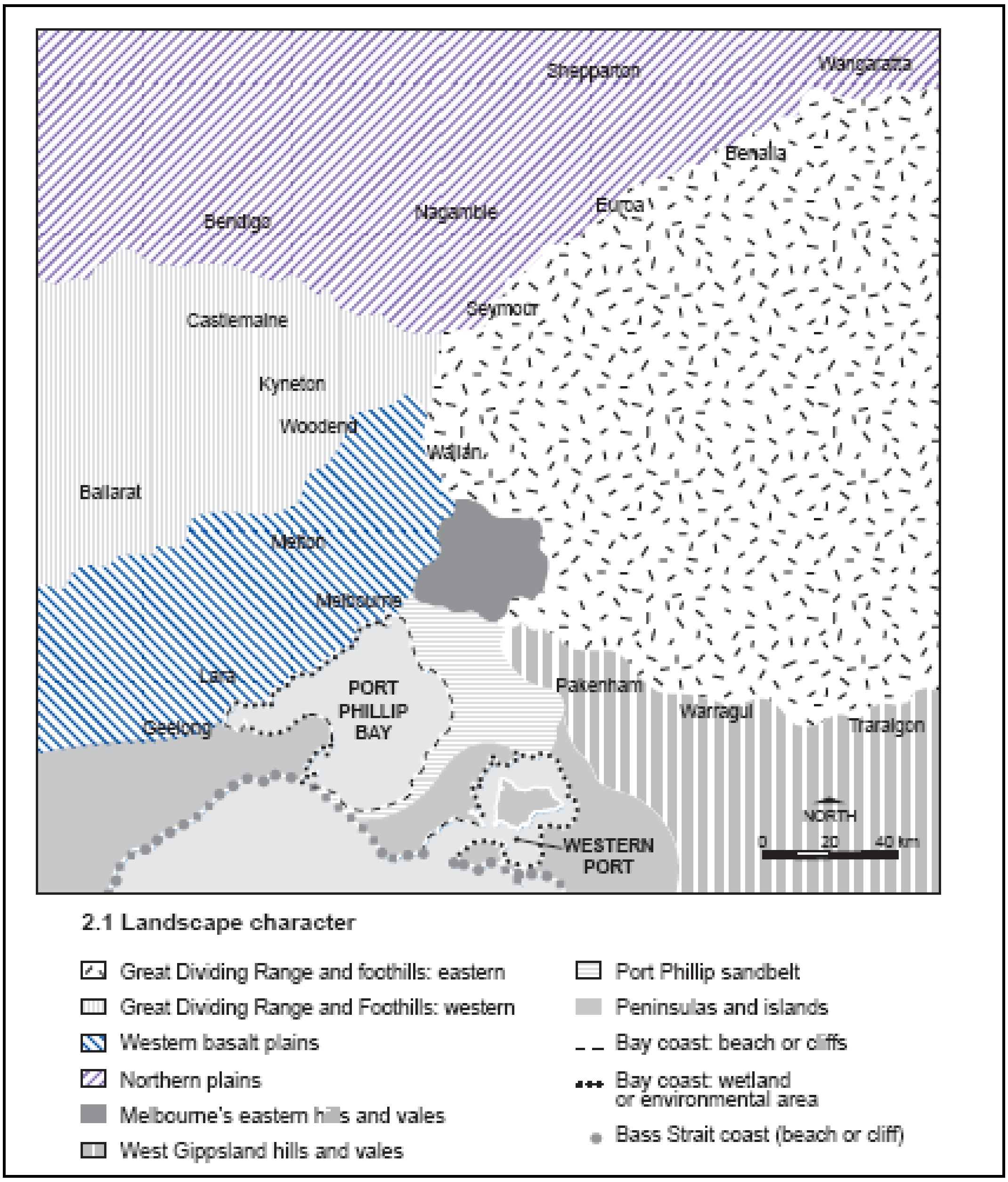


Figure 3.5: Overview of landscape character of the Melbourne Metropolitan Area (DoI, 2002d, p. 20)

3.3 Urbanisation and urban growth in the Melbourne Metropolitan Area

An account of urban growth must not only define the term but also its components. This section of Chapter 3 is devoted to that with special reference to the nature and history of the growth of Melbourne.

3.3.1 Urban area growth

During the European industrial urbanisation period, it was the British who colonised Australia and so land administration evolved from practice in the UK. By 1802, Port Phillip Bay had been discovered by John Murray and Matthew Flinders. Melbourne was founded in 1835. By 1837, Robert Hoddle had designed the street pattern, covering one mile (east to west) along the Yarra River covering land three-quarters of a mile (north to south) on either bank. In 1851, urban settlement in Melbourne was in Melbourne town, South Melbourne, Sandridge, and Port Melbourne. It totalled only about 14 square kilometres. Subsequently, the city developed and expanded as the wealth from gold mining in Bendigo and Ballarat (rural areas to the north and the north west of the Melbourne city) greatly added to an economy hitherto dependent on grazing and subsidy from the Mother colony in Sydney. The discovery of gold in 1851, shortly after separation from NSW heralded rapid economic and population growth. By the end of the nineteenth century, Melbourne city had become among those with the highest level of urbanisation (Forster, 1991).

The first rapid growth period (1837-1883) saw Melbourne increase its area six fold (DSE, 2006a). The next major expansionary period was between 1971 and 2004, when the city area almost doubled its size (Figure 3.6). In 2004, the estimated MMA urban land use was about 2,100 square kilometres, in which residential uses accounted for 57.2% of Melbourne's land (DSE, 2006a). Figure 3.6 depicts the concentric growth pattern by which the urban fringe gradually expanded outward, and is so doing, imposed a particular cultural context upon Australian urban settlement. According to Forster (1991) the European migrants to Australia settled in the coastal areas before people moved out into the interior areas, establishing a rural settlement pattern under the ruling influence of the colonial capitals.

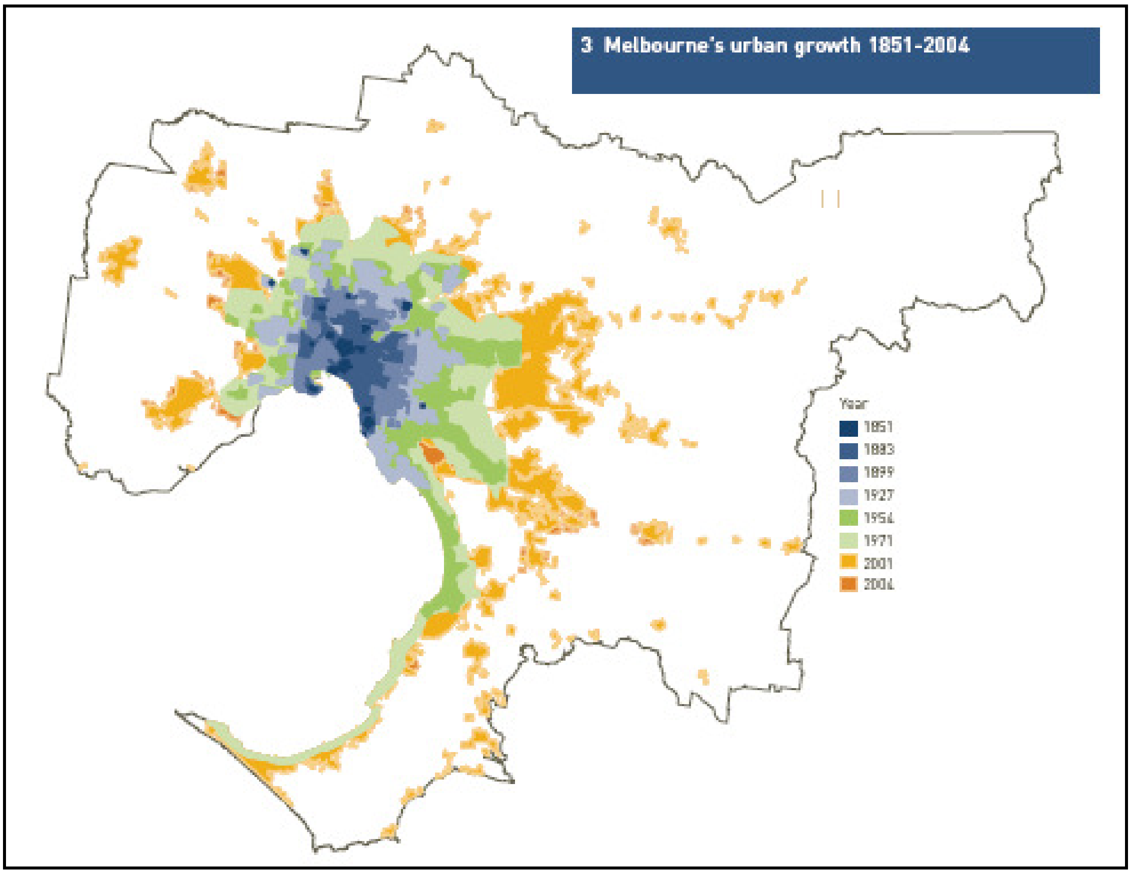


Figure 3.6: Melbourne growth between 1851 and 2004 (DSE, 2006a, p.12). Early preference for expansion south and south east refers to compartive geotechnical ease with which foundations and drainage can be established there compared to the basaltic lava plains to the west (See Figure 3.4)

During the first settlement, the marshy environment and flat basalt plains to the west were less physically attractive than the better water eastern and southern areas (e.g. see Johnston, 1966). In 1901, the Australian states Federated. The Federal government was based in Melbourne until 1927 when an especially-designed city, Canberra, was deemed ready to house the federal functions. The evolution of the Melbourne urban landscape was little affected by this change: growth, continued to be shaped by the way the transport (trains and trams) network had evolved during the boom period of the 1880s driven according to the rate of population growth affordability, and nature of availability of cheap land and open space in the suburban areas (O'Connor, 1997). In that home ownership has long been an aspiration which, until recently (e.g. see Moran, 2006) has been met by most households, the land development industry has thrived. Accordingly, since the late nineteenth century, so has urban sprawl: urbanised expansion of suburbs into adjacent farmlands was the rule. Indeed, the aspiration is still sold as “The Great Australian Dream”: owning a conventional suburban house on a quarter-acre block of land (about 1000 square meter) with a garden.

As the urban area expands, the MMA administrative boundary shifts outward. The currently designated MMA boundary encloses an area of 8,835km^2 that includes both urban and sub-urban regions. Being no older than 175 years (young in comparison with other Organisation for Economic Cooperation and Development (OECD) cities) the MMA houses the second largest urbanised population in Australia and is rated as amongst the world “most liveable cities” (The Economic Intelligence Unit, 2011). The MMA continues to grow (Figure 3.8).

3.3.2 Population growth

Population growth in Australian states is by both natural increase and immigration. Figure 3.7 shows that in the history of development, the first surge of population growth dates to the Gold Rush of the 1850s. The economic boom across the MMA following WWII accounted for about 85% of population growth in the Victorian State during that time.

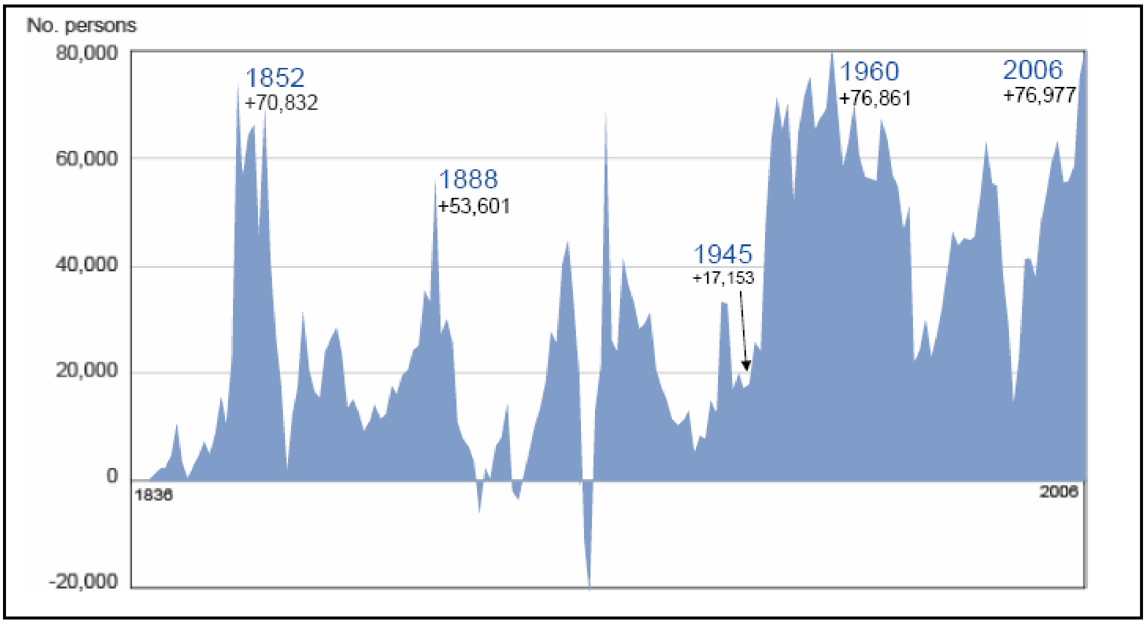


Figure 3.7: Annual Population growth, Victoria 1836-2006 (Spatial Analysis & Research Branch, 2007)

It is also shown in Figure 3.8 that by 1971, Melbourne's population had reached 2.5 million, having doubled in size over the 20 years.

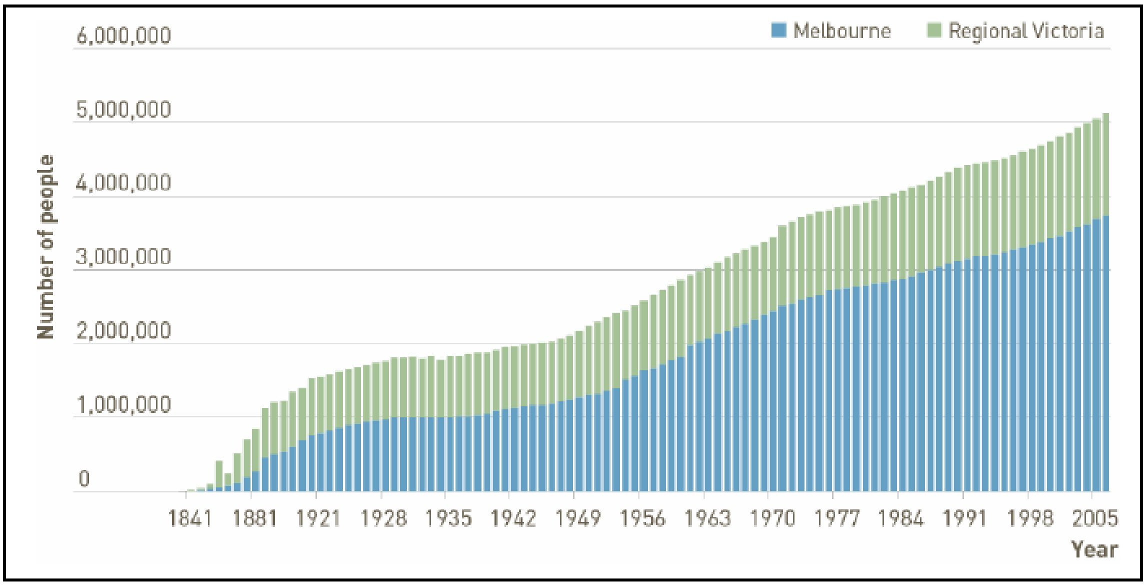


Figure 3.8: Melbourne and regional Victoria's estimated population 1841-2005 (Spatial Analysis & Research Branch, 2007). The figure shows an upward trend of population growth both within and without the MMA.

Apart from rapid (planned) population growth, the MMA has also seen a radical change in its structure. According to Forster (1991), the sprawling, decentralised, automobile-dependent, ethically diverse characteristics of Australian cities are mainly a legacy of the 1950s and 1960s. During these times, economic growth, population growth, automobile ownership all increased in ways that determined how government housing and planning policies evolved. In 1971, 75% of Melbourne households owned at least one car (Forster, 1991). This reflected the nature of the residential development pattern, its expansion seemingly directed along the various arms of the public transport network, which radiated from a soon-to-be less dominant city centre. As manufacturing and industrial places moved and relocated to suburban regions, Melbourne's urban form was transformed to one of polycentric configuration. Dwelling design also changed, such that land developers enticed buyers by offering wider frontages to accommodate a driveway and garage, wider suburban streets and there was inclusion of car parks around shopping centres (Frost and Dingle, 1995) such that the legacy strip shopping centre were disadvantaged in the competetion for trade. This exacerbated the tendency for urban development to involve land consumption at rates per dwelling that encouraged urban sprawl and car ownership.

3.3.3 Housing growth

Policy and practice, costs and fashions, technology and products have all evolved during this time (Figure 3.8 and Figure 3.10). As the population grew, the number and the nature of housing developments also changed. Goodman *et al.* (2010) show an upward trend in the number of new residenital dwellings that were constructed and completed during the 1990-2003 period in the MMA (Figure 3.9). However, there was a decline in the rate of new residenital constructions between 2003 and 2007 (Figure 3.9). It is estimated that the rate of new dwelling supply is about 0.78 dwellings per additional head of population during the 1990-2007 period (Goodman *et al.*, 2010, p.26).

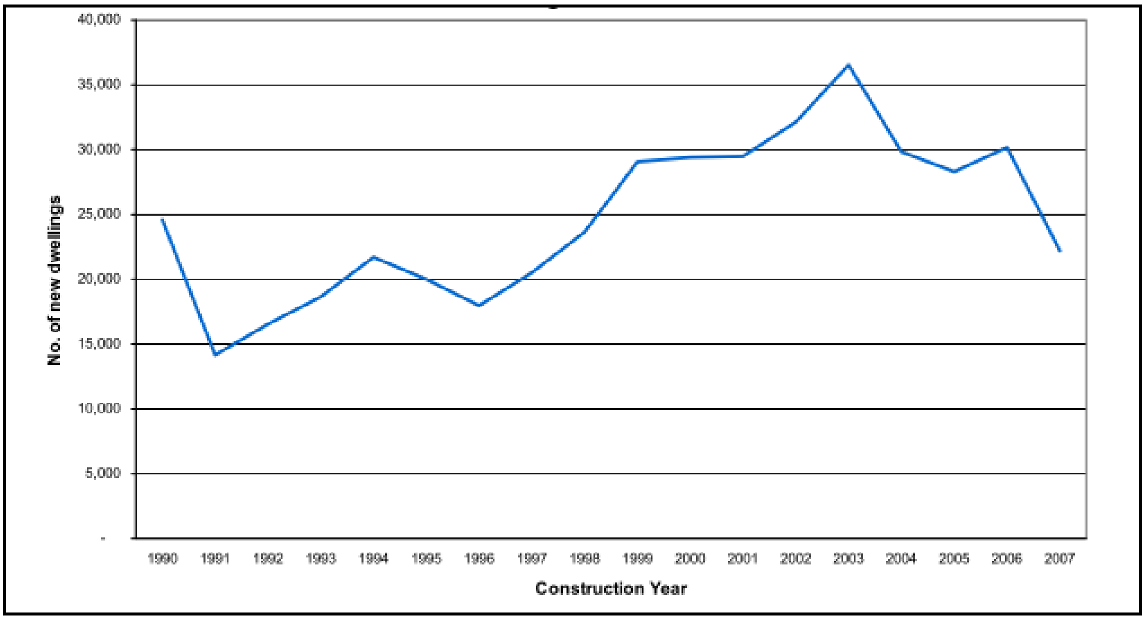


Figure 3.9: New residential construction from 1990-2007 (Goodman *et al.*, 2010, p.27)

Time-series data also shows a contrasting pattern between rooms or floor area per house and persons per house. As can be seen in Figure 3.10, the household size (in terms of number of people in a house) decreased dramatically over the last century. In contrast, the number of rooms per house and the total floor area per house showed upward trends.

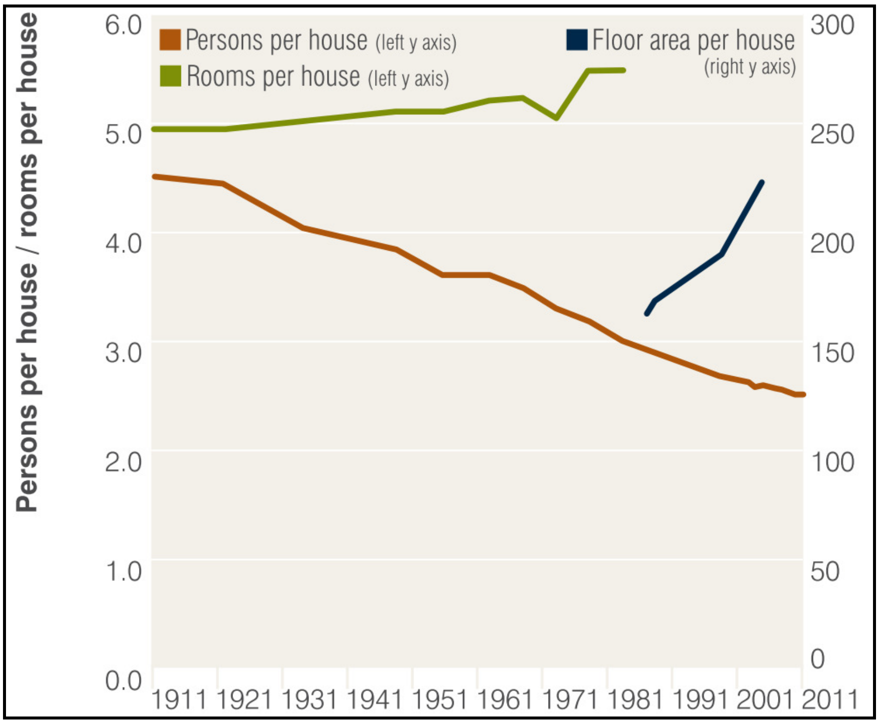


Figure 3.10: Change in average house size (rooms and floor area per house) compared to average household size (persons per house) Australia 1911-2003 (Commisioner for Environmental Sustainability, 2008, p.60)

Although the average household size decreased (DPCD, 2007b), the average floor area of new houses increased by 36% and 25% over the last 20 and 10 years, respectively (Table 3.1). For instance, in 2003 the average dwelling floor-area of dwellings built in Craigieburne (Hume) and Sunbury was 184m^2 and 208m^2, respectively (Birrell *et al.*, 2005a, p.03-13).

.

Table 3.1: Average Floor Area of new houses in Australian States (ABS, 2005)

	1984-85	1993-94	2002-03	Change from 1984-85 to 2002-03	Change from 1993-94 to 2002-03
	m^2	m^2	m^2	%	%
Victoria	163.6	177.4	222.4	36.0	25.4
Australia	162.2	188.7	227.6	40.3	20.6
Source: ABS data available on request, Building Activity Survey					

Specifically, as can be in Figure 3.11 although urban consolidation has been embraced and implemented in Victoria for over 20 years, the proportion of policy-friendly medium-density housing, (includes both semidetached houses and flats) is still relatively low (around 10%). There was a slight increase in the proportion of medium density houses (including both semidetached houses and flats) between 2002 and 2004 whilst the proportion of separate houses declined. In contrast, between 2004 and 2006, there was a slight decrease in the proportion of medium density houses (Figure 3.11). These trends suggest that medium density development as envisaged in *Melbourne 2030* (as implemented in October 2002) is yet to occur. Apart from semidetached and apartment housing development, higher density development in the form of multi-detached houses should be taken into account during examination and evaluation of the progress in implementing *Melbourne 2030* (Buxton and Tieman, 2004b). The method used in this study to identify changes in the distribution of both these types of higher density development is presented in Chapter 4.

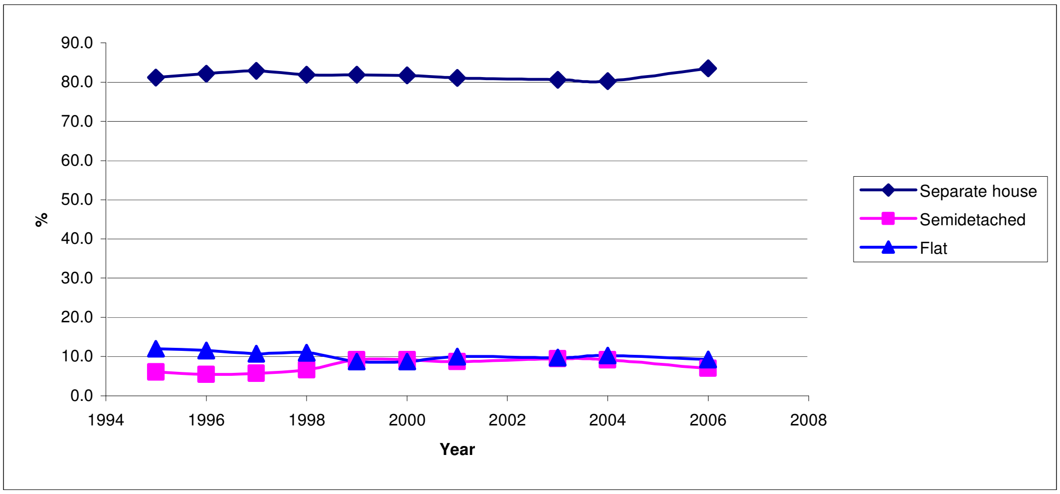


Figure 3.11: Housing trends in Victoria (ABS, 2008b). The graph shows the proportion of each housing type annually from 1995 to 2006. The graph only shows three housing types, but not the "other" group (including caravan, cabin, houseboat, improvised home, tent, sleepers out, house, or flat attached to a shop, office, ect) as categorized by the ABS. The graph (2004 and 2006) indicates that the proportion of separate houses increased while the proportion of semidetached and flats declined between.

The population in the MMA continues to grow: estimates are given such as the one stating the desirability of housing 5 million MMA residents by 2030 (DoI, 2008). The MMA's population growth and urban settlement pattern changes are, inevitably, imposing pressures upon urban planners and decision makers in Victoria intent on maintaining the liveable city status of Melbourne. The following section describes the evolution of Melbourne planning policy with a focus upon urban consolidation policy.

3.4 Urban planning and governance context

3.4.1 Urban planning in Australia

In Australia, decision makers serving all the three-tiers (federal, state and local) of government have been seeking ways of up-grading the sustainability of urban development (Stilwell and Troy, 2000). A neo-liberal approach was favoured during the Howard Government years (1996-2006). The enforcement and incentive tools that refer to deregulation, intervention, and economic rationality have been preferred by Federal Government politicians from time to time (Stilwell, 1994), the inherent economic rationalism being espoused to promote international regional competitiveness, and, economic efficiency and productivity (Buxton and Scheurer, 2007, O'Connor *et al.*, 2001). The constitutional position of the Federal government of Australia leaves it with only indirect power in urban planning and development (Stilwell and Troy, 2000). The first response at national level in Australia towards sustainable development was the development of the National strategy for Ecologically Sustainable Development (Department of the Environment Water Heritage and the Arts, 1992).

The most influential status in terms of power to make changes in urban planning policies and implementation in Australia is held by the state and local governments. While the Australian metropolitan state strategic planning is guided by state-based legislation, local government has responsibility for producing local planning schemes to control the development patterns. All over Australia, Local Government power is subordinate to that of the states (Alves, 2004). It was only after 87 years of settlement that formal urban planning was first introduced to decision making in the MMA (1922) (Figure 3.12). Since then, policy specific to urban planning has evolved from providing urban structure design (dominant paradigm in the 1950s) to promoting decentralisation and urban sprawl containment policies (dominant during the 1960s-1970s) (Figure 3.12). The latest state-wide strategic urban land use planning policy is *Melbourne 2030*, released in October 2002. Amendments refer to the re-formulation of the UGB and Residential Zones: 2007 and 2009, respectively (DoI, 2008).

Melbourne's planning history

1922 –	Metropolitan Town Planning Commission is established
1929 –	report of the Metropolitan Town Planning Commission proposes a planning scheme to prevent 'misuse' of land and protect property values, highlighting traffic congestion, the distribution of recreational open space and haphazard intermingling of land uses
1954 –	first comprehensive planning scheme for the metropolitan area, prepared by the Melbourne and Metropolitan Board of Works (MMBW), introduces the concept of district business centres and focuses major retail activity on designated centres on the public transport system that also provide central locations for housing, transport, employment and community activity
1971 –	the MMBW report, *Planning Policies for the Melbourne Metropolitan Region*, introduces long-term conservation and development policies through growth corridor and green wedge principles, and contains outward growth to a limited number of areas on the edge of the city
1980 –	the MMBW's *Metropolitan Strategy* reinforces the 1954 policy on district centres, encourages development in existing areas, and concentrates housing, transport, employment and community facilities at highly accessible points
1983 –	new district centre zones encourage office development in 14 centres and restrict it elsewhere
1987 –	*Shaping Melbourne's Future* reinforces the thrust of the 1980 Strategy
1995 –	*Living Suburbs* relaxes metropolitan-wide planning direction and controls, for example, on green wedge boundaries and the hierarchy of activity centres, and devolves much decision-making to local level or on a case-by-case basis

Figure 3.12: Key turning points in Melbourne Metropolitan urban planning policy (DoI, 2002e)

Previous studies of trends, extent and location of urban consolidation in selected local government areas (LGAs) in Melbourne (Birrell *et al.*, 2005a, Buxton and Tieman, 2005) have introduced the topic via description and analysis of the post 1970 evolution of state planning policy on urban development. To set a context for this study, a summary of the key time periods marking the changes/transitions in urban planning policies in Melbourne either at state or local government level of responsibility are presented.

Generally, four main periods of planning policy change in Melbourne can be identified. The underlying premise for the urban consolidation policy were summarised by (Gleeson and Low, 2000, p.143) as:

> "In principle, consolidation policies in Australia have attempted to manage urban "sprawl" (low density growth), underlined by a notion that more compact cities enhance sustainability"

3.4.2 Urban consolidation in Melbourne- the early stage

First, in 1970, the issues and concerns related to urban consolidation, urban containment, densification and the restriction of sprawl arose from the experience of uncontrolled suburbanisation. Thus, in 1971, The Melbourne Metropolitan Board of Works (MMBW) produced *Planning Policies for the Melbourne Metropolitan Region*. This particular policy placed a decreased importance of the Central Business District (CBD) in an attempt to contain suburbia by limiting growth to corridors rather than allowing circular growth outwards (McLoughlin, 1991, McLoughlin, 1992). However, this idea came under scrutiny with renewed debate about the status of the CBD as the central node. From the early 1970s until the early 1990s, urban consolidation was controlled by each municipality under its "flat codes" (in terms of type, design, location and density) practice. These were non-statutory and varied across municipalities. Conformity arose when the state planning agency of the time, the MMBW, introduced dual occupancy provisions into the Melbourne Metropolitan Planning Scheme (MMPS) in Amendment 150 in 1981 (Buxton and Tieman, 2005). Initially, dual occupancy was in the form of (an) additional dwelling(s) in the backyard of a suburban house. Later there were examples of house replacement by two detached houses (Birrell *et al.*, 2005b, McLoughlin, 1992).

The Metropolitan Strategy, released in 1980 put the focus back on major areas of activity by concentrating retail and office activities into 'district centres'. This approach echoed in the 'activity centres' outlined by the *Melbourne 2030* plan. Twenty such 'district centres' were proposed in which consolidation of suburban, commercial and other services, higher density housing and public investment would be concentrated. This particular policy was approved in the amendment to the MMPS in 1983 (McLoughlin, 1991, McLoughlin, 1992). Another significant step toward urban consolidation occurred in 1987 with the aim to reduce urban sprawl by increasing housing density. Statutory measures such as allowing dual occupancy on suburban housing blocks were utilised to implement the overall policy. Demonstration projects designed to convince developers about this change in direction were instigated (McLoughlin, 1991).

3.4.3 Urban consolidation since 1990s-VicCode 2

Secondly, when the Liberal Party under Premier Jeff Kennett took control of the State Government of Victoria in 1992, a much more aggressive approach was taken to promotion of urban consolidation. The Victorian Government introduced *The Victorian Code for Residential Development (Multi-Dwellings)*, named VicCode 2, in December 1993. It was designed to control medium density developments (Buxton and Tieman, 2005). Under this policy, all metropolitan councils were required to frame and enforce provisions regarding planning permits for 3+ dwellings or dual occupancy in any urban zone or reserved land. The implementation of VicCode 2 meant that multi-unit developments could be larger, higher and closer to the property boundaries although certain criteria such as neighbourhood character, overshadowing, density, efficient use of energy, open space and visual privacy were still firmly entrenched within the policy. In summary, VicCode 2 made it easier for subdivisions and multi-unit developments to be approved. It was a genuine attempt at promoting urban consolidation (Birrell *et al.*, 2005b).

VicCode 2 was reviewed by an independent panel in August 1994 after local opposition on a number of contentious multi-unit development proposals (Eccles, 1995). *The Good Design Guide for Medium Density Housing* was then introduced in July 1995 to impose further requirements on the local government approval process for medium density development applications. Specifically, a planning permit is required before a lot can be improved with:

- 2+ dwelling development, other than a moveable dwelling unit, not exceeding four storeys, or
- 1 dwelling on a lot less than 300m^2

The inclusion of a dwelling situated on lots that are less than 300 square meters constituted the only major difference. The State Government claimed that medium density housing would diversify the choice of housing in both established areas and on the urban fringe, better match house size and type with population changes and individual and community needs, increase the supply and diversity of affordable housing, help limit outward urban growth, locate denser housing closer to public transport, and reduce the wasteful use of infrastructure and energy costs (DPCD, 1995, p.1, cited in Buxton and Tieman, 2005). However, except for the density criterion, which was described quantitatively, other standards such as neighbourhood character were described in ways allowing subjective interpretation. Under the Victorian Planning Provisions (VPPs), the responsible authority must consider the *Guide* in approvals of medium density development for appropriate zones. Although the *Guide* received a lot of local opposition and criticism, the Government, by its commitment in a market oriented planning policy, showed little sign of changing its development facilitation stance (Buxton and Tieman, 2004b).

3.4.4 Rescode

Thirdly, *Rescode*, a medium density planning code, was introduced by the Victorian Government in August 2001 to become a statutory tool for controlling medium density development. When the Australian Labour Party (ALP) under Premier Steve Bracks took office in 1999, a new planning strategy was devised to cope with ongoing criticisms associated with *The Good Design Guide*. In response to community criticism of infill development in established suburbs, the ALP clearly stated that the “right places” for medium density development were areas around public transport and activity centres (Thwaites, 1999, cited in Buxton and Tieman, 2004b, p.7). Under *Rescode*, requirements and standards are given for each dwelling development application category, namely

- Permit not required
- Single dwellings
- Multiple dwellings on a lot and
- Subdivision

The Government claimed that the key aspect of *Rescode* was “respect for neighbourhood character” and that “the standards to achieve these goals have been significantly strengthened compared with *The* Good *Design Guide* and *Viccode1”* (DoI, 2005, cited in Birrell *et al.*, 2005b, p.05-6). Standards must be considered when lodging for planning permit to build a medium density development; however some of them were not statutory. Birrell *el al.* (2005b) have revealed that in practice, as long as the medium density development (either in the form of dual occupancy, semidetached or flats) met the minimum setbacks, “site occupancy” standard, and with “the building style consistent with that of the nearby houses”, the development will often be granted a building permit. Thus *Rescode* loosely controls the practice of infill development. For instance it restricts widespread infill development in suburban regions which would jeopardise the extent of private open space for both shrubs and canopy trees. Buxton and Tieman (2005, p.141) asserted that historically, the success of urban planning policy was not as much as envisaged by those who framed it because of “the discretionary nature of much content, the use of qualitative measures, and the lack of clarity” (in specifications) .

Accordingly, there is an incentive to derive a quantitative approach to translate the planning policy’s principles and objectives into implementation outcomes. In Chapter 5, housing development and accessibility factors were quantitatively determined and comparative analysis among selected LGAs were undertaken. Implications for bringing *Melbourne 2030* planning policy to practice emerged for discussion.

3.4.5 Melbourne 2030

Fourthly, in October 2002, the Victorian State Government introduced its thirty-year strategic urban land use planning policy: *Melbourne 2030*. It was released as a strategic plan for accommodating a projected (2030) MMA population increase of one million while at the same time maintaining the community’s liveability, improving economic efficiency, and environmental sustainability. As in Sydney, Melbourne faced the need to evolve new plans and policies about metropolitan growth and change for the future residential populations and jobs, and travel as well as to catch up on 1990s legacy of neglect for infrastructural improvement and maintenance, especially in the public transport sectors (Bunker and Searle, 2007). The vision of *Melbourne 2030* is to provide a liveable, attractive and prosperous urban living environment for residents, business and visitors (DoI, 2002e). To fulfil this vision, *Melbourne 2030* has nine directions:

1. A more compact city
2. Better management of metropolitan growth
3. Networks with the regional cities
4. A more prosperous city
5. A great place to be
6. A fairer city
7. A greener city
8. Better transport links
9. Better planning decisions, careful management

This strategic plan seeks to change radically the traditional pattern of Melbourne's low density urban form to that conforming more to "a more compact city" model, as stated as Principle one in the *Melbourne 2030 document*. Principle one aims to (DoI, 2002e, p.45):

> 1.3 Locate a substantial proportion of new housing in or close to activity centres and other strategic redevelopment sites that offer good access to services and transport

Specifically, according to *Melbourne 2030*, location of new residential housing should be (DoI, 2002e, p.57):

- In or around the central activities district (CAD)
- In or within easy walking distance of Principal or Major Activity Centres
- In or beside Neighbourhood Activity Centres that are served by local public transport
- Abutting tram, train, light rail and bus routes that are part of Principal Public transport network (PPTN) and close to principal or major activity centres
- In or near major modal public transport interchanges that are not in principal or Major Activity Centres and/or

- In major redevelopment sites, that can provide space for 10 or more dwelling units, close to activity centres and well-served by public transport

Melbourne 2030 designates 110 Activity Centres and encourages mixed-use, and different housing forms and densities of development around those Activity Centres (DoI, 2002e). Improvement in public transport networks (in terms of frequency and connectivity between Activity centres) is intended. This is interlinked with good urban design (shown in Direction 5) to encourage sustainability in urban development. Figure 3.13 shows the location activity centres and PPTN. Figure 3.14 shows a preferred urban form with spatial distribution of development within 400 meters of the public transport network. These principles are used to examine the progress of implementing *Melbourne 2030* in practice (Chapter 5), for example in determining how much new high density development occurred within 400 meters of Major Activity Centres.

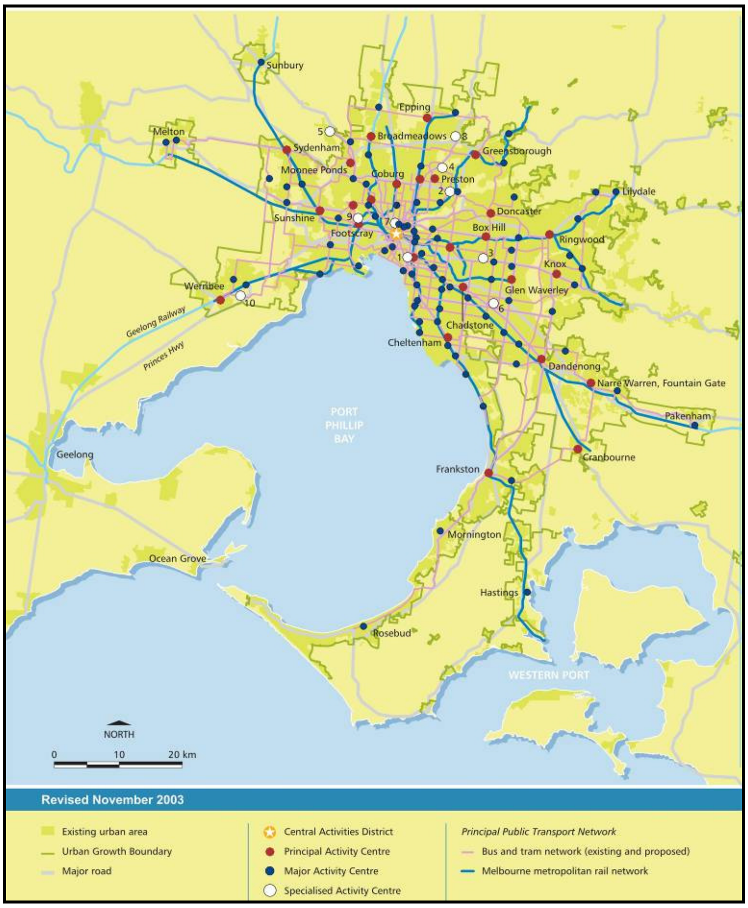


Figure 3.13: Location of Activity Centres and PPTN (DoI, 2002e). Strategic redevelopment sites are depicted within buffer of Principal and Major Activity Centres (points).

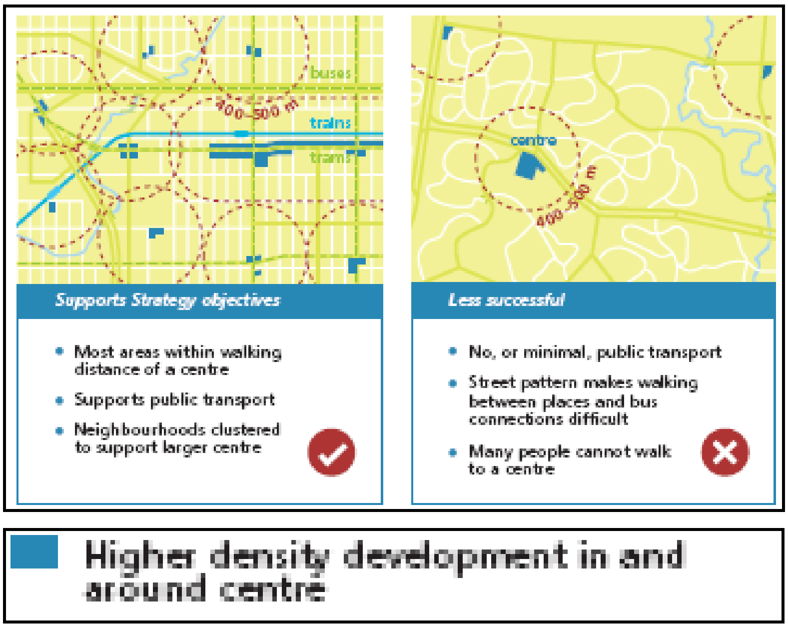


Figure 3.14: Conceptual model of Sustainable Urban structure (DoI, 2002e, p.109). Higher density development is in or within 400-500 meters of public transportation hubs on tram and train lines.

Specifically, *Melbourne 2030* seeks to reduce the number of new dwelling developments on the urban fringe and promote residential development close to public transport networks and designated activity centres. It is estimated that dispersed development will reduce from 38% to 28% while an increase from 24% to 41% of new dwellings development will be close to activity centre by 2030 (Table 3.2).

Table 3.2: Proposed distribution of new households across metropolitan Melbourne from 2001-30 (Implementation Plan 3- Housing) (Adapted from DoI, 2002a, p.8)

	Average distribution of new dwellings	Proposed distribution of new households metropolitan Melbourne 2001-30						Overall distribution of new households
Location	1997-2001	2001-2005	2006-10	2011-15	2016-20	2021-25	2026-30	2001-30
Greenfield development	38%	52,000 45.2%	42,500 37.6%	32,500 28.9%	25,800 23.7%	23,500 25.4%	17,500 22.4%	193,800 31%
Activity centres and other strategic redevelopment sites	24%	30,000 26.1%	36,800 32.6%	47,400 42.1%	52,560 48.2%	46,300 50.1%	41,700 53.5%	254,760 41%
Dispersed residential development	38%	33,000 28.7%	33,700 29.8%	32,600 29.0%	30,640 28.1%	22,700 24.5%	18,800 24.1%	171,400 28%

Much concern has been raised about the implications of *Melbourne 2030* for municipalities, for example in terms of projected population growth and dwelling development with the availability of land supply for new development. In addition, consideration between gross and net growth (i.e. relationship between new dwelling development and demolition rates) should be examined to understand the net land supply for projected population growth in each LGA (Buxton and Tieman, 2004).

The Urban Growth Boundary (UGB) was introduced in October 2002 and was legally implemented in October 2004 to limit urban expansion and sprawl. On the urban fringe, new development and urban expansion are directed into four designated urban growth corridors so that the Green Wedge Areas can be preserved. The Government claimed that growth is managed in harmony with public transportation infrastructures and services (DoI, 2002e). The UGB should not be easily altered and changes should be "infrequent" (DoI, 2002e, p.62). However, within three years of introduction, in November 2005, the UGB was amended and extended. It was argued that this expansion was to ensure adequate land supply for housing a growing population within a 15-year time frame. Figure 3.15 shows that the UGB was extended outward in growth areas of the south-east, north and west of the MMA between October 2002 and November 2005.

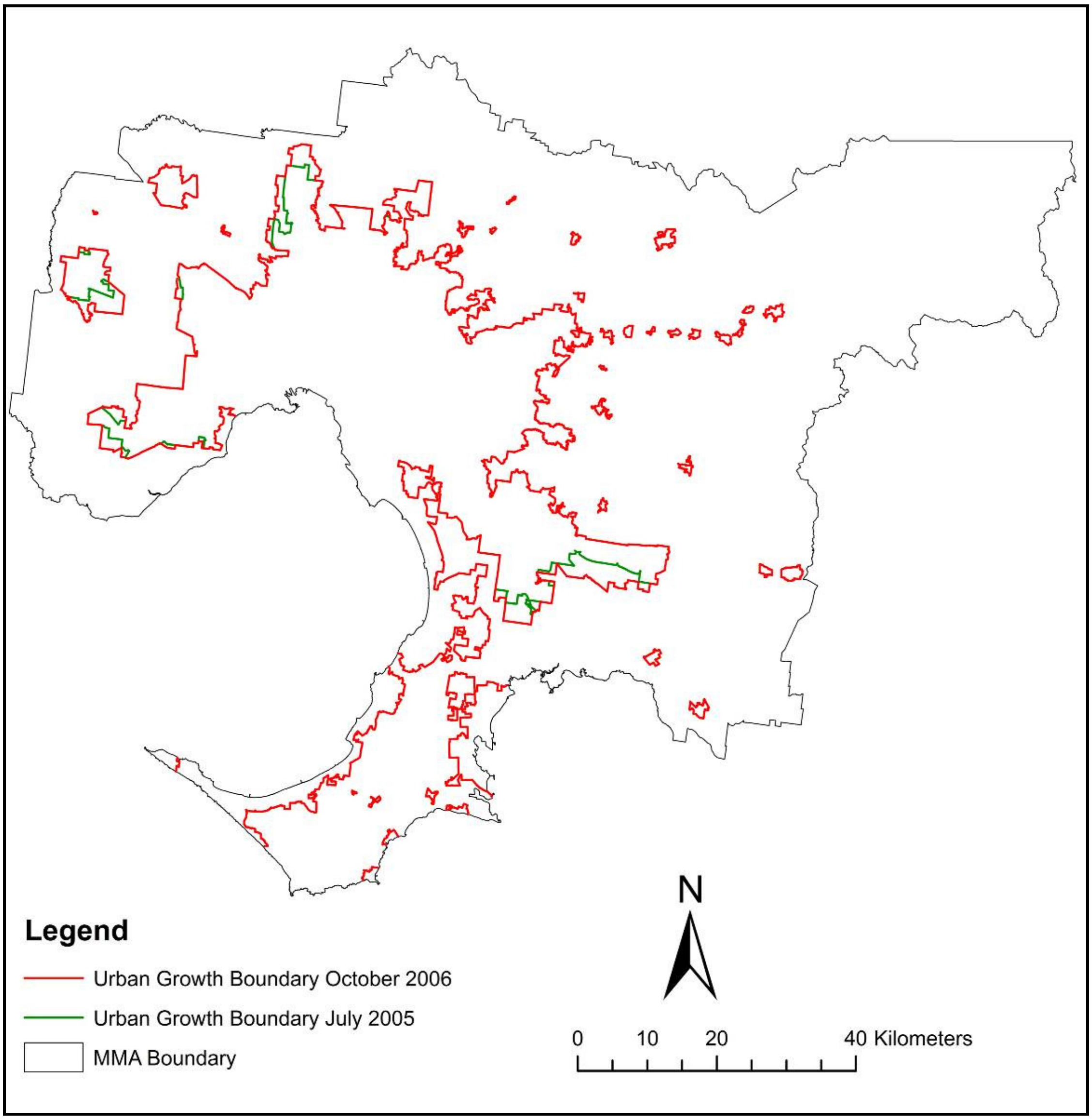


Figure 3.15: Spatial extent of Urban Growth Boundary in 2005 and 2006. The UGB for 2006 was overlaid on that in 2005. If only red line is evident, the spatial UGB in 2005 and 2006 boundaries are the same.

Between 2002 and 2006, other planning initiatives that purport to be a part of management and control of residential development in a sustainable manner include:

- *Design Guidelines for Higher Density Residential Development* (DPCD, 2009b)
- the *Protecting the suburbs* package, in which Victorian Government introduced of interim height controls for centres and a new Residential 3 Zone
- *A plan for Melbourne's growth areas* in November 2005[7]

[7] Between 2003 and 2005, Smart Growth Committees was formed by the Victorian Government. The committees and the Victorian Government worked together to develop proposals for managing future growth in the five growth areas designated in *Melbourne 2030*. After considering all proposals from the

- The *Sustainable Neighbourhoods* package of enhanced planning scheme requirements for all residential subdivisions was introduced in 2006[8].

Clearly, any audit of the impact of these various measures should involve consideration of a range of issues.

3.4.6 Audit of Melbourne 2030

The first audit of the *Melbourne 2030* strategic plan was undertaken in 2006 and 2007 in two stages. Stage one was conducted by the DPCD, an agency responsible for the implementation issues of *Melbourne 2030*. This stage involved (1) meetings between DPCD with senior planning staff in each of the 31 LGA councils, (2) and the compilation of a report: *Melbourne 2030 Audit: Analysis of Progress and Findings from the 2006 Census*, which presents development trends and patterns from the 2006 census data, reviews progress in implementing Victorian Government actions to put *Melbourne 2030* into practice, and summarises the feedbacks from key stakeholders. After that, stage two was conducted by four independent experts. They considered outcomes from stage one, submissions from all stakeholders before providing advice to the Minister for Planning on the ongoing implementation of *Melbourne 2030* (DPCD, 2007b). It is found that there is little evidence that the plan had achieved plan objectives during the period of 2001-2006. In particular, the household development trend does not conform to planning policy. For example, greenfield development was recorded at 48.3% of household growth between 2001 and 2006 whereas the policy targets for greenfield development of 31% of total household growth by 2030. The audit report suggests that a ten year timeframe might be long enough for policy-conforming change to occur (DPCD, 2008, p.40 & p.59). However, Buxton (2008) argued that radical actions need to be undertaken and specific measures should have been recommended in order to meet certain key principles of *Melbourne 2030*. For instance, growth has not been directed away from car-based, dormitory suburbs dominated by detached housing on the urban

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committees, in November 2005, *A plan for Melbourne's growth areas* was released and amended UGB was introduced to ensure sufficient land supply in 25 years DPCD (2007) Melbourne 2030 Audit: Analysis of Progress and Findings from the 2006 Census. Department of Planning and Community Development..

[8] It implements Victorian Government policy to achieve more liveable and sustainable communities. The new residential subdivision provisions set out requirements for designing and assessing residential subdivisions in urban areas throughout Victoria. These changes are supported by complementary State Planning Policy provisions for subdivisions, and changes in relevant zones, overlays and planning practice notes Ibid..

fringes. Thus, high energy use and affordability problems remained as did further calls for public transport improvement.

The Victorian Government Response to the *Melbourne 2030* Audit was published in 2008 (The Victorian Government, 2008). It is clearly reported that "The lack of a comprehensive in-built monitoring system for *Melbourne 2030* has been a significant constraint on our ability to report adequately on the progress of the Plan's implementation" (The Victorian Government, 2008, p.63). The report also recommended developing an outcomes-based monitoring framework for *Melbourne 2030* that would provide information to decision makers and stakeholders. Specifically, the framework should:

- **Assess progress in moving towards Melbourne 2030 outcomes**
- Assess the effectiveness of Melbourne 2030 implementation
- Provide a basis for adjusting the implementation of Melbourne 2030 and updating the Plan in the future

In the present study, integration of spatial datasets in Chapter 4 and (from DPCD), in Chapter 5, it is demonstrated that closer settlement style and accessibility indicators can be used to assess the progress achieved by each LGA in moving towards *Melbourne 2030* housing development outcomes: reducing greenfield development on the fringe whilst promoting infill development and/or brownfield development within or near activity centres or public transport networks.

Clearly, any test of attempts to devise improved monitoring methods will need to involve the full range of MMA LGAs in terms of land parcel history. Land parcel history becomes known after the time series of land uses has been documented. For instance, a land parcel on the fringe of an expanding urban area is destined to have a history involving the whole range of landuse/land cover change: from forest to rural and horticultural land cover, each land use change being to one of more intensive development: Greenfield (residential or other built-up use) , followed by residential re-development (residential or brownfield). For a city expanding under a land-use planning policy that is enforced, the changes will probably be documented in general from the history of land use planning zone amendments.

Unlike the cadastral information available in some jurisdictions (e.g. the United States of America), the Victorian cadastre is not directly attributed for land use history and so that information must be assembled from other sources, the most obvious of which is the dates of the individual development tracts, and the information about land cover change that can be deduced for time series image analysis. As mentioned in Chapter 2, page 22, the first Victorian cadastral level land use database is still in preparation. Given that the MMA has expanded as urban growth boundaries (as shown in Figure 3.15) extended ever outwards, and new cities/LGAs proclaimed, the range of residential urban forms can be classified according to the age (and corresponding style) of the individual development tracts: inner, middle suburban, and outer LGAs.

Given that inner city population densification is by major redevelopment, and the main challenge in monitoring the impact of the MMA urban consolidation policy is in the middle and outer LGAs, the range of differences in the relative significance of urban forms across the MMA LGAs can be sampled by choosing LGAs from middle and outer regions.

3.5 Selection of Local Government Areas

Four LGAs in the MMA are selected to demonstrate the utility of applying a developed analytical approach in identifying and quantifying high density development (Chapter 4 and Chapter 5). These are selected to represent:

- a range (middle and outer regions in the MMA) of distances from the Melbourne Central Business District (CBD) (Figure 3.16)

areas subject to densification (population and dwellings) in the 2001-2006 period (see Table 3.3 and Table 3.4).

- Table 3.3 shows that four LGAs positively increased between 2001 and 2006. In the same period, Table 3.4 indicates that the proportion of separate houses declined in City of Monash whilst other dwelling types in all four representative sample LGAs positively increased.

Table 3.3: Summary of total population (estimated population) in 2001 and 2006 in different Local Government Areas (Australian Bureau of Statistics, 2001 & 2006)

Local Government Areas	2001	2006	Change (%)
Whittlesea	118118	129793	9.88
Knox	147433	151804	2.96
Monash	163141	168708	3.41
Casey	181562	222681	22.65

Table 3.4: Summary of dwelling types in each LGAs in 2001 and 2006

LGAs	Separate houses			Medium & High density houses			Others	
	2001	2006	Change	2001	2006	Change	2001	2006
Monash	47697	47043	-654	8627	11968	3341	3813	3898
Knox	43043	44514	1471	4548	6458	1910	2828	2641
Casey	52818	65358	12540	4205	5858	1653	2997	3712
Whittlesea	32748	36975	4227	2641	3617	976	1517	1958
Source:(Australian Bureau of Statistics, 2001 & 2006), City of Monash, Whittlesea, Knox, Casey, Community profile								

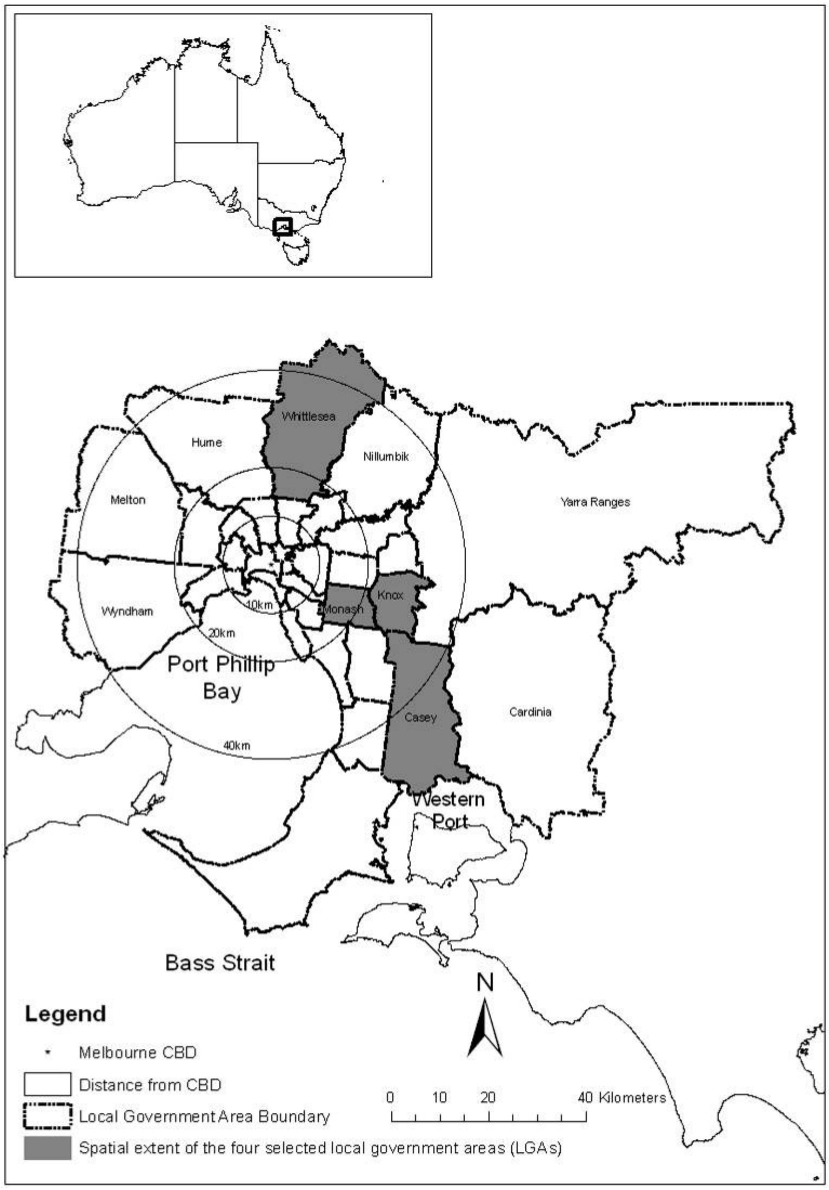

Figure 3.16: Spatial extent of four selected LGAs within the Melbourne Metropolitan Area. They are within 20 to 40 kilometre of Melbourne CBD : together, they represent "older' and " younger" phases of urban expansion

3.5.1 City of Whittlesea

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 of around 1,800 new households per year between 2008 and 2012 (City of Whittlesea, 2008, p.38). To plan for future growth, LGA planners have prepared some plans and strategic documents, namely:

- Housing Strategy (in August 2001),
- Community Plan, which sets out the long-term vision of the community and presents a short-term action plan (2009-2013) so as the vision can be achieved and the recent Draft Housing Diversity Policy Briefing Paper (March 2010), which seeks to address housing diversity issues in the LGA.
- Northern Regional Housing Statement
- City of Whittlesea Urban Character Assessment 1999 and
- Municipal Strategic Statement

Despite of these efforts, it is clearly identified in the Draft Housing Diversity Policy Briefing Paper (City of Whittlesea, 2010, p.15) that

> "At present, the Local Planning Provisions contained in the Whittlesea Planning Scheme provide minimal strategic direction with regard to the preferred location for more diverse housing outcomes and in particular, increased residential density. As a result, planning applications for higher density residential developments have been granted on an ad-hoc basis throughout the residential areas of the municipality, with little regard to their strategic context."

3.5.2 City of Knox

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: Blind Creek, Monbulk Creek and Corhanwarrabul Creek provide waterways and are buffered with 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).

3.5.3 City of Casey

The City of Casey (813.3 km^2) is one of Australia's most rapidly growing regions in the fringe regions of the MMA. It is located about 35km southeast of the Melbourne CBD. Early European settlement occurred in the late 1830's, at much 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 original City of Casey (City of Casey, 2008). The present 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, 2007b). 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).

3.5.4 City of Monash

The City of Monash (81.5km^2) is located within 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 area but hosts a considerable amount of industrial, commercial and recreational space (City of Monash, 2009). The Europeans 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 see conformable to styles of existing neighbourhoods though inevitably increasing the variety of different housing styles so as to serve the state public policy favouring densification (City of Monash, 2006).

The City of Monash Housing Strategy produced in draft in 2004 identified the roles and actions being implemented in conformity with the vision of *Melbourne 2030*. In assessing the new development proposal, the Local Council is using Local Planning Policy Frameworks, Zones and Overlays (e.g. Vegetation Protection Overlay (VPO) and Heritage Overlay), and specific provisions to control particular uses and development. The major strategic directions underpinning the Strategic Framework for Monash include (City of Monash, 2006):

- Identification of existing treed environments where the special leafy character valued by the community is to be protected by a VPO.
- Identification of the hierarchy of the existing activity centres and promotion of the development and expansion of retail and related facilities appropriate to the centre's role.
- Conservation of locally significant residential, commercial and industrial heritage buildings, places, streetscapes and natural environments.
- Maintenance of visually significant sites that enhance the image of Monash.
- Maintenance and enhancement of the established Garden City Character of Monash on both private and public land including along main roads and
- Integration of land use and transport planning around major arterial roads, fixed public transport routes and bicycle paths, in commercial, residential and industrial land use areas.

3.6 Summary

In this chapter, it has been seen that the MMA LGAs include a range of urban form patterns and its residential urban form components vary in relative significance. The patterns are evolving as urban consolidation policies are implemented while at the same time the UGB expands. As land developers launch new projects, geographical variation in the scope for conforming to the spirit and purpose of *Melbourne 2030*[9] emerges. In areas where the relative significance of infill and brownfield development is high, on-going audit of the success of *Melbourne 2030* implementation calls for land-parcel status change mapping time series in such a way that the access to supporting data streams can be assured. Such adoption is more likely if:

- The data and information processing flow path is feasible in a routine way
- The applications of the data integration involved are demonstrably useful and implemental
- Both strategic and statutory planners are interested in implementation and
- The community appreciates the value of the application of results, for instance via visualisation

The technology and expertise necessary for the data assembly, quality testing and integration have been demonstrated (Phan *et al.*, 2008, Phan *et al.*, 2009a). In the next chapter, a GIS land-parcel approach to identify and map infill development in the MMA is presented. It aims to close the information gap that opened when *Melbourne 2030* was launched. Specifically this refers to a failure to support information systems with the time-series detailed geographies necessary if infill development is to be monitored.

[9] Patterns of protest against urban consolidation vary likewise as seen from the VCAT records http://www.docstoc.com/docs/31719069/Role-of-VCAT---Melbourne-2030-Vi

4. CHAPTER 4: A PARCEL-BASED GIS TO IDENTIFY AND MONITOR INFILL DEVELOPMENT IN THE MELBOURNE METROPOLITAN AREA

4.1. Introduction

This Chapter aims to achieve the first objective of the study: *to develop a GIS-based land parcel framework for automatic and systematic identification of residential intensification that can be applied for all local government areas (LGAs) in the MMA, which will produce outputs that can be used further for quantifying spatial patterns and spatial modelling.*

As mentioned in Chapter 2 (see Table 2.2 and section 2.3.1) the current information about infill development is only available in aggregated form, thus leaving information gap. In the latest annual report, it is clearly identified by DPCD that the land parcel subdivision at fewer than ten dwellings per single lot should be communally available as a complement to the current MMA residential redevelopment monitoring data (DPCD, 2009a). Apart from that, it is also reported that reliable figures about if new housing is being built in activity centres or suburban streets in the MMA are not available (Millar, 2008). Thus, it is necessary to develop a suitable and effective method to identify the location and spatial extent of infill development in the existing urban areas. Clearly, one obvious approach would be to make use of time-series image data. Figure 4.1 shows an example of infill development site in City of Monash. As can be seen in Figure 4.1, one dwelling was demolished and replaced by two dwelling between 2001 and 2005. However, attempts to automate the kind of land cover change detection process that would need to be implemented produced ambiguous results, the more so in the case of semi-detached and multi-storey dwellings.

Figure 4.1 An example Infill development site in City of Monash. The boundary of the infill development site is in red colour. The picture on the left was taken from 2001 City of Monash aerial photo archive and the one on the right was taken from 2005 City of Monash aerial photo archive.

This Chapter will present a more effective and reproducible data-processing path to mapping MMA infill development. Because response to the *Melbourne 2030* policy varies from one LGA to another, the methods have been tested across the age and terrain range of suburbs using a "before and after" *Melbourne 2030* implementation approach. The framework identified in this Chapter will complement the current land development monitoring program by DPCD in the UDP by providing a framework to identify and quantify MMA infill development via documentation of selected LGAs, particularly for dispersed infill development identification.

Results from this Chapter are relevant to elucidating both local impacts of urban consolidation policy (Chapter 5) and the relative significance of factors in determining the location of infill development in City of Monash (Chapter 6).

4.2. Definition of infill development

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). As discussed in Chapter 2, implementation of urban consolidation policy has been considered by some authors and planners as a solution to the problems of containing urban sprawl while still accommodating an increasing population. As such, most urban consolidation research data collections have focused on either population increase or housing number and density changes, or even both (e.g. Anthony, 2004, Buxton and Scheurer, 2005, Yates, 2001). Some researchers used density alone as the independent variable (Burton, 2000) whilst planners and designers are inclined to use attributes, such as dwelling and population density, street widths, setbacks, lot size, and presence and nature of sidewalks (Duany *et al.*, 2001). From a remote sensing perspective, infill is considered as urban land cover (development) that occurs within the internal open space, which is contained in the built up area (Sheppard, 2006).

The Victorian Department of Infrastructure (DoI) *Municipal Fact Sheets* define medium density housing as more than one dwelling on a lot (Buxton and Tieman, 1999, p.2). As discussed in Chapter 2, Table 2.1, the terms have been defined in various ways. For mapping and monitoring residential development patterns, the essential analytical spatial data input 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 are unavailable, surrogate datasets, such as building permit approvals and indicators of the number of semi-detached, units and flats have also been used (Birrell *et al.*, 2005b, Bunker *et al.*, 2002, Buxton and Tieman, 2004b).

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) (DoI, 2000).

Hence, conceptually, if spatial boundary changes of a house can be mapped, infill development sites can be identified. It is true that in a perfect database, each house/property or dwelling is registered with a unique address for delivering daily mails, bills and other corresponding issues. The spatial boundary of dwelling is also needed for land taxation purpose. In Victoria, this information can be accessed from Vicmap spatial data products: Vicmap property and Vicmap address. These two datasets are described and discussed in section 4.4.

The Australian Institute of Health and Welfare defines a dwelling as (Australian Institute of Health and Welfare, 2005):

> "[a] structure or a discrete space within a structure intended for people to live in or where a person or group of people live. Thus a structure that people actually live in is a dwelling regardless of its intended purpose, but a vacant structure is only a dwelling if intended for human residence."

Following the ABS, in terms of definition, a dwelling can be a separate house; semi–detached, row or terrace house, townhouse; flat, unit or apartment; or other dwelling (ABS, 2006). In this study, a dwelling is defined by combining both address point and spatial structure using Vicmap products. Specifically, a land parcel is considered as a dwelling if:

- It is within Residential Zones
- It contains only one non-duplicate address point
- Its spatial boundary is unique in the Vicmap property database

For examination of land use changes at the land parcel level, Huxhold (1991) noted the following potential sources of changes:

- buildings are built and demolished
- existing buildings are renovated (conversion of house into commercial enterprise without demolishing it and rebuilding)
- boundaries of parcel change
- a new subdivision is created
- resize or relocation of public right-of-way
- a street is vacated
- property outside the jurisdiction is annexed
- errors are detected and corrected

These changes can be documented in terms of attribute and/or location (Raza and Kainz, 2002). Because the urban consolidation policy in Australia encourages higher density development, much interest attaches to monitoring outcomes in terms of geographical variation in impact on urban form (Bunker *et al.*, 2002, Buxton and Tieman, 2004b). In pursuit of information about this, and in accord with study Objective 1, this Chapter is devoted to exploring options for monitoring dwelling density pattern changes (2000 and 2006) with special reference to infill development. Dwelling density change is determined by an increase number of dwellings (in 2006) per lot compared with previous year (in this Chapter it is demonstrated for the year of 2000). In other words, infill development is identified and mapped on a lot by lot and dwelling by dwelling basis.

4.3. Input data assembly and quality control

All datasets (for example cadastre, address point, planning scheme, and *Melbourne 2030* Activity Centres) used in this Chapter were assembled from Victorian Spatial Data Infrastructure, and DPCD sources. Table 4.1 presents a summary of spatial datasets acquired for achieving Objective 1.

Table 4.1: Summary of datasets using in Chapter 4

Spatial Datasets	Resolution	Source	Data year (s)/ Date of acquiring dataset	Key data characteristics
Cadastre		Vicmap Spatial Data Office	December 2000 October 2006	Property-parcel location
Address point			October 2006	Location of address of property/house
Landmark			October 2006	Location of non-residential building, such as school, or church
Planning Scheme			August 2001 October 2006	Land use planning zones
Aerial photos	0.35m 0.13m 0.35 0.65m	DSE[1] City of Monash City of Monash, Knox, Casey City of Casey	2005 2001 1999 2005	
Google Earth Images		Google Earth version 5.0	Various years	

[1] DSE: Department of Sustainability and Environment

The cadastre is a register of the precise location, extent, value, use and ownership of land. Together with information about improvements (for example buildings), the cadastre is used to establish rateable land values, and so will be maintained/up–dated for, among other reasons, taxation purposes (Holloway and Bunker, 2003). Vicmap property provides information about land parcels and property details for the whole Victorian

State. It is captured at various scales up to 1:25000. The dataset includes property polygons in the metropolitan areas, and since 2002 (due to the upgrade of spatial database design); the polygons have not been attributed for street address. Instead, a common field is created to link Vicmap property with Vicmap Address products (Department of Sustainability and Environment (DSE), 2007a).

The Vicmap Address dataset (VADD) is a fully geocoded digital street–address, dataset. The records include the spatial relationship of each address to the relevant land parcel in the cadastre. The georeferenced locations for urban addresses in Metropolitan Melbourne are assigned to a point 8 metres back from the property road frontage mid–point (Department of Sustainability and Environment (DSE), 2007c). Because in 2006 all dwelling non–spatial attributes (for instance, unit number, house number, or street name) are in the VADD, both the property dataset and the VADD were used for analysing the 2006 dwelling patterns.

Other datasets, such as planning scheme boundaries and landmark datasets (including non–residential properties, such as abattoir, camping grounds, caravan parks, car parks, cemeteries, parks, recreation areas, showgrounds, and sports areas) (Department of Sustainability and Environment (DSE), 2007b), were also used to differentiate residential property from non–residential property.

4.4. Data pre-processing and cleaning

After undertaking quality check of uses of the address point for indication of presence of dwelling in each land parcel or land lot, it is found that before the relevant history of each land parcel can be determined, input datasets (address point and cadastre in 2006) need to be cleaned. Especially, there is a need to remove and/or detect and edit:

1. address duplication
2. common property tenure in multiple-unit/apartment blocks
3. base property[10] in cadastre dataset
4. multiple dwellings in single lot

[10] In some circumstances, one single dwelling might be associated with two polygons, representing base property and primary property. These are used for different taxable purposes (Personal Communication with DSE officer, dated 14 July 2008)

The key attributes used to filter address points which are not representing dwellings/houses or indicating duplicate dwellings/houses are: locality (LOCALITY), street name (ST_NAME), street type (ST_TYPE), house number 1 (HSE_NUM1), house suffix 1(HSE_SUF1), house number 2 (HSE_NUM2), unit number (BUNIT_ID1), geographical address (GEO_ADD) and full address field (EZI_ADD). While the GEO_ADD only contains street number, street name and street type, the EZI_ADD covers all the field attributes including unit number, street number, street suffix, street type, locality and postcode. Thus the addresses, which are not representing dwellings/ housing, include:

1. duplicate address, meaning
    a. either its EZI_ADD is exactly the same as other in the database (Figure 4.3)
    b. or it HSE_NUM1 or HSE_NUM2 is within the range house number, all other fields are equal
2. common property in multiple-unit/apartment, meaning:
    a. either its BUNIT_ID1 equals to 0, whilst at least other two records which BUNIT_ID1 are greater than 0, all other fields are equal (Figure 4.4)
    b. its BUNIT_ID1 equals to 0, whilst at least other two records which BUNIT_ID1 are greater than 0, HSE_NUM1 or HSE_NUM2 is within the range house number, all other fields are equal

This filtering process is automated by developing a GIS customised tool written in Visual Basic for Applications (VBA) scripts (*RemoveDupAdd Tool)* (Figure 4.2). Figure 4.3 and Figure 4.4 show snapshots of the result of using *RemoveDupAdd* tool in cleaning up the address point dataset. It allows selection of records, which indicate the presence of dwellings only. Duplicate address points or address points within common property (for instance the driveway shared by multi unit residents) are not selected.

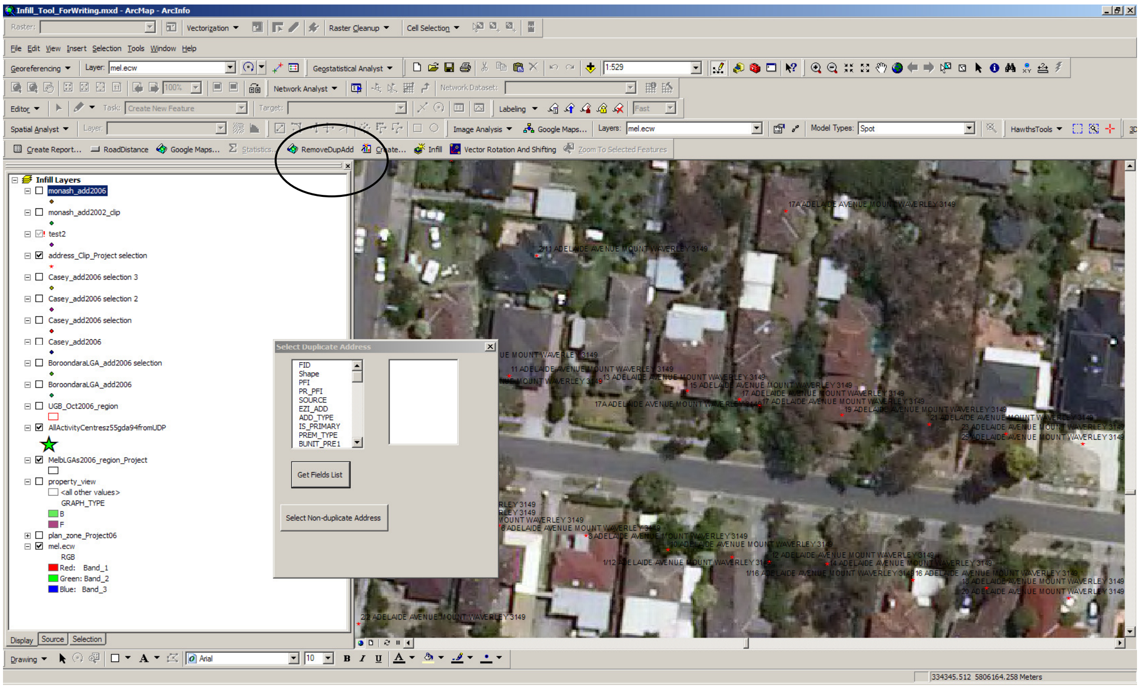

Figure 4.2: Screenshot of RemoveDupAdd tool in ArcGIS 9.2. The tool was developed in Visual Basic Applications (VBA) in ArcGIS 9.2. The tool includes a list box containing fieldnames of vector dataset selected in the current map. After clicking the "Get Fields List" name, these fieldnames are displayed. The analyst needs to choose on EZI_ADD field to select non-duplicate address

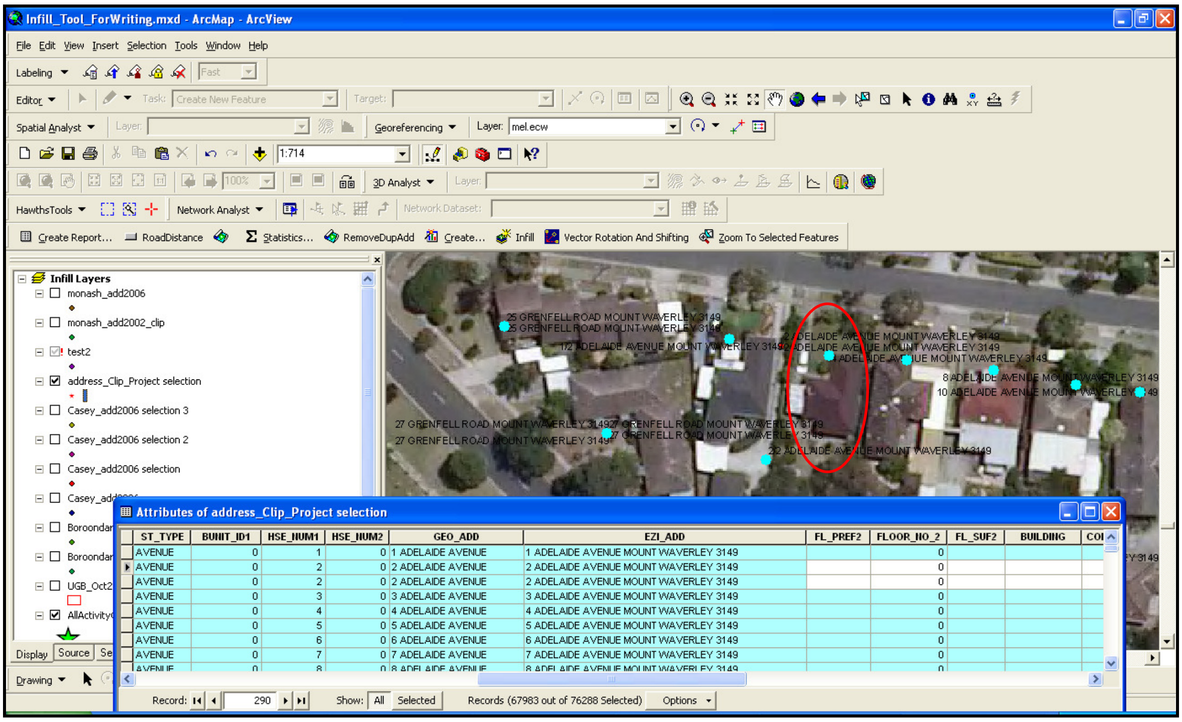

Figure 4.3: Screenshot of result after using RemoveDupAdd tool. The attribute table shows that base addresses (2 Adelaide Avenue Mount Waverley 3149) were not selected whilst the background map shows that others two addresses indicating dwellings (1/2 & 2/2 Adelaide Avenue Mount Waverley 3149) were selected.

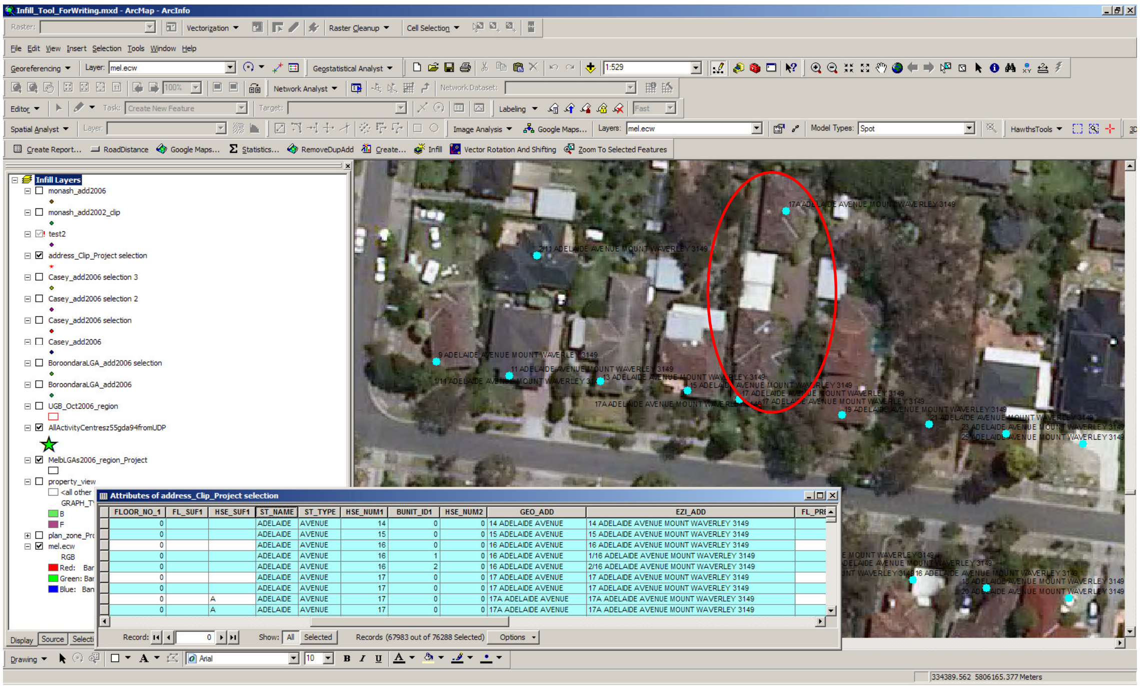

Figure 4.4: Screenshot of result after using RemoveDupAdd tool. The attribute table shows that there were duplicate records for dwellings at address: 17A Adelaide Avenue Mount Waverley 3149 and 17 Adelaide Avenue Mount Waverley 3149. Using RemoveDupAdd tool duplicate records were removed.

4.5. Infill tool development

To facilitate the process of pre-processing and data analysis, *Infill*, a mapping tool using a Visual Basic for Applications (VBA) language within the ESRI ArcGIS environment (ESRI, 2007) was developed. VBA is one of many object-oriented programming languages that is embedded within ArcGIS. Thus the user of VBA within ArcGIS environment will inherit the spatial analysis capability of ArcGIS during automation of the spatial handling process. At present, it is customised for comparing the situation in 2000 with that in 2006. Figure 4.5 shows that user forms with drop box are provided: the first selection is for identification of the LGA to be examined. Then the attribute value of planning zones in that LGA for 2000 and 2006 will pop up, ranging from residential, commercial to public land zones and so on. The S*patial Join* command yields the total number of dwellings per previous year residential dwelling parcel (i.e. 2000). *Spatial Join* creates a table join in which fields from one layer's attribute table (cadastre 2000 dataset) are appended to another layer's attribute table (address point 2006) based on the relative locations of the features in the two layers (ESRI, 2007). An increase in the total number of dwellings between years (i.e. 2000 and 2006) will dictate the location of infill or high density development at each land parcel. These locations were compared and validated with the aerial ortho-photo mosaic that was captured on the closest dates (October 2000 and October 2006). Currently, the tool aims to serve new development monitoring by state and local government authorities in terms of location, extent and intensity of infill development. Infill sites are identified by changes, one year to the next, in the number of dwelling address points associated with their land parcel.

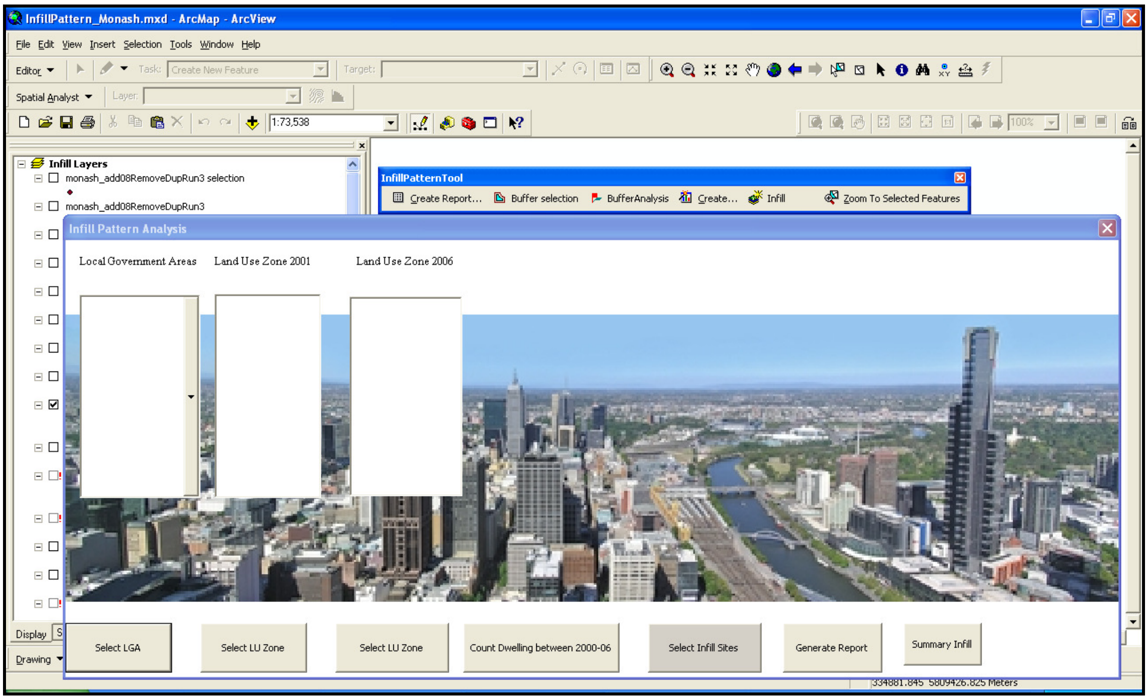

Figure 4.5: Screenshot of *Infill* tool. It includes a user form, which stores the list of LGA names and two list boxes, containing the land use zone codes in 2001 and 2006. The background image of Melbourne City was downloaded from http://www.melbourneflighttraining.com.au/international/images/melbourne_cbd_2.jpg

Figure 4.5 shows a snapshot of the *Infill* Tool interface. Apart from the capability of identify infill development locations, it can generate a summary report of infill sites using "Generate Report" command button (Figure 4.5). This information is presented as a report. It is possible because since ArcGIS 9.2, the Crystal Report function is embedded in the software (ESRI, 2007). ArcGIS users can design their report using *Crystal Report Wizard* (ESRI, 2007). Figure 4.6 shows an example of report outline from using such a function for the City of Monash. The report includes City Council logo, title of the report, date and time when report is created, and a list number of dwellings per infill development sites and their summary statistics, such as average area, the maximum area, and the minimum area of the dwellings in the same group. This information will provide the analysts the overview about infill development sites.

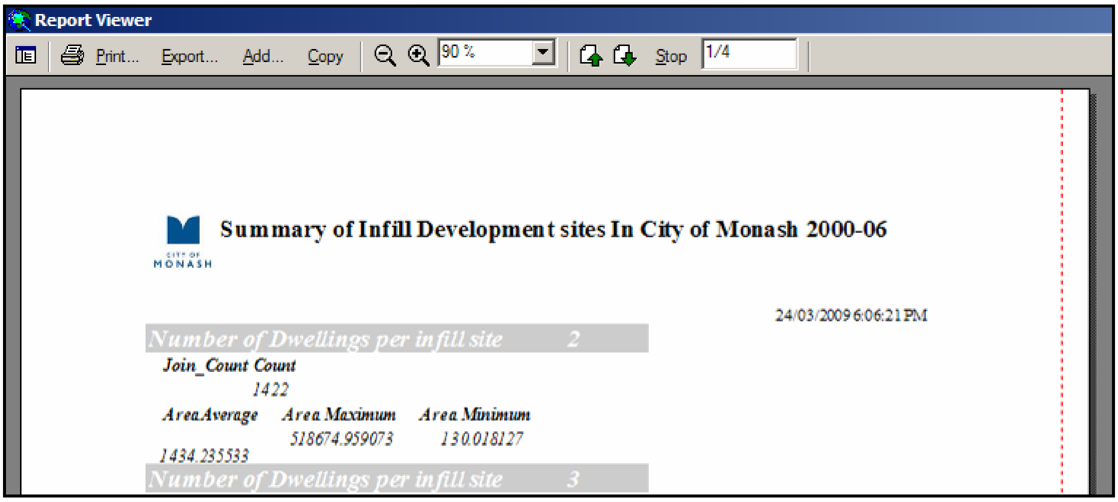

Figure 4.6: Overview of summary report

The data and information flow path deployed for manipulating and analysing of spatial datasets listed in Table 4.1 are shown in Figure 4.7.

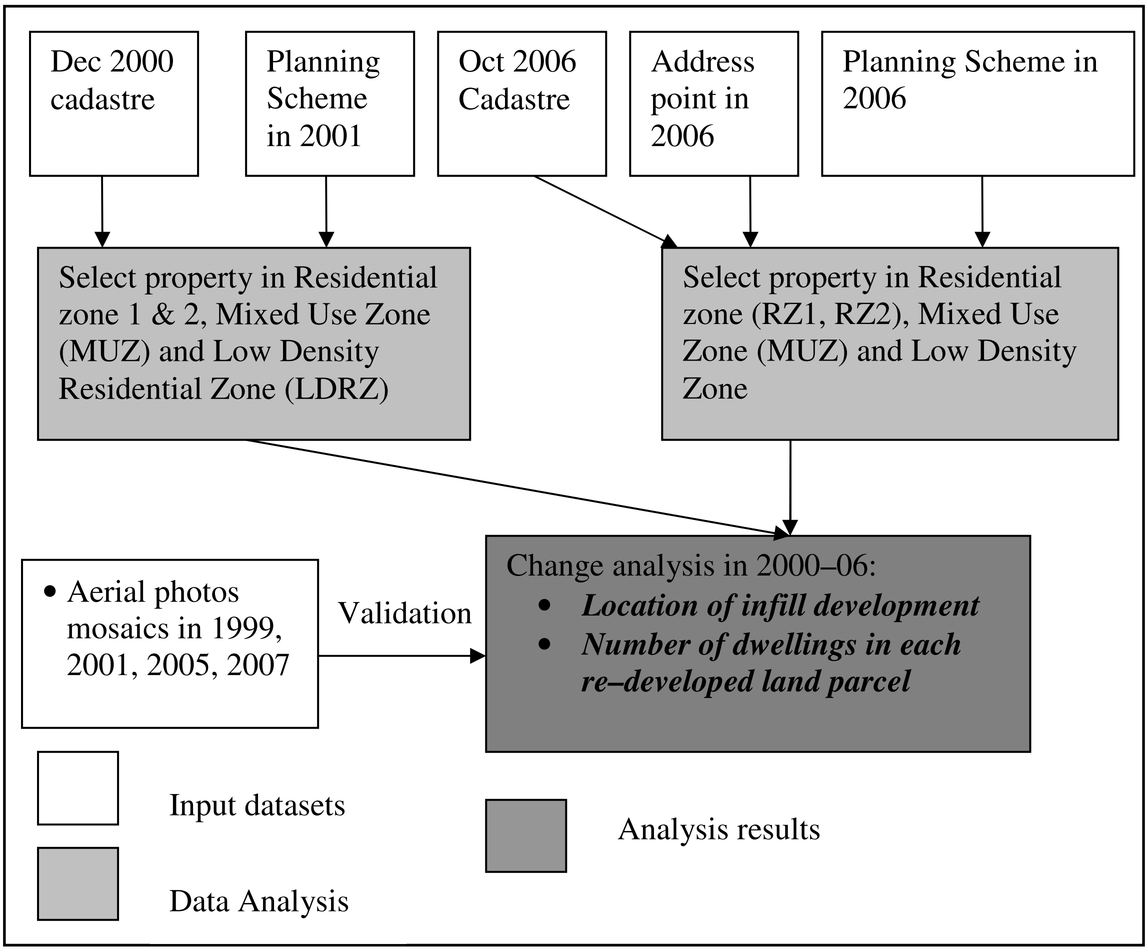

Figure 4.7: Summary of flow path for infill development mapping and identification (Adapted from Phan *et al.*, 2008)

4.6. Case studies

To demonstrate the utility of the *Infill* tool in identifying and mapping the location, scale and extent of the infill development in the MMA, case studies were undertaken at different LGAs. LGAs are selected within the middle and outer region of the MMA. Figure 4.8 shows the geographical location of these selected LGAs in the MMA. These regions have not been not studied by previous studies in Melbourne (e.g. Birrell *et al.*, 2005b, Buxton and Tieman, 2004b).

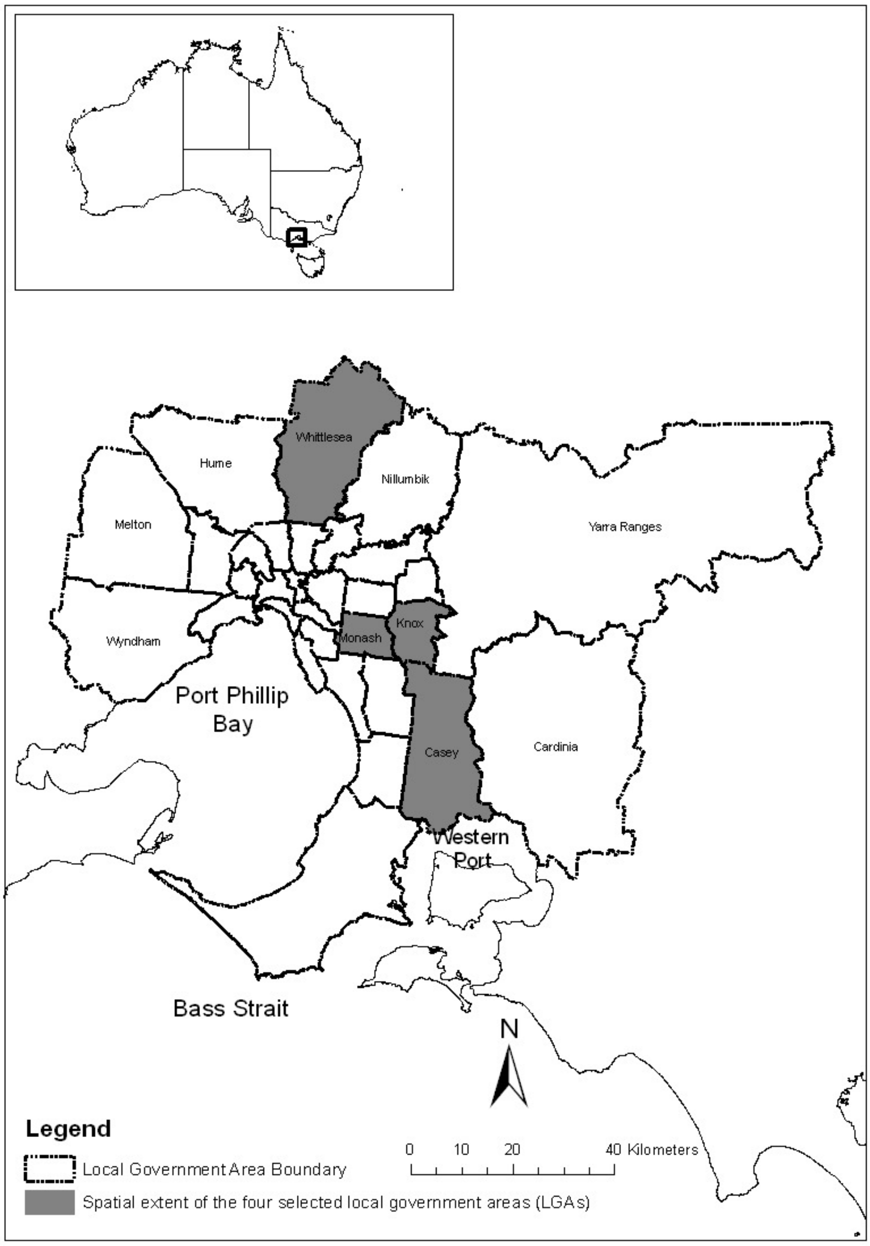

Figure 4.8: Selected Local Government Areas examined in Chapter 4

To provide an overview of housing development in these LGAs, census datasets about dwellings from ABS in 2001 and 2006 were extracted. Table 4.2 shows that there was an increase in total dwellings in the selected LGAs between 2001 and 2006 using. In terms of changes in dwelling types, whilst in the City of Monash, separate houses declined by over 650 dwellings, all outer LGAs saw increases in this dwelling type (1471 houses in Knox, 12540 houses in Casey, and 4227 houses in Whittlesea), as well as in medium and high Density housing types (1910 in Knox, 1653 in Casey, and 976 in Whittlesea). In the City of Monash, the increased number of medium and high density houses/dwellings (3341) was much higher than that in other outer LGAs. This indicates that in the City of Monash, separate houses have been demolished and that new residential development in existing residential areas (infill) and/or brownfields was more likely to occur as a result of medium and high density housing projects. In contrast, outer LGAs, especially in the City of Casey, development of separate houses is dominant. Thus, the selection of these four LGAs can represent different dwelling densification urban form changes in the MMA.

Table 4.2: Summary of dwelling types in each LGA in 2001 and 2006

LGAs	Separate houses			Medium & High density houses*			Others**	
	2001	2006	Change 2001 to 2006	2001	2006	Change 2001 to 2006	2001	2006
Monash	47697	47043	-654	8627	11968	3341	3813	3898
Knox	43043	44514	1471	4548	6458	1910	2828	2641
Casey	52818	65358	12540	4205	5858	1653	2997	3712
Whittlesea	32748	36975	4227	2641	3617	976	1517	1958

Source: ABS Census Data 2001 & 2006, City of Monash, Whittlesea, Knox, Casey, Community profile

* Medium & High density houses include semi-detached, row or terrace, townhouse, flat, unit or apartment

** Others include caravan, cabin, houseboat, improvised home, tent, sleepers out, house, or flat attached to a shop, office, ect

Results from applying *Infill* tool are validated by reference to the aerial ortho-photo mosaic. The orthopho mosaic was captured on the closest dates as October 2000 and October 2006. In addition, vector datasets of infill development sites (after running *Infill* tool) was converted into *kml*, which then can be overlaid in Google Earth version 5.0 (Google Earth, 2009). The *Historical Image* Function embedded in Google Earth allows the users to access time-series high resolution data worldwide assuming that the relevant data has been acquired and stored in Google Earth database. In some areas where aerial photos (shown in Table 4.1) did not cover the whole LGAs, *Historical Image* of Google Earth was used. This incorporation of free spatial datasets, such as

Google Earth images indicates the scope to integrate spatial information from different sources.

4.7. Results

The outcomes of applying the *Infill* tool to the necessary input data pertaining to Monash City, Casey City, Whittlesea City and Knox City are presented in Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12. The number of dwellings per (re)-developed land parcel is presented in five classes. By plotting infill development sites with transport networks and designated activity centres, the changes in residential intensification between 2000 and 2006 can be observed.

Table 4.3 presents a descriptive summary of these classes by dwelling development intensity. The exemplification of method presented in this Chapter was initially undertaken for the City of Monash as a pilot study for this project. Natural break classification [11] (Jenk's method) (ESRI, 2007) was used for thematic mapping presentation (Phan *et al.*, 2008) because the dwelling development per each land parcel was skewed to the right. Mitchell (1999a) suggests to use natural break classification when the data is unevenly distributed (many features have the same or similar values, and there are gaps between groups of values).

Subsequently, for comparative analysis, these classes were also applied for the other three LGAs. It can be seen from Figure 4.9, Figure 4.11, and Table 4.3 that infill development of the 2-7 class (orange class) is dominant (representing 98.11% and 92.32%) in the cities of Monash and Knox. It is seen from Figure 4.10 and Figure 4.12 that in the cities of Casey and Whittlesea the proportion of higher intense infill development (78+ class) (purple class), ranges between 4.83% and 8.82%. In the City of Monash, major redevelopment sites are in the highest intense-infill group (78+ class) whilst in the Cities of Whittlesea or Casey, greenfield sites dominate this class. The number of infill developments or redevelopments within 400 meters and 800 meters of major and principal activity centres are seen (see Figures 4.9 to 4.12) to vary both within and between LGA(s). A descriptive summary of each development types is presented in Chapter 5.

[11] The natural break classification method divides data into classes in a way that maximize the differences between classes

Table 4.3: Descriptive Summary of Infill Development in different Local Government Areas

	Local Government Areas							
Infill Development Class	Monash		Knox		Casey		Whittlesea	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
2-7	1455	98.11	565	92.32	948	73.83	205	66.99
8-19	17	1.15	30	4.90	116	9.03	26	8.50
20-39	7	0.47	9	1.47	91	7.09	33	10.78
40-77	3	0.20	4	0.65	67	5.22	15	4.90
78+	1	0.77	4	0.65	62	4.83	27	8.82
SUM	1483	100.0	612	100.0	1284	100.0	306	100.0

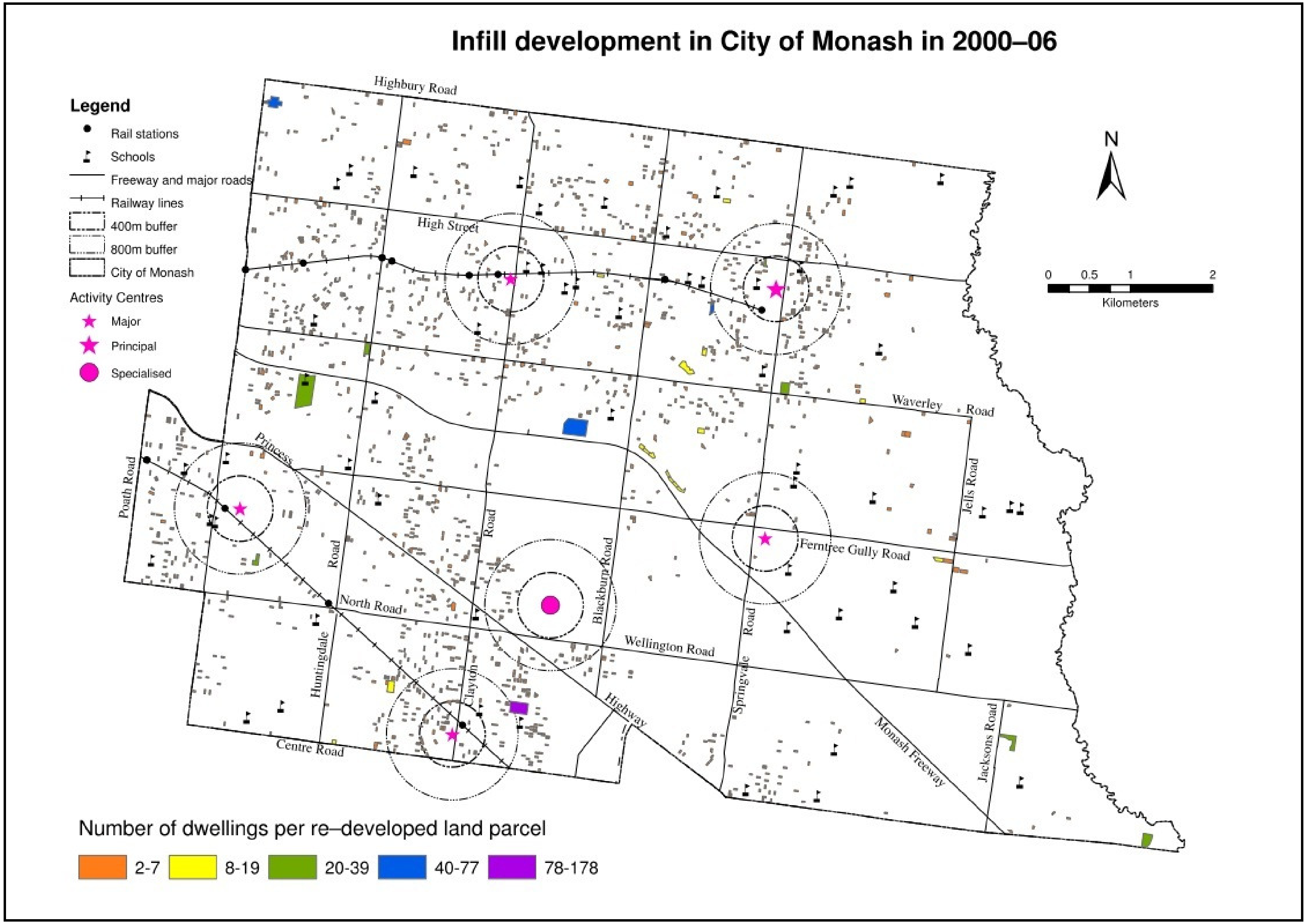

Figure 4.9: Thematic map of Infill development in 2001-06 in City of Monash (Phan *et al.*, 2008, p.27)

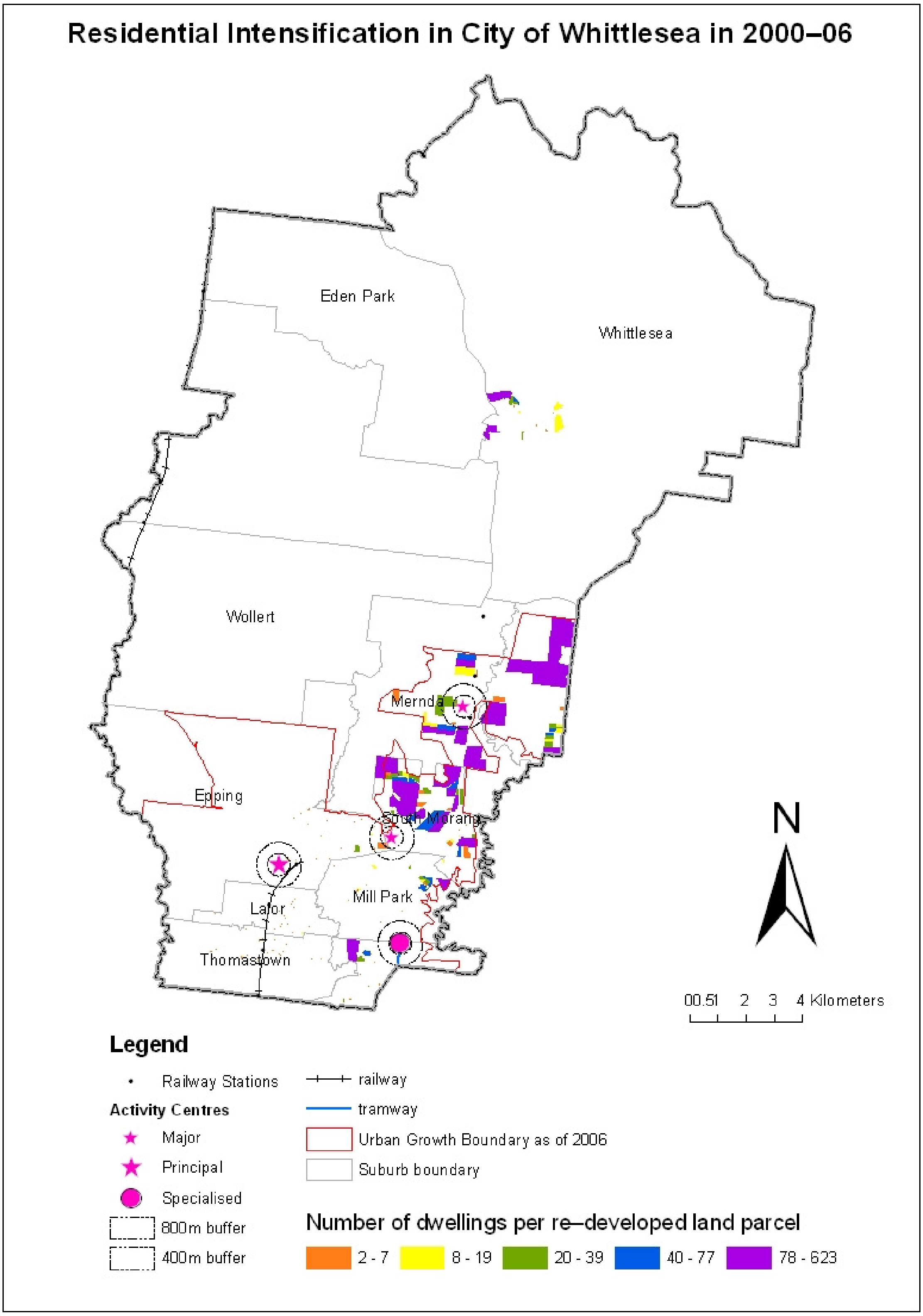

Figure 4.10: Residential intensification[12] in City of Whittlesea. The map does not include new residential developments resulting from land use planning zone amendments, from rural land use to residential zones 1 between 2001 and 2006 in Epping (near the UGB). The map clearly shows the distribution of the 27 (see Table 4.3) dense-settlement subdivisions (78-623 class). Most of these lots are not within a 400 and 800 meters buffer of any designated activity centres or railway routes.

[12] Residential Intensification was used because some subdivisions occurred in greenfield sites.

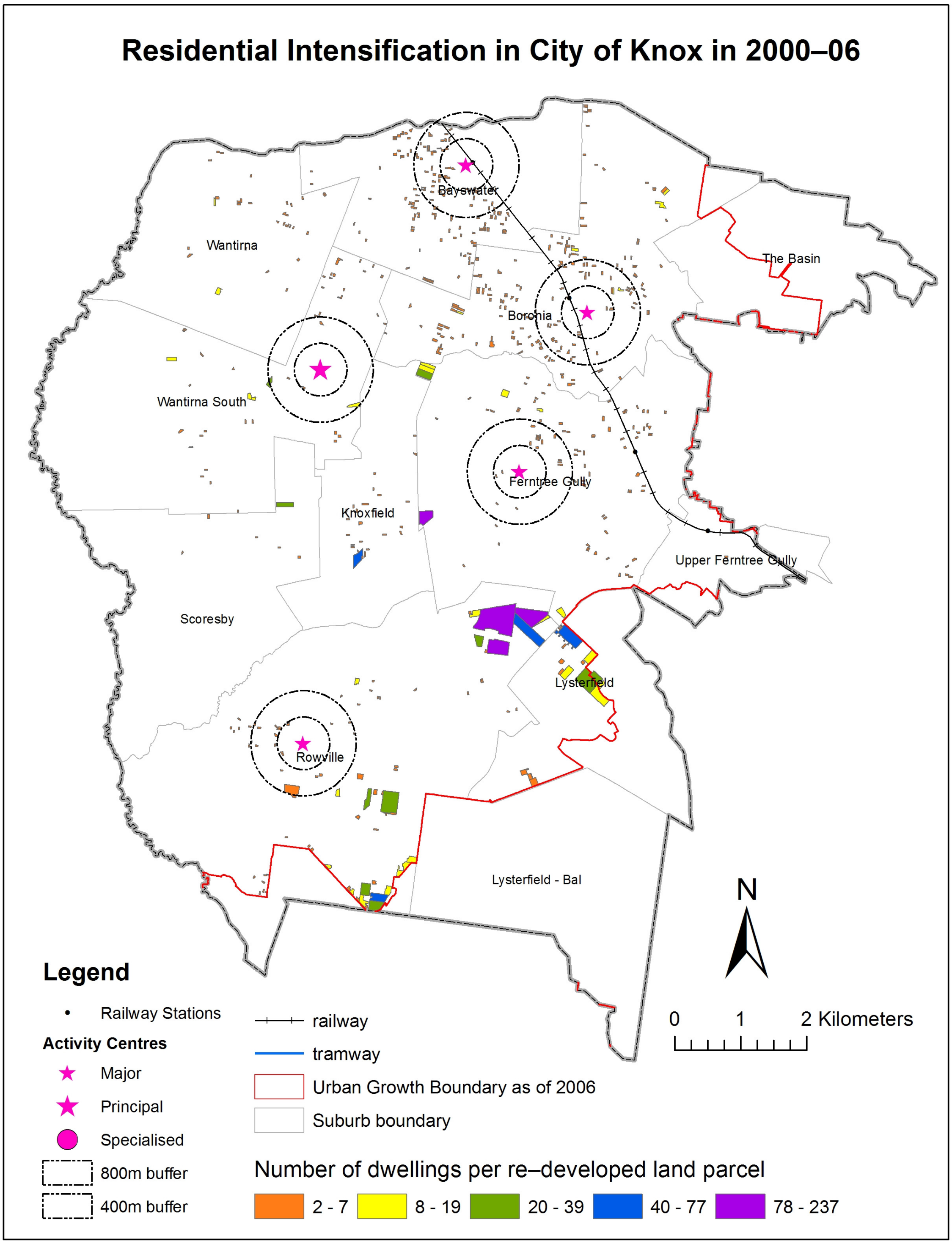

Figure 4.11: Residential intensification in the City of Knox (notes suburb boundaries). The map shows geographical spatial variation of infill development and lot subdivision in the City of Knox by proximity to designated activity centres, railway routes, and UGB. In the older suburbs, such as Bayswater and Boronia, infill development or lot subdivision of the 2-7 class was dominant. There were more developments around designated activity centres in these two suburbs than in the other suburbs. Infill development or lot subdivision of the 20-39 class to the 78-237 classes was sparsely distributed in the middle of the city and more toward to city's UGB.

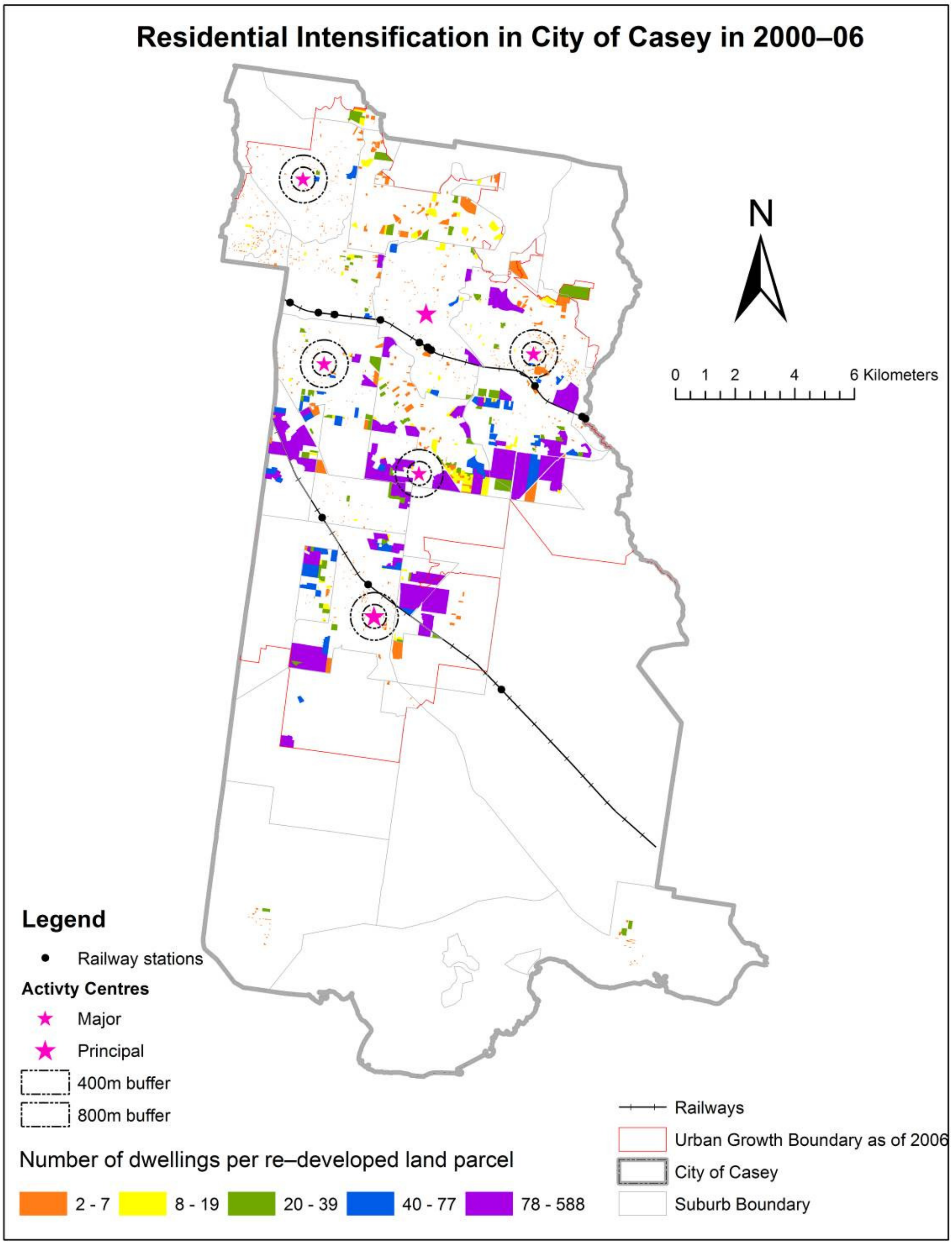

Figure 4.12: Residential development in the City of Casey. Both development and redevelopment occurred. Whilst the most intense subdivision (i.e. 78-588 class) occurred south of the railway routes, many subdivisions of the 2-7 class or the 8-19 class occurred to the north of it. The map shows the geographical spatial variation of infill development sites within the LGA as well as in relation to designated activity centres and railway routes.

4.8. Discussions

This section discusses the utility of using the *Infill* tool in infill development mapping. Apart from that, the use of the 3D Analyst tool in ArcGIS for visualisation of infill development sites is also discussed.

4.8.1. The utility of parcel-based GIS infill development mapping

The 2001 and 2006 intercensal period ABS data (Table 4.3) shows dwelling growth for all four LGAs mapped in the present study. The scope for meeting the implied demand for more dwelling space varies from one LGA to another according to urban form. Given the nature of Victorian government policy about land use planning (Chapter 3), 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. Previous study also asserted that this information is needed for local impact assessment of infill development (Birrell et al., 2005b). 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) is data integration of a kind that has not been attempted by planners in Melbourne before the first research results of the present study were published (Phan *et al.*, 2008, Phan *et al.*, 2009a).

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 contrasts with the approach of Buxton and Tieman (2004b, 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 readily geocoded unless to a "tagged polygon". However, and as Irwin *et al.* (2003) have argued, monitoring urban sprawl and urban intensification is better done at the land-parcel scale of detail because access to data about the precise geographic location of each new residence minimises the problems, as reviewed in Chapter 2 (section 2.5). These refer to the long recognised problem of quantifying sprawl from analysis of aggregated data (e.g. population and building permit records edited for privacy reasons) using census geography that must change regularly and in ways that confront the researcher with the modifiable areal unit problem (MAUP)[13].

Additionally, by using land parcel geography (or that pre-cursor to street address: the lot number) as a spatial unit for mapping and analysis, the extent and location of infill development and new development in greenfield sites can be identified. This is clearly at a much more detailed scale than obtainable by using the traditional aggregated (e.g. census collection unit; ~230 dwellings at a time (ABS, 2006)) data. Apart from identification of dwelling densification enabled by subdivision of a single–dwelling land parcel into two or more dwellings, the approach pioneered here supports identification of:

- the spatial pattern of multi–unit development, and
- dual occupancy development, that is the development of (a) new dwelling(s) on the backyard of existing dwelling.

The latter type of dwelling is normally counted and grouped in the "separate house" class in the ABS dataset, and thus has not been counted as infill development in previous studies that relied on ABS data (Birrell et al., 2005b, Buxton and Tieman, 2004b). The *Infill* tool facilitates 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) (Chapter 5) the data offers urban planners and decision makers a chance to understand and monitor the trends and patterns of different densification types. Further discussion about the type of development is presented in Chapter 5.

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

[13] The MAUP refers to the spatial configuration changes of zones that are used to aggregate or summarise data. When zones change, statistical analyses and interpretation of data can be influenced ROGERSON, P. A. (2001) *Statistical Methods for Geography*, London, Sage.. As in section 2.5 of Chapter 2, the spatial boundary of CCD is subject to change. The changes or modification of polygon boundary can lead to MAUP.

for up-grade to meet increased demand (e.g. on facilities and on network infrastructure: e.g. storm water, sewerage, and transport). Although the mapping approach is demonstrated for a six-year period, it can be called upon whenever the new or update spatial datasets (e.g. Vicmap property and Vicmap Address) are available. For instance, applying this mapping approach, using Vicmap products (including property, address, planning schemes, and images), Figure 4.13 presented a map showing the location of infill development in the City of Monash between October 2006 and April 2009. Thus in comparison with the census dataset (five year interval), the infill mapping approach provides a more updated information.

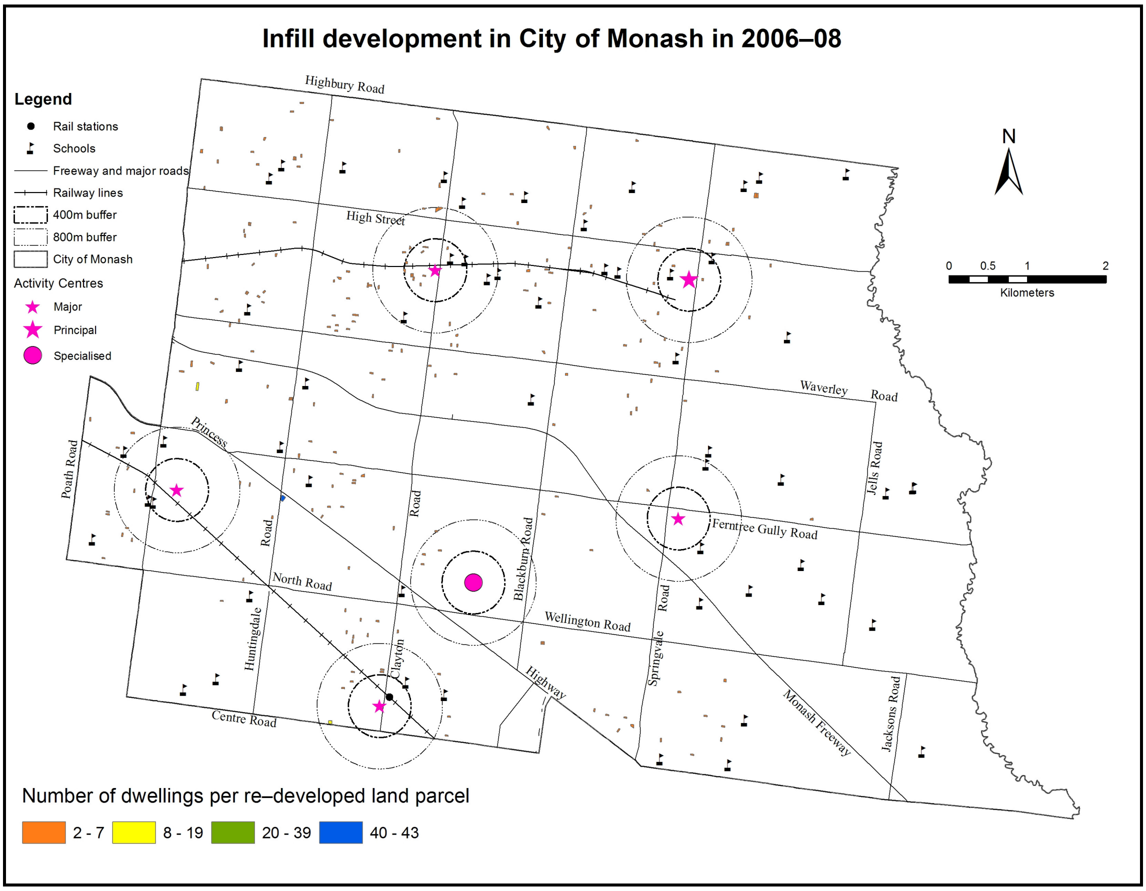

Figure 4.13: Location of infill development sites in City of Monash between 2006 and 2008. This map shows that the most intense development class (78+) did not occur in the City of Monash during this period.

4.8.2. The utility of infill pattern maps for visualising infill development

While the data directly supports the composition of a thematic map showing the location of infill development in any MMA LGA, it also supports other useful depictions such as kernel density, and the number of designated features by designated areal unit, (e.g. square meter or square kilometre). Mapping density is especially useful when mapping areas, which vary greatly in size (e.g. census tracts or countries (Mitchell, 1999a)). Torrens (2008) reported that there are but few attempts to map and visualise the components of urban sprawl. Campoli and MacLean (2007) used a number of high resolution aerial photos to illustrate various housing density changes in different USA cities. Figure 4.14 shows a geographical variation in infill development in the City of Monash using the address point dataset and the *3D Analyst Tool* in ArcGIS 9.2 software (ESRI, 2007). Figure 4.14 shows that infill development (between 2000 and 2006) reached the greatest intensity in the 800 meter buffer around the Clayton Activity Centre. This clearly shows the utility of thematic mapping to visualise location and extent of infill development. Together with tabular results (e.g. Table 4.3) information about infill development in the City of Monash is clearly presented. Quick visualisation is offered from Figure 4.14 whilst detail examination can be seen in Figure 4.9 to Figure 4.12.

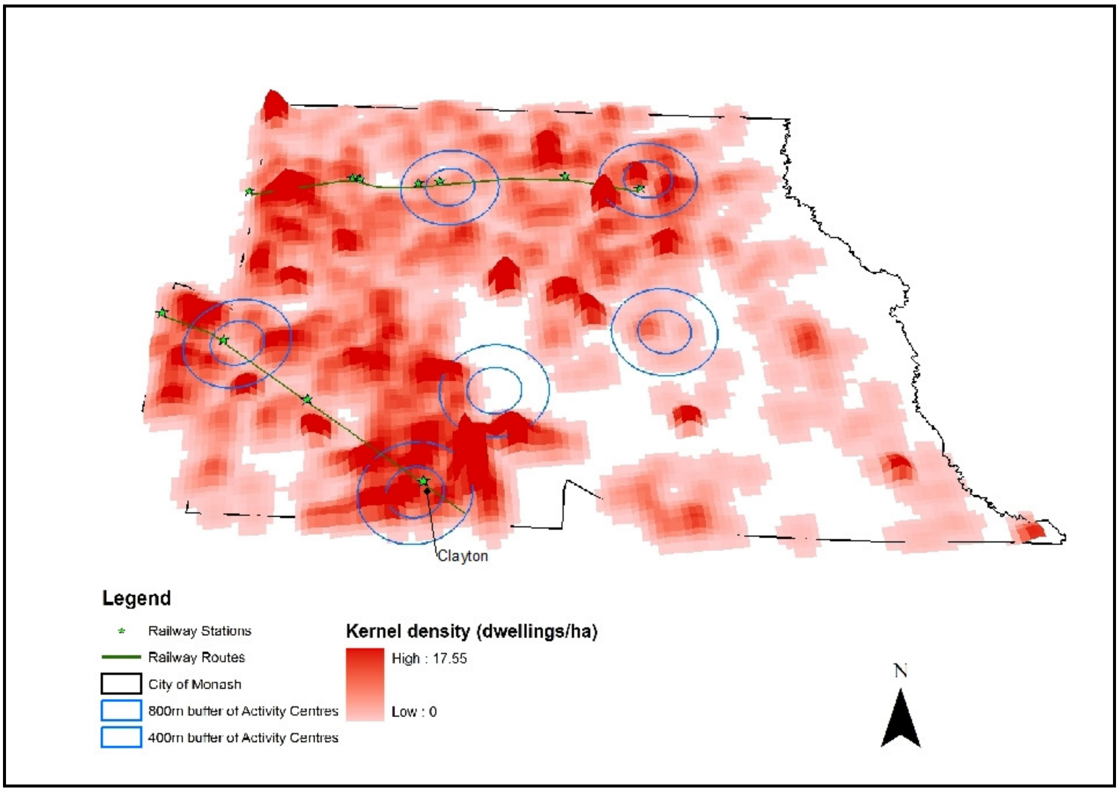

Figure 4.14: 3D view of surface density of infill development in City of Monash between December 2000 and October 2006

In contrast to the nature of urban form change commonly documented for many parts of Europe and North America, where much infill development has occurred through redevelopment of brownfield sites, the traditional earlier post-WWII residential development pattern in Australian was generally dominated by greenfield development, later to be supplemented by dispersed infill development in already-established areas (Bunker and Searle, 2007, Bunker and Searle, 2009). The findings in this Chapter support this analysis because it is shown that dispersed infill development was prevalent in the City of Monash during the 2000-2006 period whilst greenfield development dominated the fringe cities like Whittlesea or Casey. This finding also supports results from a recent study using an aggregated MMA dataset (Charter Keck Cramer, 2006). The prevalence of dispersed infill development in Monash City was also reported in the Monash City Annual Report 2007-08. Residential development in the City of Monash is prevalently infill development although in some areas it is vacant land that is being developed. The findings of this Chapter are not incompatible with those in previous studies. For instance, Buxton & Tieman (2005, p.155) found that there was ongoing spread of "urban dispersal throughout low population outer urban greenfield densities". Birrell *et al.* (2005) recorded a number of extensive medium density housing zones in existing urban areas outside activity centres.

Compact city advocates argue that infill development will promote a more efficient use of land and community infra-structure in existing residential areas, thus promoting environmental sustainability while accommodating the need to house a growing population without adding to urban sprawl and violating (locally much valued) green wedges. Results presented here (and elsewhere (Phan *et al.*, 2008, Phan *et al.*, 2009a)) 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 to mitigation of the effect, of unplanned settlement outcomes.

4.8.3. Some limitations

For validating results from application of the *Infill tool* in mapping urban form change, time-series orthophoto mosaics (between 1999 and 2006) with resolution ranging from 0.35m to 2m (Table 4.1) were used. 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 this approach refers to identification of infill development sites in established urban areas. As defined in section 4.4, the mapping of re-development (infill) between 2000 and 2006 refers 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 (it will have a street address unless it is zoned as a single-parcel open space area) 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 orthophoto 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. It is found that in a suburban LGA with City-of-Monash urban residential form, there were only a few circumstances in which land-cover change detection showed that it was a single house depicted on the 2006 photo as a change from the vacancy depicted on the 2000 mosaic. It was also found that such changes were more likely to be seen from analysis of changing patterns in fringe 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 bound soon to follow.

The choice of temporal scale plays an important role in evaluation of urban compact policy implementation because there is a considerable time lag between application of policy strategies and manifestation of their expected effect (Bengston *et al.*, 2004). As stated in Chapter 1, this study only examines the location and extent of residential densification in the six year intercensal period between late 2000 and late 2006. However, it is possible to extend the temporal scale of the study to take in younger data once the analytical approach exemplified here has been tested, in local institutional term, and adopted. For instance, Figure 4.13 shows the result of applying the *Infill* tool to City of Monash data documenting the period (October 2006 and April 2009).

4.9. Conclusion

A GIS-based land parcel framework for automatic and systematic identification of residential intensification was developed in this chapter. The utility of applying such a framework was demonstrated for four LGAs, together representing a range of MMA LGA types of urban residential urban form. It is shown that the framework offers an infill development mapping at land parcel scale, of more detailed scale than can be offered using either development permit records or aggregated census data as was the case with in previous studies. The framework is reproducible and is ready to be called upon as the relevant up-dated datasets become available. Results from the mapping approach are compatible with previous (laboriously obtained) research findings. Thus suitability and utility is demonstrated.

Results from infill pattern maps can be further analysed for visualising the overall spatial patterns of infill development. In the next chapter, it is shown that infill pattern maps can be integrated with other spatial datasets to assist urban compact city policy implementation evaluation.

5. CHAPTER 5: DEVELOPMENT OF A METHOD FOR DETAILED TIME-SERIES SOCIAL MAPPING FOR AUDIT OF COMPACT CITY/URBAN CONSOLIDATION POLICY IMPLEMENTATION

5.1. Introduction

As mention in Chapter 2, section 2.3, a methodology for detailed evaluation of *Melbourne 2030* implementation is yet to be disseminated and adopted, despite the fact that policy was launched in October 2002. The *Melbourne 2030* Expert Audit report (DPCD, 2008, p.63) states that:

> "The lack of a comprehensive in-built monitoring system for *Melbourne 2030* has been a significant constraint on our ability to report adequately on the progress of the Plan's implementation. If this is not addressed, it will also pose a problem for future implementation and evaluation…An outcome-based monitoring system is an essential management tool for the implementation of *Melbourne 2030*."

Thus, new approaches to monitoring and evaluation of *Melbourne 2030* as being developed in this study have been called for.

Generally, urban planning professionals have identified major gaps in undertaking evaluation of urban planning implementation. First, it is a lack of methodologies for systematic analysis of plan implementation that contributes to a gap in understanding the linkages between plans and their outcomes (Laurian *et al.*, 2004, Talen, 1997). The second barrier refers to a lack of spatial datasets, specially detailed disaggregated spatial datasets at the land-parcel or household levels. As Talen (2003) states, the detailed scale analysis usually makes a trade-off for a small extent of the study area due to its substantial dataset preparation time and effort. The third barrier refers to the content of the plan. In regard to smart growth policy, although the preservation of agricultural land and open space are common goals among planners intent on mitigating the worst effects of urban sprawl, the monitoring of urban form change in these terms is not sufficient to derive explicit plan implementation evaluation criteria (Gennaio *et al.*, 2009). Further, whilst some goals can be quantitatively evaluated, others can not, because they are subject to judgement and interpretation. Indeed, as Bengston *et al.* (2004) have noted, evaluation of the success of urban growth management strategies is challenging because, with explicit goals varying from one planning authority to another, generic evaluation tools will not be readily developed or agreed upon.

Similarly, in Australia, and as the literature review in Chapter 2, section 2.3 shows, urban consolidation researchers in Australia are yet to realise the potential for improvement in decision support exemplified in other jurisdictions from application of spatial analysis via spatial data integration using GIS. Before this study, the detailed disaggregated spatial datasets needed for urban consolidation research had not been assembled and collated in ways that could support systematic and city-wide analysis.

In Chapter 4, a framework for collecting, analysing, identifying and mapping infill development was identified and validated, as a basis for on-demand thematic mapping and further analysis. Along with the realisation that the modern spatial data handling industry and practice is commensurate with calls for more detailed decision support, the objective of this chapter is to demonstrate the use of quantitative metrics to examine the conformity to state-wide planning policy of urban planning as practiced in the LGA(s). Thus it contributes to provide an analytical approach for plan implementation evaluation. The policy aspect of particular interest is that which calls for intensification in or within proximity to activity centres and the public transport network, whilst reducing the relative significance of land development in the greenfields. By comparing the progress of different development types against what was defined in urban planning policy, the influence of land use planning policy on residential urban development is revealed and understood.

As reviewed in Chapter 2, some analytical approaches have been proposed and conducted in plan evaluation and monitoring. Among these is the indicator-based approach, in which quantified metrics are examined spatially and temporally. For instance, to explore the trends and patterns of new residential development (Couch and Karecha, 2006, Weitz and

Moore, 1998) use indicators, which quantify the composition and configuration of new residential developments. Other researchers in Australia, including Randolph (2006) and Bunker *et al.* (2002), examine the changes in the extent and location of attached housing and social profiles intercensal period by period, as well as their relative proximity to the public transport network and to major roads or highways (Birrell *et al.*, 2005b, Buxton and Tieman, 2004a, Holloway and Bunker, 2003). However, their relative proximity to designated activity centres is neither examined nor mapped.

Other approaches to urban form change analysis in Australia have also neglected the scope of mapping the changed pattern. For instance, the physical characteristics of buildings and their nearby streetscapes have been examined. A study of selective sites in the growth areas on the Melbourne fringe (Buxton and Scheurer, 2005) and a study in selected old and new developed areas in Victoria, Perth and Queensland (Hall, 2007) both testify to the fact that researchers are not entirely unaware of the application of spatial data. Buxton and Scheurer (2005) examined the incorporation of sustainable design in eleven sites identified in greenfields: growth areas in the Cities of Wyndham, Whittlesea, Casey and Cardinia. Hall (2007) exemplified the use of aerial photos (displayed and measured urban design parameters in Google Earth) in comparative analysis of urban morphology between old and new suburbs in different states in Australia. Some of these studies demonstrate the utility of spatial datasets to the naïve GIS users in ways that promise increased understanding and exploration of urban morphology.

As mentioned in Chapter 1, the analytical focus in this study is on improved monitoring of environmental and social impacts of urban growth and urban development before and after the implementation of *Melbourne 2030*. More than naïve GIS use is called upon here. Given the need for area-wide analysis at higher spatial resolution (Chhetri *et al.*, 2008, Oliveira and Pinho, 2009, Talen, 2003), new housing and accessibility indicators at land-parcel scale are derived and tested. This Chapter particularly focuses on its contribution for monitoring, understanding, and examining progress of meeting *Melbourne 2030*'s objectives LGA by LGA whether dominated by greenfield or infill development/densification. A selection of development tracts[14] (DTs) in these LGAs is conducted and compared using urban design indicators to examine the extent of urban consolidation in general and *Melbourne 2030* in particular influence the new urban form development.

5.2. MMA Policy context, a brief summary

Melbourne 2030 can be regarded as a defence of the favoured status Melbourne enjoys in the minds of those arriving in Australia since implementation of Commonwealth government policy about increased immigration. It is expected that the population would increase by one million and there would be an additional of 620, 000 households by 2030 (DoI, 2002e). However, the 2006 Census data showed a higher rate of population growth than previous anticipated. Recent projection in *Victorian Future 2008* indicates that between 2006 and 2036, population in the MMA will increase by 1.8 million (DoI, 2008, p.5). The MMA population will be likely to reach 5 million before 2030 (DoI, 2008). In response to such predictions and the Audit of Melbourne 2030 (DPCD, 2008), the government released *Melbourne@5Million* (December 2008) (DoI, 2008). Success for the policies and strategies contained in *Melbourne 2030* and *Melbourne@5Million* is very important in meeting the challenge of accommodating not only new people but those from natural increase of population. As would be expected, the decision support at all levels of government is supposed to include design, test and improvement of metrics for evaluation and monitoring (DPCD, 2008). However as mentioned in Chapter 2, specifications for such activity were not identified and so the value of monitoring activity already conducted is somewhat limited.

As mentioned in Chapter 3, at the State level of evaluation, particular attention is given to monitoring effectiveness of implementation of *Melbourne 2030* principle 5.5: improving neighbourhood liveability (DoI, 2002e, p.102):

- diversity in lot size and housing types to satisfy the needs and aspirations of different groups of people

[14] The development tract is defined and justified in section 5.4.3

- a range of open spaces to meet a variety of needs with link to open space networks and regional parks where possible
- compact neighbourhoods that are oriented around walkable distances between activities and where neighbourhood centres provide access to services and facilities to meet day-to-day needs

In this context, it is noteworthy that the *Melbourne 2030* implementation strategy identification of priority areas includes mention of (DoI, 2002e, p.170):

- urban growth boundary
- growth areas
- housing
- activity centres
- green wedges and
- integrated transport

Clearly, the most desirable policy implementation monitoring design will provide for data integration and for documentation of time series urban form pattern change. Much of the relative success of the associated decision support activities would depend upon the extent to which the ideal data and information flow paths can be identified and implemented on a routine basis (Laurian *et al.*, 2004).

5.3. Selection of study areas

To exemplify the utility of housing and accessibity indicators for plan implementation evaluation, four LGAs studied in Chapter 4 are chosen for the analysis, namely Monash, Knox, Casey and Whittlesea. This is because the spatial datasets needed are already assembled and results of Chapter 4 can be used as one of the inputs. Additionally, two of these LGAs are in the *Melbourne 2030* designated growth areas: Casey and Whittlesea. Thus the approach presented in this study can be tested in a range of MMA densification contexts.

5.4. Methodology

The overall spatial analysis identified for this Chapter is presented in Figure 5.1. As can be seen in Figure 5.1, analysis is taken at both LGA (detailed in sections 5.4.1 and 5.4.2) and

DT (detailed in section 5.4.3) levels. Inputs data sources were acquired from state, LGA and Chapter 4's results.

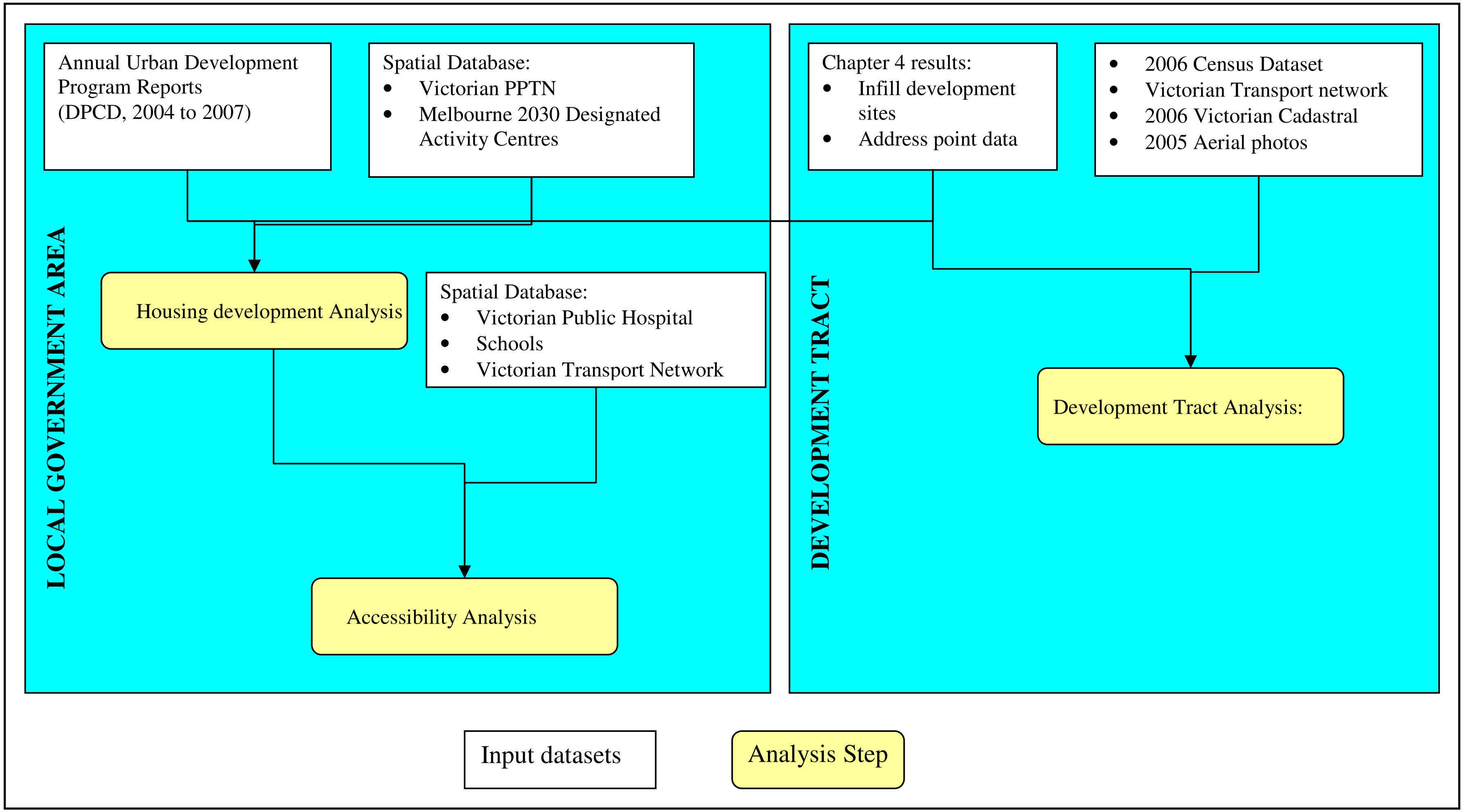

Figure 5.1: Summary of spatial data analysis in Chapter 5. Detailed spatial data analysis is presented in Figure 5.2, Figure 5.3 and section 5.5.3

5.4.1. Derivation of closer-settlement style indicator

The Melbourne 2030 Housing Implementation Plan envisages three residential (re)development categories (DoI, 2002a)

- *Dispersed Development*: this comprises development within established urban areas, and remaining major redevelopment sites not well-located in terms of access to major public transport network facilities, as well as non-urban residential development. Non-urban development is generally located in an around small townships (DoI, 2002a)
- *Strategic Development*: this comprises development within 400 meters of designated Activity Centres (DOI, 2002b, p.8) and of Principal Public Transport Network (PPTN) corridors, and 800 meters of railway stations along the PPTN (DSE, 2006c). PPTN refers to bus and rail services which offer pick-up/put-down at a frequency of between 15 to 30 minutes or better. The PPTN data was acquired from DPCD
- *Greenfield Development*: this comprises undeveloped land identified for residential or industrial or commercial development, generally on the fringe of the metropolitan area. In this study, “Broadhectare/Broadacre” development sites (within Growth Areas, but not being designated for strategic development (as, for instance, along transport corridors between the MMA and nearby townships), are classified as greenfield development sites

These categories were derived by integrating Chapter 4 results with extant UDP datasets. As shown in Figure 5.2, data referring to LGA residential zone infill development change (Chapter 4 results) are incorporated with the Urban Development Program (UDP) datasets. The UDP datasets include location of broadhectare (BH) and major redevelopment sites (MRS) in each of the 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) as a trigger to land use planning scheme amendment in the “host LGA”. From the archive for these datasets (reported annually since 2004) a time-series account of such development is available.

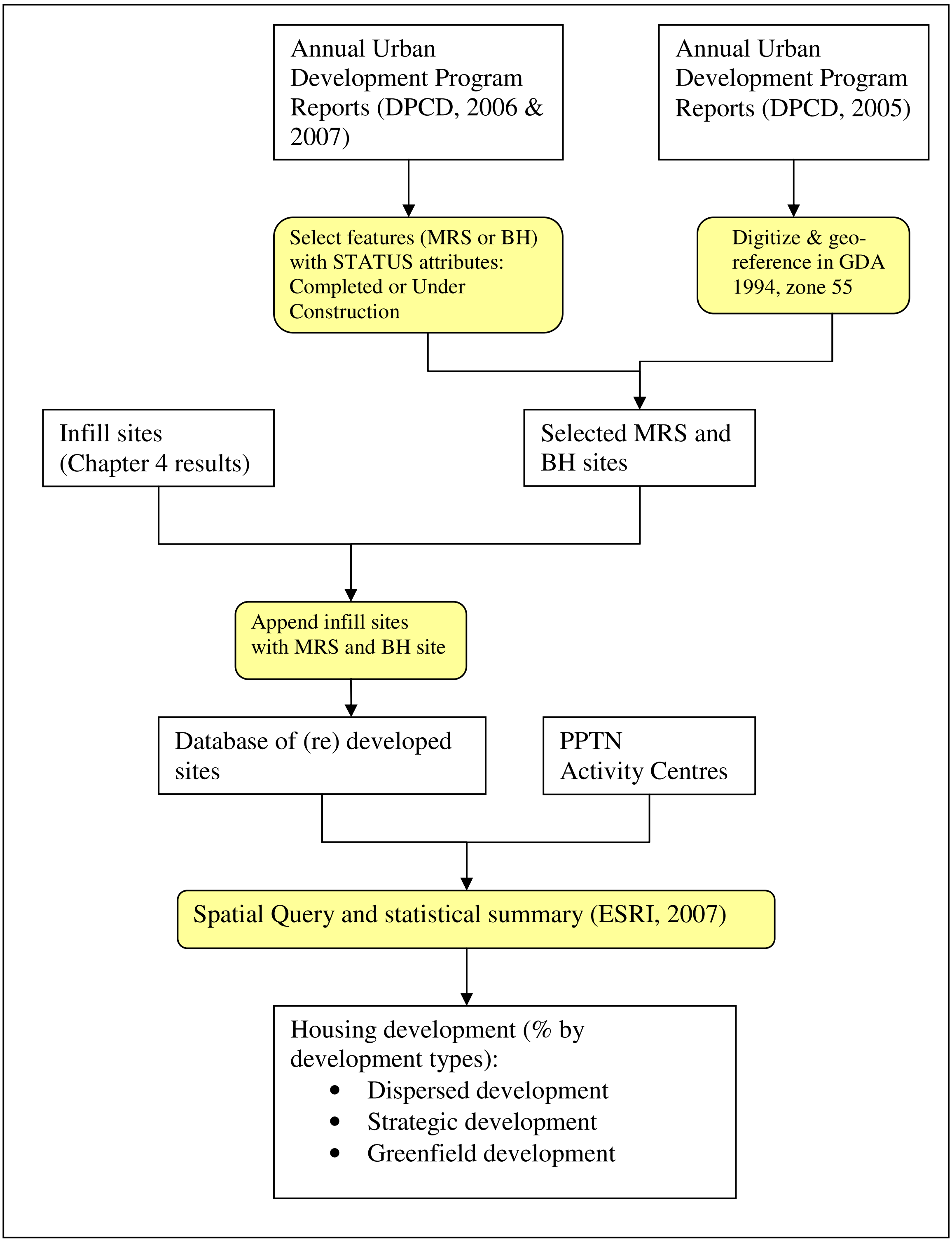

Figure 5.2: Flow path of determining relative significance of closer settlement style, LGA by LGA. It combines spatial datasets from results in Chapter 4, and selected Annual Urban development program reports (from 2005 to 2007)

Data from 2006 and 2007 are available in GIS format from UDP MapsOnline (http://services.land.vic.gov.au/maps/content/udpintroduction). The 2005 dataset used in this study was digitised from UDP 2004 maps, which were downloaded from the UDP website (DSE, 2004). Only land parcels in the UDP datasets of status (1) Completed and (2) Under Construction were chosen.

Monitoring changes in the relative significance of these closer settlement style classes can be used not only to reveal the different rate and extent of different housing development classes LGA by LGA, but also, when analysed across the MMA as a whole, the extent to which residential urban form changes inspired by implementation by *Melbourne 2030,* conform with the policy vision. The influence of urban consolidation planning policy, *Melbourne 2030*, on such urban form change can then be referred to in discussion and evaluation (Phan et al., 2009b). To generate the closer settlement style pattern in each LGA during the study period, ArcGIS 9.2 Spatial Query tool and statistical summary tool (ESRI, 2007), were used.

5.4.2. Accessibility Analysis

Accessibility analysis was applied in order to examine the link between *Melbourne 2030* plan and practice (i.e. accessibility to infrastructures and services). This section describes the accessibility analysis for MMA dwellings developed between late 2000 and late 2006. A justification of the chosen method is presented first, followed by a description of the data collection and analysis.

Monitoring of accessibility to public and private services and facilities is important in evaluating the degree to which well-being, quality of life and residential satisfaction is being maintained (Apparicio *et al.*, 2008, Witten *et al.*, 2003). Accessibility refers to the relationship between origin (O) and destination (D). Thus, the facility with which the household members can move between O and D is an outcome of accessibility. In some instances, the proximity measures of accessibility (network or Euclidean distance) should be qualified in reference to the quality of services and facilities (Blumenfeld 1969, cited in Apparicio *et al.*, 2008), for instance in terms of frequencies and capacities of services. In this chapter, the pattern of spatial proximity relevant to the lives of people in higher density urban areas, and existing facilities and services, is examined.

Both nearest network distance and Euclidean distance were used to determine how far each new development (type by type) is to existing facilities and services (Figure 5.3). Given the nature of datasets at present routinely available, the analysis of the proximity of facilities and services to new housing developments is examined without taking into account the profile of the residents and their needs. The location of new dwellings is represented by the address point. Only address points that are completely within infill development, BH and MRS sites (those are used to determine the closer settlement type indicator) are selected.

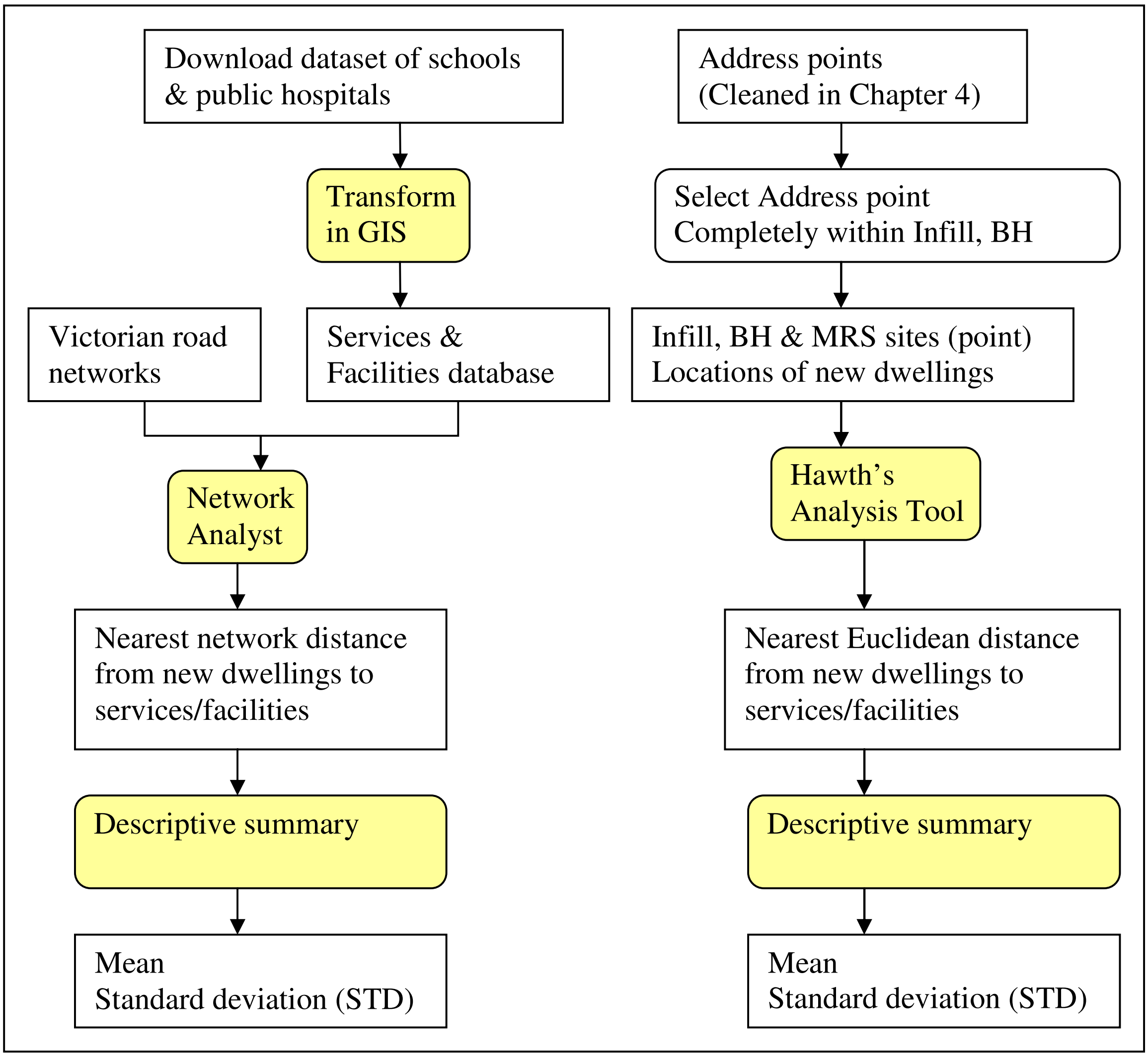

Figure 5.3: Flow path of accessibility analysis in intensified parts of the MMA

As an exemplification of the spatial analytical handling and manipulation, only two services (schools and public hospitals) are selected. A list of Victorian schools was downloaded from the Australian mashup project website (http://www.data.vic.gov.au/raw_data/school-locations/156). All schools within four studied LGAs were chosen and geocoded in ArcGIS 9.2 (ESRI, 2007). The public hospital database (in Google Earth KMZ file) was downloaded from the Victorian Government Health Information website (http://www.health.vic.gov.au/maps/index.htm). This dataset was then converted to ArcGIS file format (.shp) using Microsoft Excel and ArcGIS. The Hawth's Analysis tool (Beyer, 2004), an extension of ArcGIS, was then used to calculate the nearest Euclidean distance between each address point in areas of new dwelling developments to specified facilities. A further proximity measure was obtained using nearest network distance as determined from deployment of the *Network Analysis* tool in ArcGIS 9.2 (ESRI, 2007). Results are presented as the mean and standard deviation (STD) of nearest distance between public service points and the housing units newly occupied between 2000 and 2006 (Figure 5.3). Although there are many more complex approaches to determine accessibility between O and D, researchers favour using the nearest distance approach due to ease of computation and presentation (e.g. Lotfi and Koohsari, 2009). This latter is an important matter when results must be presented and discussed with a range of stakeholders, ranging from policy makers and community members (Oliveira and Pinho, 2009, Talen, 1998). The further away residential land is to a public utility service, the greater the likelihood that residents who can be expected to rely on it can become disadvantaged.

5.4.3. Selection of Development tract subdivisions

Urbanising land development takes place, planning scheme amendment by amendment, instigated developer by developer. Accordingly, Hasse (2004) found it useful to define development tracts (DTs) in these terms. Essentially, DT geography is one example of the way neighbourhood geographies can be derived. Other researchers have been using census boundaries, such as mesh blocks[15] (Ghosh *et al.*, 2007), or traffic analysis zone (TAZ) (Song, 2005) as a residential neighbourhood unit of analysis.

[15] Mesh blocks is a new micro level of geographical unit, which is designed to collect socio-demographic information and other available data, such as economic activity at relative small aggregated scale by the

Derivation of the neighbourhood-level measures of urban area land cover changes provide not only more detail on the design character of urban form in different cities but also assists in densification of areas where up-date of implementation of land use and transportation policies might be most needed and influential (Song and Knaap, 2007). In this chapter, a neighbourhood analysis unit is defined as land parcel attribute change to record the highest number of dwellings (via subdivision) (Chapter 4). It is at neighbourhood level that social and environmental implications from residential urban form changes can then be examined and discussed in detail. It should be noted that the use of address point data to identify dwelling presence in the land parcel (as discussed in Chapter 4) allows aggregation to the widest range of geographies, such as watershed or catchment, census boundaries or administrative boundaries. For the present analysis, aggregation DT by DT offers the following advantages:

- These lots are big enough to enable development of diverse dwelling types and dwelling size
- These lots are big enough so that in either undeveloped or redeveloped form, via land use rezoning, scope remains for evolution of geographical variation, for instance streetscapes. Among the streetscape changes, the suburban road design is a key indicator, the diagnostic feature being presence or proliferation (or not) of the cul- de-sac. According to Hasse (2004), the more cul-de-sacs and the fewer intersections per each new housing unit within a DT, the greater the sprawling mode of suburban growth.

In each DT, urban form characters were determined as follows:

1. **The proportion of cul-de-sac (PC)**

$$PC = \frac{\sum C}{\sum (C + I)}$$

In this formula, C is the number of cul-de-sacs (or dead ends) while I is the number of intersections (four ways and T junctions) (Soltani and Bosman, 2005) for each DT. PC was

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Bureau Office ABS (2004) Information Paper Mesh Blocks. Australian Bureau of Statistics, Canberra. Catalogue No. 1209.0.. In Australia, each mesh block contains between 20 and 50 dwellings. Mesh block is designed so that they can aggregate reasonably accurately to many different geographical regions, administrative, management and political boundaries ABS (2004) Information Paper Mesh Blocks. Australian Bureau of Statistics, Canberra. Catalogue No. 1209.0.Mesh block product was firstly released by ABS in 2008 with only a few attributes: land use type, total number of dwellings, and total number of population ABS (2008) 1209.0.55.002 - Mesh Blocks Digitial Boundaries, Australia, 2006.. The next release will be in 2011, together with other census products.

calculated using *Network Analyst* tool, *selection query* and *spatial join* Tool in ArcGIS 9.2. This metric indicates the relative availability of pedestrian access and mobility in urban street design.

2. **Density**: the critics of urban sprawl argue that the traditional detached house (i.e. low density development) on a relatively large lot increases automobile dependence and the cost of public infrastructure. In this Chapter, the density is calculated as: lot size, lot density and lot impervious surface area

Lot_size: mean lot size of dwelling units in the DT, the smaller the lot size, the higher the density

Impervious surface area: median impervious surface of dwelling units built in DT, the smaller the impervious surface area, the higher the density. On-screen digitising with orthorectified mosaic, DT by DT, was conducted to map the impervious surface pattern.

Lot density: the number of dwelling units built or proposed in a DT, the higher the ratio the higher the density

3. **Accessibility**: two measures of accessibility: distance to shopping centres, and distance to bus stop were determined

Dis_Com: mean network distance to the nearest commercial use; the greater the distance, the lower the accessibility

Dis_Bus: mean network distance to the nearest bus stop, the greater the distance, the lower the accessibility

For exemplification, the locations of commercial areas are defined as the same of designated activity centres in *Melbourne 2030*. The bus stop dataset (in csv format) was downloaded from Australian mashup project website (http://www.data.vic.gov.au/raw_data/bus-tram-and-train-stops-transnet/123). It was then transformed into GIS format using ArcGIS 9.2 (ESRI, 2007).

4. **Socio-economic analysis**: Census Collection Districts (CCD) intersecting four selected DTs in four LGAs were selected in order to incorporate other socio-demographic information, such as dwelling types or modes of journey-to-work transportation.

Four DTs were selected for analysis, and presented in Figure 5.4 (City of Whittlesea), Figure 5.5 (City of Knox), Figure 5.6 (City of Casey), and Figure 5.7 (City of Monash).

Figure 5.4 shows the location of the selected City of Whittlesea DT and its surrounding characters. The DT comprises 623 housing units in an area of 89.16 hectares. It is a greenfield site in Mill Park suburb, which is about 30 kilometres north of the Melbourne Central Business District. As can be seen from Figure 5.4 in this DT, the land uses include residential houses, public schools, and sports oval and playgrounds. The DT is adjacent to a natural reserve, which has two walking path tracks (City of Whittlesea, 2009). It is about 1.5 kilometres from the South Morang Activity Centre, and about 500 meters from the UGB.

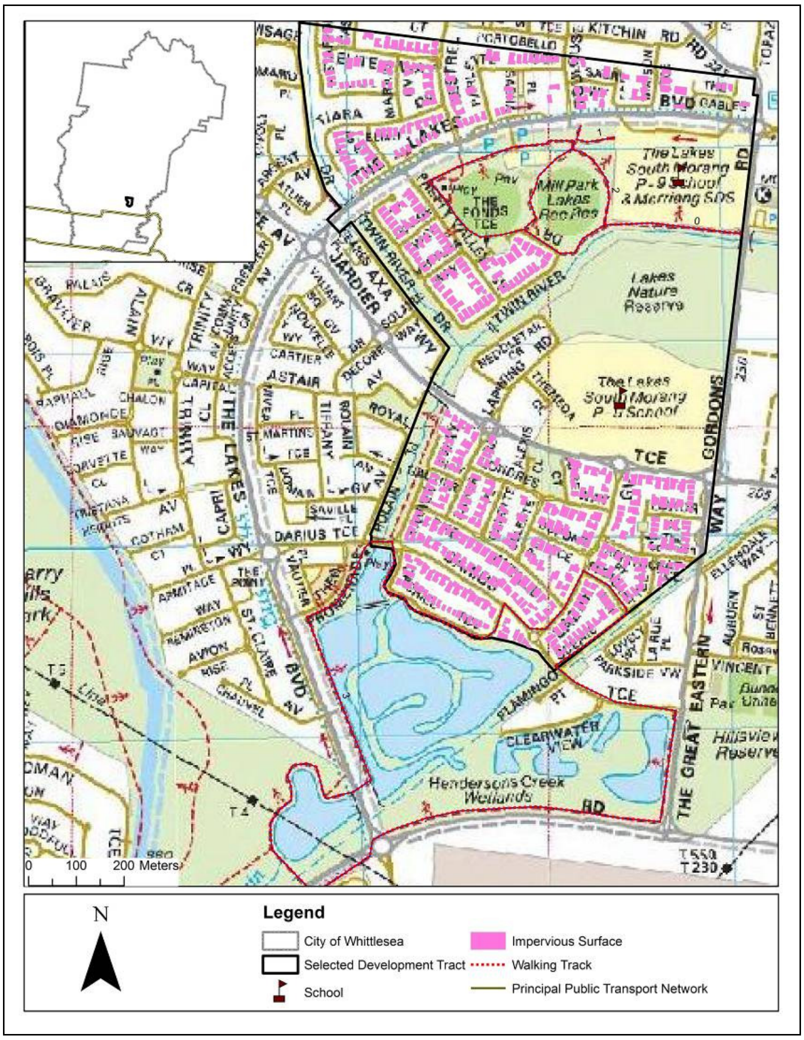


Figure 5.4: Location of selected City of Whittlesea development tract. The street directory map (in background) was acquired from Victorian online map service (http://services.land.vic.gov.au/maps/pmo.jsp). The walking track map in the South Morang region was downloaded from City of Whittlesea website (City of Whittlesea, 2009)

Figure 5.5 shows the location of the selected City of Knox DT and its surrounding characters. This DT includes 237 housing units in an area of 21 hectares. This 800 household estate was developed by Sovereign Crest Estate in 2000. Residents had taken possession by August 2005 (Pask Living Property, 2005). Nearby open space areas include Glenfern Park (to the north), King Park (to the east) and Knox Park (to the west), and Karoo Reserve (to the south west). The public transport bus routes (681 and 682) pass through this DT.

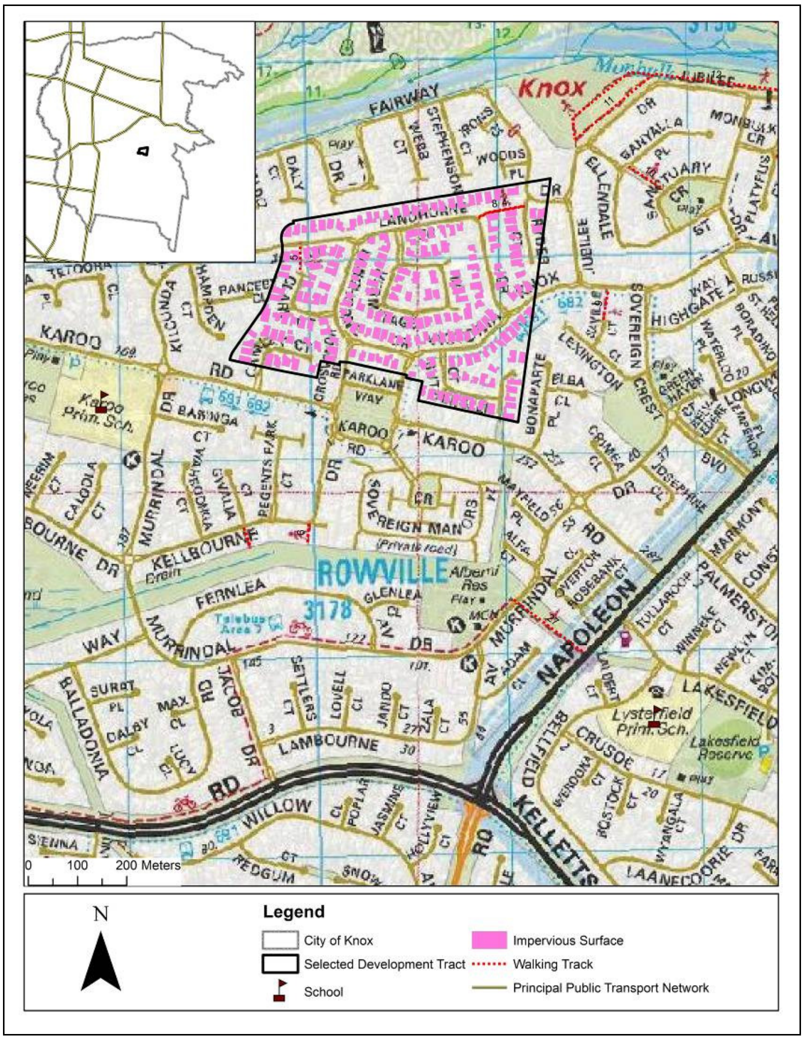


Figure 5.5: Location of the selected City of Knox development tract. The street directory map (in background) was acquired from Victorian online map service (http://services.land.vic.gov.au/maps/pmo.jsp)

Figure 5.6 shows the location of a DT in City of Casey. It is a greenfield site with 599 housing units in an area of 61.03 hectares. Land uses in this DT include residential housing in the south west and reserved land immediately to the north. A proposed shopping centre site is located to the northwest. Apart from that, there is a Play Hunt Club garden to the east, and two green spaces to the north. Bus routes (896/897) and four walking tracks pass through this DT.

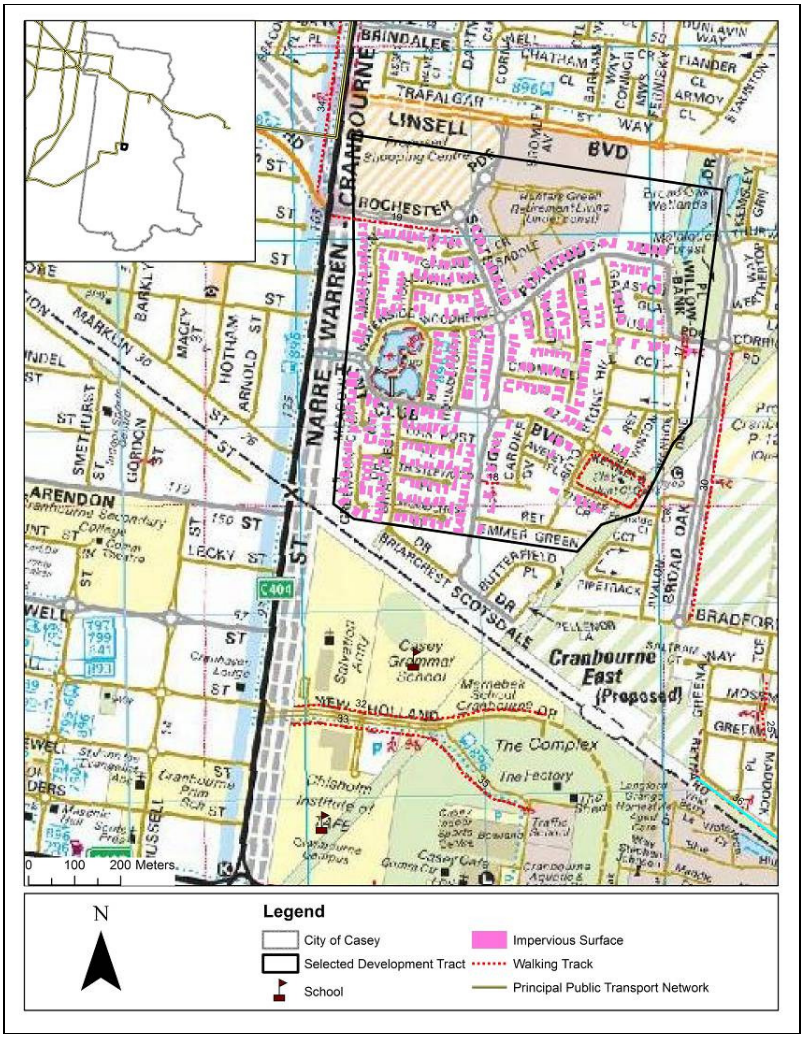


Figure 5.6: Location of selected City of Casey development tract. The street directory map (in background) was acquired from Victorian online map service (http://services.land.vic.gov.au/maps/pmo.jsp)

The selected City of Monash DT is a redevelopment site on the former Waverley football stadium. Currently, 360 housing units were constructed and are under construction on the area of 19.47 hectares. It is close to a bike route and Waverley Shopping Centre (in the east and south respectively). This DT is within 400 meter of PPTN (Figure 5.7).

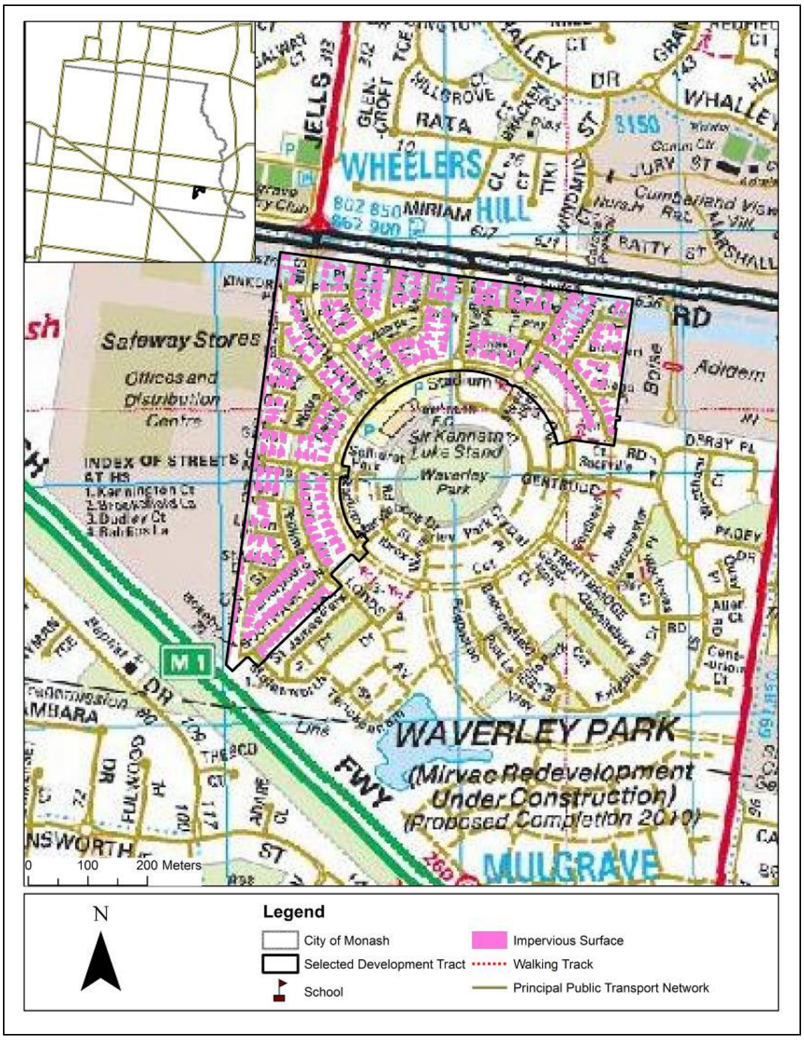


Figure 5.7: Location of selected City of Monash development tract. The street directory map (in background) was acquired from Victorian online map service (http://services.land.vic.gov.au/maps/pmo.jsp)

Figure 5.8 shows an overview of urban morphology[16] in the four selected development tract subdivisions. As can be seen in Figure 5.8 (overlaid on the subset from 2005 aerial photo mosaic acquired from Victorian Environmental Protection Agency (EPA)) they were arranged in different patterns and surrounded by different landmarks and features.

[16] Morphology” refers to the pattern of streets, blocks, lots and buildings TALEN, E. (2009) *Urban Design Reclaimed: Tools, Techniques and Strategies for Planners* Planners Press (American Planning Association).

Figure 5.8: Urban morphology of selected development tract (DT) subdivisions, from left to right, top to down: City of Whittlesea, City of Knox, City of Casey and City of Monash. Street designs in DTs in City of Whittlesea and City of Casey are of a grid pattern whilst those in City of Knox and City of Monash are in radial form.

5.5. Results

In this section, both housing and accessibility indicators at LGA level (sections 5.4.1 and 5.4.2) are presented and compared among the exemplar LGAs. Results of analysis at DT subdivision scale (in section 5.5.3) are then presented in terms of dwelling types (i.e. single houses, semi-detached units and high density apartment), street morphology, housing density, total population and modes of travelling to work.

5.5.1. Closer settlement style indicator

As clearly defined in section 5.4.1, the closer settlement style indicator defines the proportion of each housing development type in a given period. From analysis of the data referring to the period 2000-2006, as can be seen from Table 5.1, the Cities of Whittlesea and Casey have been subject to the highest percentage of greenfield development (about 68% of all development), followed by Knox (14.7%). In contrast, the City of Monash has been subject to one of the highest proportions (nearly 60%) of dispersed development, compared to the Cities of Knox (55.5%), Whittlesea (22%) and Casey (5.4%). The City of Monash ranked first in the strategic development classification (40%) whilst the City of Whittlesea had a lowest proportion of strategic development sites (9.8%). These results demonstrate that the relative significance of housing development types vary LGA by LGA.

Table 5.1: Descriptive summary of development types: infill development, strategic development and greenfields development in four Local Government Areas

Development Types	Monash		Knox		Casey		Whittlesea	
	Total Dwellings	%	Total Dwellings	%	Total Dwellings	%	Total Dwellings	%
Dispersed development	2595	59.9	1743	55.5	1070	5.4	1840	22.00
Strategic development	1736	40.1	935	29.8	5176	26.3	824	9.8
Greenfield development	0	0.00	460	14.7	13449	68.3	5699	68.2

5.5.2. Accessibility Analysis

Results of accessibility analysis are presented for each LGA. A comparison among four LGAs is discussed in section 5.6.3. It can be seen from Table 5.2 and Figure 5.9 that, on average, strategic development sites in the City of Monash are further from services (public hospitals and schools) (in both network and Euclidean distance) than is the case for dispersed development sites. However, Table 5.2 indicates that the standard deviation of nearest distance (in both network and Euclidean distance analyses) from dispersed development sites to public hospitals and schools is higher than that from strategic development sites. This indicates the more clustered nature of the strategic development site pattern around public hospitals and schools than is the case for dispersed development sites.

Table 5.2: Mean and standard deviation (STD) of nearest distance to schools and public hospitals, City of Monash

Development Types	Nearest Network Distance to School (m)		Nearest Euclidean Distance to School (m)		Nearest Network Distance to Public Hospital (m)		Nearest Euclidean Distance to Public Hospital (m)	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD
Dispersed development	822.4	430.2	572.4	311.85	1336.2	867.4	558.5	301.7
Strategic development	917.9	397.7	590.6	274.3	1706.2	852.9	567.7	284.8
Greenfield development	0	0.0	0	0.0	0	0.0	0	0.0

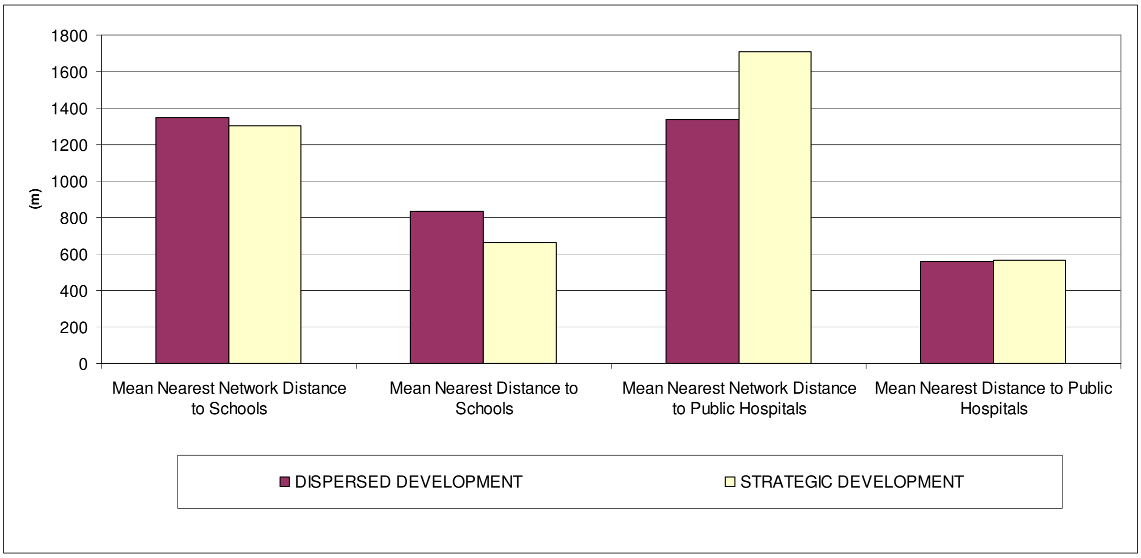


Figure 5.9: Mean Nearest Distance to schools and public hospitals by each development type, City of Monash

Table 5.3 and Figure 5.10 reveal that in the City of Casey, on average, dispersed development sites are closer to public hospitals (both in network and Euclidean distance) than Greenfield sites. On average, of all three types of closer settlement styles, the strategic development sites have biggest distance to hospitals (both in network and Euclidean distance). However, with regards to nearest Euclidean distance to schools, strategic development sites have the biggest distance. Overall, Greenfield sites, on average, are further to schools and hospitals than dispersed development sites or strategic development sites.

Table 5.3: Mean and standard deviation (STD) of nearest distance to schools and public hospitals, City of Casey

Development Types	Nearest Network Distance to School		Nearest Distance to School		Nearest Network Distance to Public Hospital		Nearest Distance to Public Hospital	
	Mean (m)	STD	Mean (m)	STD	Mean (m)	STD	Mean (m)	STD
Dispersed development	1060.4	604.6	717.2	413.5	4341.3	2486.1	3418.6	2248.8
Strategic development	1226.8	667.8	784.0	442.8	4969.7	2717.5	4246.6	2684.5
Greenfield development	1283.0	809.3	772.7	386.0	4899.9	2237.9	3797.4	2263.9

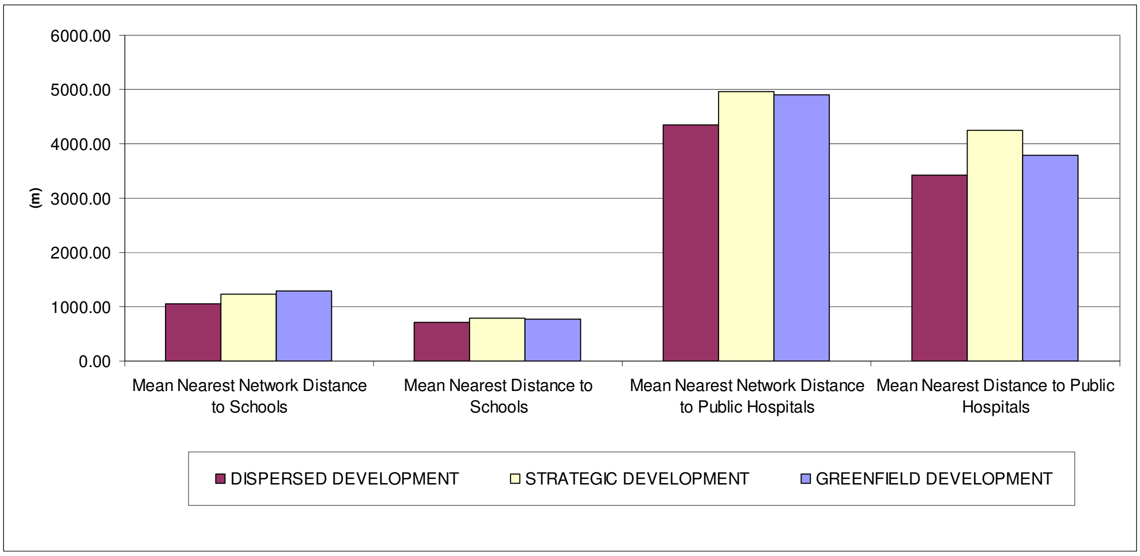


Figure 5.10: Mean Nearest Distance to schools and public hospitals by each development type, City of Casey

In the City of Knox, Table 5.4 and Figure 5.11 indicate that the average nearest distance to public hospitals (both in network and Euclidean distance) and schools (both in network and Euclidean distance) from strategic sites is smallest, followed by dispersed development and greenfield sites respectively. This trend is similar to City of Casey as discussed above.

Table 5.4: Mean and standard deviation (STD) of nearest distance to schools and public hospitals, City of Knox

Development Types	Nearest Network Distance to School		Nearest Distance to School		Nearest Network Distance to Public Hospital		Nearest Distance to Public Hospital	
	Mean (m)	STD	Mean (m)	STD	Mean (m)	STD	Mean (m)	STD
Dispersed development	904.5	538.9	591.3	298.6	3764.1	1318.6	2796.3	1280.4
Strategic development	834.9	418.5	543.0	287.4	2786.3	516.7	2223.9	1306.6
Greenfield development	1608.4	293.7	1045.2	272.7	4793.5	434.9	3807.9	875.8

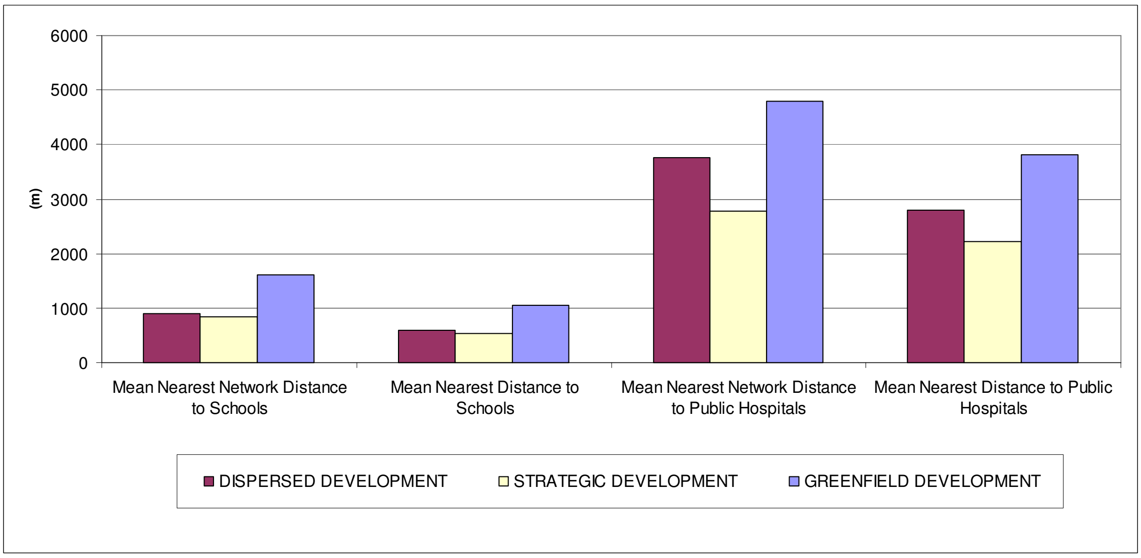


Figure 5.11: Mean Nearest Distance to schools and public hospitals by each development type, City of Knox

Table 5.5 and Figure 5.12 show that in the City of Whittlesea, the average nearest distance from strategic development sites to schools (in both network and Euclidean distance) is smallest, followed by dispersed development and greenfield sites respectively. However, on average, the dispersed development sites are closer to public hospitals than those in strategic and greenfield development sites (in network distance). In network distance, greenfield development sites are much further than strategic and dispersed development sites (about 1.6 to 1.8 kilometres) from public hospitals (Table 5.5).

Table 5.5: Mean and standard deviation (STD) of nearest distance to schools and public hospitals, City of Whittlesea

Development Types	Nearest Network Distance to School (m)		Nearest Distance to School (m)		Nearest Network Distance to Public Hospital (m)		Nearest Distance to Public Hospital (m)	
	Mean (m)	STD	Mean	STD	Mean	STD	Mean	STD
Dispersed development	1346.7	586.4	834.7	371.3	6839.0	7342.6	6413.9	5449.5
Strategic development	1300.4	1121.5	661.9	565.1	6679.9	3939.4	5022.6	2855.4
Greenfield development	1991.8	1042.0	1181.4	609.6	8222.1	3877.2	6139.6	2976.2

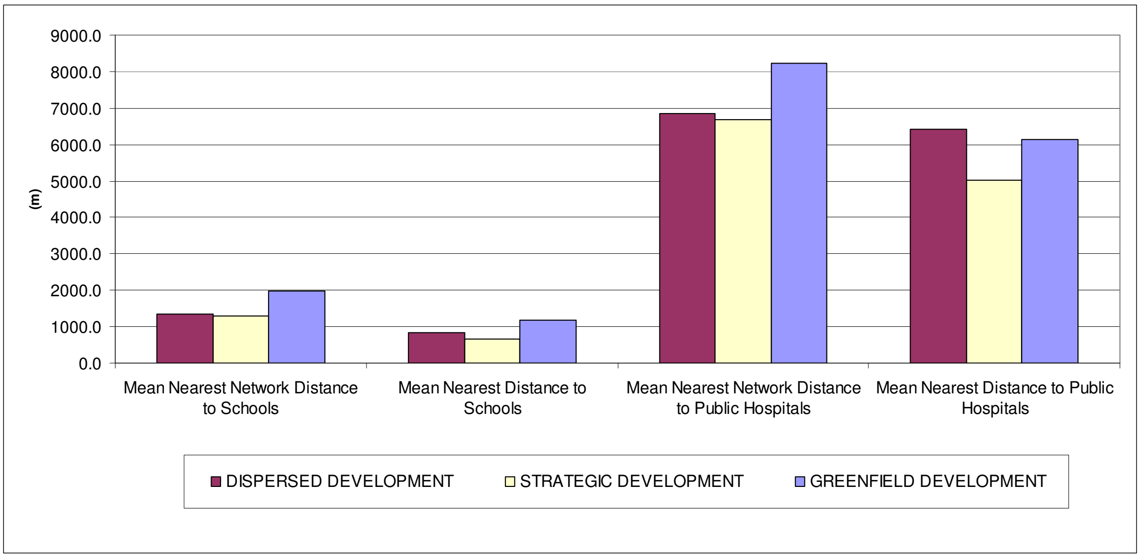


Figure 5.12: Mean Nearest Distance to schools and public hospitals by each development type, City of Whittlesea

5.5.3. Development tract subdivision

Census data from 2006 was analysed to provide an overview of socio-demographic profiles of residents living around each DT. By extracting information of CCDs which intersects selected DT in each LGA, information about the socio-demographic of residents living in recent developed dwellings (i.e. total populations, number of dwellings in each dwelling types (as presented Table 5.6) and total number of residents using each mode of transport to work (as presented Table 5.7)) is revealed.

Analysis of the associated Census datasets (Table 5.6) shows that "Separate house" is a dominant dwelling type in each DT. Semi-detached units were more developed in the City of Monash DT (76 units out of 252 dwellings in Monash, Waverley East CCD) and the City of Casey DT (72 units out of 222 dwellings in Casey, Cranbourne CCD) than in the City of Knox DT (10 units out of 235 dwellings in Knox, South CCD). The City of Whittlesea DT has only single house development. In all of the four DTs, no high density housing (i.e. flat or multi-storey apartment) was developed during the last census year.

Table 5.6: Total Population and Dwelling types in eight Census Collection Districts, which intersect with selected development tracts in four Local Government Areas (ABS 2006)

CCD Code	SLA_Name	Total Population (persons)	Dwelling types (dwellings)			
			Separate House	Semi-detached Units	High Density Development*	Total
2251713	Monash- Waverley East	660	176	76	0	252
2341918	Casey-Cranbourne	739	222	0	0	222
2341919	Casey-Cranbourne	1124	287	72	0	359
2240411	Knox-South	1046	279	8	0	287
2240416	Knox-South	813	225	10	0	235
2160321	Whittlesea-North	748	197	0	0	197
2160323	Whittlesea-North	337	109	0	0	109
2160324	Whittlesea-North	1053	317	0	0	317

*High density development includes flat, unit or apartment in multi-storey buildings

Table 5.7 shows that in all CCDs intersecting with selected DT, the majority of people travel to work by car as drivers.

Table 5.7: Total number of people using modes of transportation to work in eight Census Collection Districts, which intersect with selected development tract subdivisions in four Local Government Areas (ABS 2006)

CCD Code	SLA_Name	Travel to Work (persons)						
		Train	Bus	Ferry/ Tram	Car as Drivers	Car as Passengers	Bike	Walk
2251713	Monash- Waverley East	11	0	0	308	17	0	4
2341918	Casey-Cranbourne	13	0	0	267	21	0	3
2341919	Casey-Cranbourne	20	0	0	410	31	5	0
2240411	Knox-South	7	6	0	398	25	0	3
2240416	Knox-South	9	0	0	342	21	4	0
2160321	Whittlesea-North	8	4	0	251	12	7	4
2160323	Whittlesea-North	7	0	0	122	0	0	0
2160324	Whittlesea-North	11	3	0	385	33	0	0

5.5.3.1. The proportion of cul-de-sacs

Table 5.8: Comparative Analysis of Urban form characters in each development tract in each LGA

LGA of Development tract subdivision	City of Whittlesea	City of Knox	City of Casey	City of Monash
Area (ha)	89.16	38.2	61.03	19.47
PC[1] (number)	8.00	21.00	33.00	30.00
Int[2]	72.00	38.00	45.00	42.00
PC3 (%)	10.00	35.59	42.31	41.67

[1]PC: number of cul-de-sac per each development tract
[2]Int: number of intersection per each development tract
[3]Number of cul-de-sac per housing units

In terms of urban form street design, Table 5.8 shows that new residential development in selected DTs correlates with a lower number of street plans with cul-de-sacs than intersections. It is also revealed that City of Whittlesea has a lowest proportion of cul-de-sac (10%), followed by City of Knox (35.59%), City of Casey (42.31%) and City of Monash (41.67%). According to the principles of New Urbanism, the cul-de-sac street design inhibits connectivity and accessibility for residents in travelling to work and to other services or infrastructures. Curvilinear subdivision design can result in (1) heavy car dependence, (2) indirect road alignments, (3) little or no provision for public transport, (4) poor land use and transport integration in commercial areas, (5) no readily definable community centre, (6) little or no opportunity to retrospectively introduce public transport infrastructures (e.g. bus-stop lanes), (7) an over dependence on collector and arterial transport routes, and (8) an inflexible urban form which cannot adapt to change over time (City of Whittlesea, 2002). Thus, the lower the proportion of cul-de-sac configurations in the suburban road network design, the better is connectivity and accessibility. Such variation in urban street configuration can also be visualised in Figure 5.8. However, the proportion of cul-de-sac metric assists to quantitatively describe the differentiation among street design in the newly development areas.

5.5.3.2. Housing Density

Table 5.9 indicates that gross dwelling density in these selected sites varies from 7 dwellings per hectare in Whittlesea to 13 dwellings and 18.5 dwellings per hectare in Knox and Monash respectively. Whilst all active housing development projects in Casey and Knox have been finished within the studied period 2000 and 2006, much of land in the Cities of Whittlesea and Monash is undeveloped or underdeveloped, respectively. Within the existing UGB, scope for increasing dwelling number in the City of Whittlesea refers to such greenfield development. For the City of Monash, the biggest contribution to gross dwelling density increase will be brownfield development. The main options refer to subdivision, such that lot sizes are small enough to compel/force investment to be in high density (flats, and multi-storey units) dwelling projects. Of course under the land use planning laws and associated public policy, it is the market responses about supply and demand for housing that accounts for the nature of the flow of development permit applications. Dwelling size (lot size) also varies within and between DTs. Overall, the mean lot size in Monash is smallest (330.74m2), followed by Whittlesea (500m2), Casey (556.63m2), and Knox (684.71m2). Although the mean lot size in the fringe cities studied (Whittlesea and Casey) is smaller than that in Knox, their variation is larger, as indicated by their higher standard deviation (STD).

Table 5.9: Comparative analysis of density in each development tract in each LGA

LGA of Development tract subdivision	City of Whittlesea	City of Knox	City of Casey	City of Monash
Area (ha)	89.16	38.2	61.03	19.47
Housing units (number)	623	476	599	360
Lot Density (dwellings/ha)	6.99	11.40	9.81	18.49
Mean lot size (m^2)	500.08	684.71	556.63	330.74
Lot size (STD)	146.00	93.30	87.02	107.20
Total area of impervious surface (ha)	10.48	5.99	8.17	5.35
% Impervious surface	11.75	28.81	13.39	27.49

5.5.3.3. Accessibility

Table 5.10 shows that dwellings in a DT in each LGA are within walking distance (between 340 meters and 580 meters) to the nearest bus stop. The average distance between DT dwellings and their nearest activity centres (including shops) varies: it is about 2 kilometres in the City of Casey, 2.8 kilometres in the City of Whittlesea, 3.8 kilometre in the City of Monash, and 4.2 kilometres in the City of Knox.

Table 5.10: Comparative analysis of accessibility in each development tract in each LGA

LGA of Development tract subdivision	City of Whittlesea	City of Knox	City of Casey	City of Monash
Area (ha)	89.16	20.79	61.03	19.47
Nearest network distance to bus stop (m)	570.06	340.92	422.82	507.71
Nearest network distance to shopping centre (m)	2851.09	4292.38	1941.71	3840.76

5.6. Discussions

This section presents a comparative analysis of housing distribution across the four selected LGAs and *Melbourne 2030* plan implications with regards to monitoring and evaluating implementation at both LGA and MMA levels.

5.6.1. The utility of the closer settlement style indicator for plan implementation evaluation

The Audit Expert Group of *Melbourne 2030* stated that:

> "One cannot make definitive judgements on the implementation of a plan of which many of the initiatives have not yet been implemented or are in the very early stage of that process at least in terms of activity on the ground" (DPCD, 2008, p.22).

However, it is argued here that by deriving the closer settlement style indicator, the results of implementing housing initiatives[17] (DoI, 2002c, p.30) can be observed and revealed at the LGA scale. As can be seen in this Chapter, the use of the closer settlement style indicator allows the nature, rate and extent of different development types in each LGA in the MMA to be mapped and summarised. Results show that in old suburbs (Monash or Knox), dispersed development accounts for the biggest proportion of dwelling densification (59.9% and 55.5%, respectively), whilst in the fringe cities (Casey and Whittlesea), greenfield development ranks the first (68.3% and 68.2%, respectively). Dispersed development shows the biggest difference among LGAs, in which the biggest proportion was seen in the City of Monash (59.9%) as opposed to the smallest figure in the City of Casey (5.4%). Strategic development also shows a large variation among the four LGAs, in which the City of Monash ranks the first (40.1%), followed by Knox (29.8%), Casey (26.3%) and Whittlesea (9.8%).

Thus geographical variation within the MMA is better indicated than can be seen from the *Melbourne 2030* Audit report using census datasets (2001 and 2006) and dwelling approval data (DPCD, 2007, p.50). Using census datasets, The *Melbourne 2030* Audit report indicated that greenfield development (in both designated growth areas and other

[17] *Melbourne 2030* Direction 1, *A more compact city*, and its implementation plan 3 *Housing* aim to achieve housing outcomes across the MMA, of which three housing development types are defined and their proposed distribution during 2001 and 2030, at four year interval were showed DOI (2002a) Draft Implementation Plan 3 Housing. State of Victoria.

outer areas within the metropolitan Melbourne) accounted for 48.3% of all residential development between 2001 and 2006. By using dwelling approval data (available at the CCD), it was estimated that dwelling approvals at activity centres and other strategic development sites grew from 25% in the period 2001-2002 to 28% in the period 2004-2005 (DPCD, 2007, p.50). This overall MMA marginal increase of 3% dwellings in strategic development sites gives no information about the kind of geographical variation essential for on-demand monitoring of residential urban form changes.

Melbourne 2030 expects higher density development near public transport hubs and designated activity centres. The expected outcome of each housing development type was assigned for the whole MMA over a 30 year period as mentioned in Chapter 2. By way of monitoring, the *Draft Implementation Plan 3 Housing* in 2002 forecasts that 26.1% new housing in the MMA between 2001 and 2005 would be within activity centres or other MRS. Clearly, residential urban form change under *Melbourne 2030* will evolve through changing patterns that cannot be monitored without maintenance of detailed geographies, LGA by LGA.

In these terms, determination of closer settlement style indicator for each LGA details the progress of delivering and implementing MMA housing development implementation plan (DoI, 2002a, p.8) at the LGA level. Evidence from local government authority reports show that some local government councils are trying to direct major redevelopment around transport hubs or activity centres. For example, in the southeast region of Melbourne, the City of Casey is targeting "up to one third integrated housing in greenfield development, which would be situated within 400m of activity centres, close to public transport routes and public open space" (City of Casey, 2005, p.13)". The other evidence refers to land use changes from public open space land (i.e. Waverley Park Stadium in City of Monash) to residential land use. This DT is within 400 meters of the PPTN. However, the outcomes in practice as seen in the closer settlement style patterns and derived indicator show that between 2000 and 2006, dominant housing development types in older suburbs (e.g. those in the City of Monash) is dispersed development, but that in the fringe cities (e.g. the Cities of Casey and Whittlesea) is greenfield development. These results indicate that progress in meeting *Melbourne 2030* housing development refers to a range of urban forms.

State Government land use planning power allows for setting and re-setting (extending) the UGB. The motivation for this refers at least partly to the fact that re-zoning land with the UGB for residential development can be only one solution for Melbourne's housing affordability crisis (DPCD, 2007). Ultimately it is provision of sufficient land supply (DPCD, 2007) for new residential development that can solve the housing problem, and not all of the required land will be found by densification and multistorey development via amendment of land use plans in the inner LGAs. However, the expansion and amendment of the UGB within a short time (three years of its implementation) raises concern about the currency of the objectives of *Melbourne 2030*: a policy designed for curbing MMA sprawl. The dichotomy between policy and practice was recently emphasised, when the Victorian Government Planning Minister approved to expand the UGB[18] (DPCD, 2010) further west toward Ballarat by adding another 500 hectares to the 50,000 hectares under consideration for expansion to the UGB (Dowling, 2009). Is this dichotomy a serious threat to the policy? Should the policy evolve more rapidly than is the case? Clearly the answers to such questions call for data and information that seems not much to be brought to the decision support. Monitoring the location, scale and extent of high density development in the MMA is necessary to provide evidence of conformity between planning practice and planning policy. In addition, strong government intervention, for instance via provision of financial incentives and penalties to the consumers and suppliers of housing may be required to redirect the current building construction and building activity (Buxton *et al.*, 2006, p.98).

5.6.2. The utility of accessibility indicator for plan implementation evaluation

Accessibility analysis was not included of three main *Melbourne 2030* implementation reviews, such as:

- Community Indicators Victoria (http://www.communityindicators.net.au),
- Liveability surveys, The State of Environment Reporting (http://www.ces.vic.gov.au/CES/wcmn301.nsf/childdocs/-E6B87D4214877024CA256F250028E4A7?open), and

[18] The approval of the UGB expansion is now seeking parliamentary ratification. Once ratified by parliament, the amendment will be operational DPCD (2010) Delivering Melbourne's newest sustainable communities: Amendment VC67. Department of Planning and Community Development..

- Growing Victoria Together (http://www.dpc.vic.gov.au/CA256D800027B102/Lookup/GVTBooklet/$file/DPCbrochure.FA.pdf).

In this Chapter, it is also indicated that spatial analysis offers scope to widen the range of routine accessibility derivations. For instance, it is demonstrated that deployment of the spatial analysis tools from ArcGIS (ESRI, 2007) facilitates quantification of the spatial relationship between new densification housing (at the detailed geography scale of land parcel) with current infrastructures and services. Not only can the distance from each new dwelling to the nearest school or hospital become known on-demand but the exact path between them can be produced. The present analysis has been conducted on only two services (schools and public hospitals) because the set up of spatial database for services or facilities is time consuming. Quantified accessibility analysis of schools and public hospitals can provide some insight into the status of liveability[19] measures, extant or via scenario modelling of residents' access to these services. On average, of all four studied LGAs, greenfield dwellings are further from public services than those in dispersed or strategic development sites. Based on such analysis, the quality of life for residents in the greenfield sites is more likely to be revealed as comparatively disadvantaged or declining due to the comparatively longer distance between greenfield development and public infrastructure and services.

5.6.3. The utility of urban form metrics for exploration of urban form design in new development areas

At the finer scale of analysis (DT scale), it is revealed that the majority of residents in the selected DT drive to work. This is despite the fact that proximity analysis found that on average residents in these DT are within the 340 meters and 500 meters buffer of the nearest bus stop. These results suggest that the degree of perceived automobile dependence of residents has not been changed, densification policies notwithstanding. This can be explained by other factors. According to Bunker *et al.* (2005), apart from the spatial proximity to facilities and services, the several factors that influence car-dependence include household income, and size and type of households.

[19] According to Whitzman WHITZMAN, C. (2008) Planning for living well. *Planning News,* 34., liveability refers to maintaining housing affordability, tackling disadvantage, low crime rates, a cosmopolitan or multicultural way of life, and 'room to grow'.

The analysis of selected DTs also showed that greenfield site densities (Cities of Casey and Whittlesea) are not approaching the 15 dwellings/ha density as suggested in *Melbourne 2030* (DOI, 2002b, p.63). Additionally, there is variation in terms of lot sizes in these DTs. Whilst the City of Monash developments showed the lowest lot size (around 330m^2), lots developed in the outer LGAs of the City of Casey, Knox and Whittlesea ranged between 500 and 680m^2.

5.7. Conclusion

A closer settlement style measure was derived and applied to MMA *Melbourne 2030* LGA dwelling densification data so that the relative significance of styles (dispersed, strategic and greenfield), LGA by LGA, could be tabulated. Accessibility analysis tools were applied, closer settlement style by style, to derive measures of proximity to public hospitals and schools.

Results showed that between the late 2000 and the late 2006, in old suburbs, dispersed development accounts for the biggest proportion of dwelling densification (59.9% and 55.5%, respectively), whilst in the fringe cities, greenfield development ranks the first (68.3% and 68.2%, respectively). It is clear that closer settlement style indicators can be used to assist planners and decision makers to monitor the progress of *Melbourne 2030* implementation, LGA by LGA. Thus, accessibility measures derived for neighbourhoods dominated by dispersed densification, can be compared with those derived for strategic developments and for greenfield developments. Implications arising from this demonstration of utility for the stratification of densification dwellings data before accessibility analysis refer to both monitoring liveability measures and prediction via scenario modelling of residents' access to these services. With regard to the approaches exemplified here, greenfield dwellings are, on average, further from public services than those in dispersed or strategic development sites. This result suggests that there is a scope to improve accessibility to services for residents living in greenfield development sites.

Determination of urban form metrics (e.g. lot size, lot density, the number of cul-de-sacs) for selected development tracts (DTs) shows that new dwelling developments can be analysed at neighbourhood scale. These metrics refer to patterns of such detail as to be relevant in behavioural research, for instance regarding the relationship between built environment and behaviour of residents on travel mode choice, and travelling times (e.g. as in the study by Soltani and Bosman, 2005).

The methodology developed for the analysis presented here was applied within the residential urban form changes inside the UGB between the late 2000 and the late 2006. However, it can be applied again in time series as each of relevant dataset is updated. Thus, geographical variation of densification across the MMA can be monitored. Accordingly, impact of planning policy on the actual patterns of densification can be revealed in ways that support decision making both strategically and tactically.

6. CHAPTER 6: SPATIAL ANALYSIS OF INFILL DEVELOPMENT: AN EXEMPLIFICATION USING MONASH CITY DATA

6.1. Introduction

It has been shown in Chapter 5 that the City of Monash (2000-2006) (*Melbourne 2030*) policy-inspired densification occurred mainly as dispersed development. Clearly, multiple variables are involved, and as pointed out by Mitchell (1999a), spatial statistics can be deployed in search of patterns and correlations that are of use in hypothesis generation and testing in search of explanations.

Previous research (e.g. Birrell *et al.*, 2005b, Buxton and Tieman, 2004b, Yates, 2001) has offered elucidation of the nature of factors influencing the location and development of housing development in Melbourne. Factors of influence in accounting for the style of closer settlement, especially of medium density development (proximity to public transport network or its proximity to CBD and Port Phillip Bay) have been suggested by Buxton and Tieman (2004b, p.xiii). No quantitative attempt has been made to confirm and examine the putative driving forces, nor has scope to deploy disaggregated analysis been exploited. From the demand side, by analysis at the metropolitan level, Yates (2001) found that household income was the main driver in determining household decisions about location, dwelling type, and tenure. In terms of policy contribution, Buxton and Tieman (2004b) argued that it is both planning policy (for instance, the delivering of *Rescode*) and market preferences that influence the number of medium density developments. Birrell *et al.* (2005b) suggested that small property investors are one of the main suppliers of dual occupancy houses, semi-detached, attached houses, and flats, but their contribution is little understood in detail. Birrell *et al.* (2005b) anticipated that any property on sale that is perceived to be economically suitable for redevelopment will be likely to become an infill development site. The pattern of pre-redevelopment dwelling attributes i.e. the ages of the house, position of dwelling on the lot, and the nature of suburban neighbourhood (including sociological factors determining mobility) are likely to be important factors influencing the infill development rate (Birrell et al., 2005b).

Empirical studies designed to examine the relative significance of these factors on spatial patterns of dwelling developments have yet to be conducted. Such research would not only add value to the mapping of changes in residential urban form mapping but also enhance scope for comparing policy intent with implementation outcomes. If any gap found can be explained, information for guiding or supporting the identification and deployment of mitigation of the effects of nonconforming development in the future can be provided (Brody *et al.*, 2006). Application of detailed spatial analysis may be beneficial in such analysis.

This Chapter aims to quantify and explore the pattern of infill development under the *Melbourne 2030* implementation. Specifically, it seeks to answer the following questions:

1. How did infill development occur around activity centres and railway stations?
2. Did infill development cluster around activity centres or railway stations?
3. What are the determinants of infill development?
4. To what extent does the pattern of proximity to activity centres and railway stations, and land parcel areas explain the variability in number of infill development between the late 2000 and the late 2006?

To answer the research questions one and two, spatial statistics are deployed for analysis of spatial patterns and the nature of associations between infill development sites and other spatial infrastructures and services: designated activity centres and railway stations. Spatial statistics deployed in this Chapter, include kernel density, univariate K-function and bivariate K-function. They constitute the core of an explorative approach to analyse point pattern distributions. Although these spatial statistics have long been used by ecologists, biologists and health scientists (e.g. to quantify the spatial distribution of species or fast-food restaurants (Austin *et al.*, 2005a)), it has so far seen limited application by urban analysts including those interested in studying the nature of residential development pattern changes. As reviewed in Chapter 2, section 2.4.2.4, only two studies of residential development patterns using spatial statistics have been reported. Lack not only of appropriate data handling tools (Lu and Chen, 2007) but also lack of relevant spatial data, especially at property or household scale, has been mentioned in explanation (Cuthbert and Anderson, 2002a). For the present study, as shown in Chapter 4, City of Monash infill development could be identified and mapped at property scale between 2000 and 2006 so any such constraint on data availability has been overcome (Phan *et al.*, 2008) in this case.

In point-pattern analysis, the distribution of points can be grouped into three types (Murgante *et al.*, 2007):

- random distribution: the position of each point is independent of other points;
- regular distribution: points have an uniform spatial distribution; and
- clustered distribution: points are concentrated in some building clusters.

As shown in Chapter 4, the Vicmap address point dataset can be used to represent the presence of dwellings. Thus, point-based spatial statistics can be used to explore the spatial distribution of address points within infill development land parcels (see Figure 4.9) identified (question 1 and question 2). To examine the influence of driving factors on infill development (question 3 and question 4), a multivariate regression model was developed at the census collection district (CCD) level of spatial aggregation.

6.2. Study Area

Of all four LGAs examined in Chapter 4 and Chapter 5, the City of Monash exhibits best densification by infill (dispersed) (re)development, dispersed development accounting for nearly 60% of all new development (Chapter 5). As presented in Table 6.1, infill development between late 2000 and 2006 contributed 2664 new dwellings. This figure is estimated to account for 4.8% of all residential dwellings for which local government rates were paid in 2000 (Table 6.1).

Table 6.1: Summary of contribution of infill development on dwelling supply in 2000 to 2006 in City of Monash (Phan *et al.*, 2008, p.26)

Number of dwellings in 2000	55778*
Number of infill developments from 2000 to 2006	1,483
Total number of dwellings from infill development	4,147
Number of additional dwellings from 2000 to 2006	**2,664****
Percentage of additional dwellings by infill over the number of dwellings in 2000	4.8%

Notes: In this calculation, it is assumed that every infill development occurred on a developed land parcel. In only a few cases (observed in aerial photos in 1999, 2001 and 2006) were there more than 2 dwellings developed on land classified in 2000 as vacant land.

* Estimated number of dwellings in 2000 using linear interpolation of total number of dwellings in 2001 and 2006 (Table 4.4.1)

** Number of additional dwellings = Total number of dwellings from infill developments – Number of dwellings subdivided as of 2000.

In terms of the land and property market, the median housing price in the City of Monash suburbs increased steadily (growth of at least 64% of house price in 2000) between 2000 and 2006 (Figure 6.1). In two suburbs, Clayton and Oakleigh East, the median housing price doubled during this period. Hence, the choice of City of Monash as a case study can reveal the influence of market preferences on planning policy outcomes.

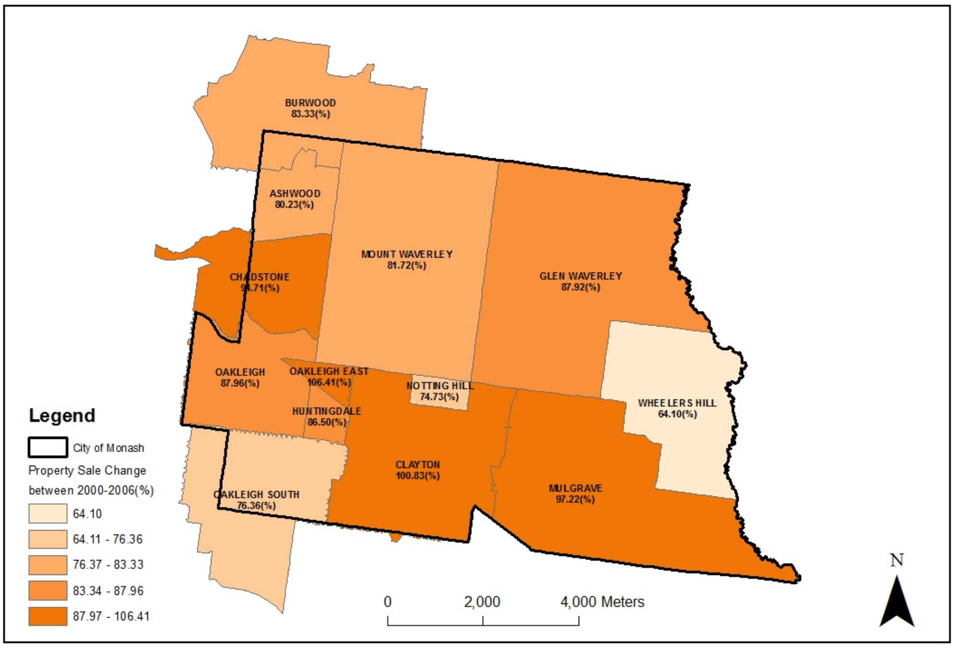


Figure 6.1: Median Property Sale Change by suburbs within and around City of Monash (2000-2006)(DSE, 2007a). The median property sale change was presented using the natural break classification (ESRI, 2007)

6.3. Methodology

To answer the research questions, the following analytical methods were applied to the results reported in Chapter 4:

- Kernel density to visualise the pattern of infill development in relation to the location of activity centres and railway stations
- Univariate and bivariate K-functions to quantify the spatial pattern of infill development and its spatial relationship with activity centres and railway stations, and
- Regression analysis to identify the relative influence of proximity, sociodemographic, site characteristics and policy variables on infill development

Rationales for choosing these methods are discussed in the following sections.

6.3.1. Kernel density

The kernel density is a spatial statistical technique that measures the variation in the mean value or intensity of a process in space (O'Sullivan and Unwin, 2010). The kernel density measures the number of observed events, such as new land parcel development, per unit area. The kernel estimate of relative density in two dimensional space around a point (x,y) can be calculated (after Fotheringham *et al.*, 2000):

Equation 6-1:

$$f\,(\mathrm{x,y}) = \frac{1}{nh^2}\sum_{1}^{n} K\left({}^{d_i}\!/_{h}\right)$$

where:

f(x,y) is the density estimate at the location (x,y),

n is the number of observations,

h is the width of the window, or is called as a smoothing factor or bandwidth by some researchers.

K is the kernel function, and

d_i is the distance between the location (x,y) and the location of the ith observation. Both h and cell size will influence the cell value of the kernel density grid. If h is too big, the value of h is closer to simple density; if h is too small, the surface does not capture the phenomenon (Mitchell, 1999).

There are two major advantages of using kernel density for exploring spatial point patterns:

1. kernel density assists in exploring the complex point patterns. The result, a smooth raster image of densities, can be used together with the point map. Thus, no information is lost in the analysis. The kernel density maps offer a quick way of visualise the hotspots, or can be used to define hot spots based on statical significance (Williamson *et al.*, 1999)
2. kernel density maps can be used for time series change analysis. Substraction of kernel density maps at two different periods can reveal areas of growth or decline in firm density (e.g. see Maoh and Kanaroglou, 2007) or residential development (e.g. seeCarlson and Dierwechter, 2007)

Different K functions (e.g. normal distribution or triangular distribution) can be used to generate a density surface of the observed point data. In GIS software, ArcGIS 9.2

(ESRI, 2007), quadratic kernel function (K function) that is offered. This is a common kernel type deployed in analysing crime data (Chainey *et al.*, 2008).

Some rules of thumbs have been used to define kernel density window size. In ArcGIS the default value of window size is equal to shorter side of the minimum bounding rectangle surrounding the study area study area divided by 30 (ESRI, 2007). In other spatial pattern analysis tools, for instance in *CrimeStat*, this number is set to provide a suitable enough cell resolution without requiring a significant number of iterations to generate a representative kernel density estimation surface (Chainey *et al.*, 2008). Bailey and Gatrell (1995) suggest a bandwidth defined by 0.68 times the number of points raised to the -0.2 power scaled to the areal extent of the study area (i.e. 0.68(n)-0.2). This can be adjusted depending on the size of the study area by multiplying by the square root of the study area size. However, according to Williamson *et al.* (1999), all of those settings of window size are arbitrary because it only takes into account the areal extent of point distribution without the relative spatial distribution between points. To take into account this factor, Williamson *et al.* (1999) suggest to use the average k nearest neighbour distance among points in determining the window size. The authors also compared kernel density maps using window size estimated by (1) ArcGIS, (2) Bailey and Gatrell, and (3) k nearest neighbour and found that the estimates of window size of kernel density maps do not influence by the areal extent of the study area. Instead, the window size depends on the choice of k (Williamson *et al.*, 1999). Williamson *et al.* (1999) suggested that if the number of points is small, k should be chosen to be small as well.

For the purpose of visualisation and exploration of infill development point patterns in this study, a number of window sizes, estimated by using by k nearest neighbour distance and the default setting of window size of ArcGIS 9.2 (cell size equals to 37.08m and window size equals to 309m) were tested. To determine the nearest distance of k^{th} neighbourhood in point-based City of Monash infill development dataset (2000-2006), the *Calculate Distance Band on Neighbourhood Count* Tool in ArcGIS 9.2 (ESRI, 2007) was used. It was found that the average of neighbour distance of 10, 20, 30 infill development sites is 156.02, 244.42, and 317.86 meters, respectively. They were used as in puts for window size. The cell size of all generated the kernel surfaces were set by default as in ArcGIS 9.2 of 37.08 meter. The kernel density surface is presented in Figure 6.3.

6.3.2. Univariate K functions

While the kernel density map (Figure 6.3) provides a visual examination of the intensity of infill development, it does not measure the spatial dependence or clustering of infill development. The univariate and bivariate K functions can be used to analyse spatial dependence (Cuthbert and Anderson, 2002). As mentioned in section 6.1, the spatial distribution of point datasets can be quantified into three types: regular, random and clustered. Both univariate and bivariate K functions techniques are used for statistically classifying the observed patterns of City of Monash infill development (between 2000 and 2006).

The univariate K function is an explicit test for spatial dependence or clustering among different events (Cuthbert and Anderson, 2002, Rowlingson and Diggle, 1993). To explore land parcel scale residential development, the univariate K function is defined as the expected number of parcels within distance *h* of a randomly selected parcel, divided by the overall intensity of parcels, which is denoted as K(*h*). The expected number of points within that radius is (after Cuthbert and Anderson, 2002):

Equation 6-2:

$$\text{E (\# of points within distance h)} = \frac{N}{A} * K(h)$$

Where N is the sample size, A is the total study area, and K(h) is the area of a circle defined by radius, h.

Under unconstrained conditions, K is defined as

Equation 6-3:

$$K(h) = \frac{A}{N^2} \sum_{1}^{i} \sum_{1}^{j} I(h_{ij})$$

where: $I(h_{ij})$ is the number of points, j, found within distance, h, summed over all points, I.

The estimation of K(h) in *Equation 6.3* suffers from edge effects. The *CrimeStat 3.1* software embeds functions that correct for edge effects using rectangular or circular shapes of the study area (CrimeStat, 2008). A friendly user interface is provided in

CrimeStat 3.1 with detailed documentation. Therefore, it was chosen for estimating univariate K-function.

According to Lu and Chen (2007), if the events being analytically mapped are more likely distributed along a street network (e.g. crimes), analysis of distance by street network (i.e. network distance K-function) would be more appropriate than analysis by Euclidean distance (named traditional planar K function). Lu and Chen (2007) compared outcomes from applying traditional planar K-function with a network distance K-function and found that in terms of outcome, somewhat contrasting conclusions about spatial distribution of crime patterns emerged. Cuthbert and Anderson (2005) and Lu and Chen (2007) did not apply any edge correction because there is no such capability in the tool that they used to calculate traditional planar and network distance K-function, respectively. Lu and Chen (2007) recommended incorporating a network K-function tool in any crime analysis toolkit so that applications of spatial statistics in crime research could be more effectively conducted.

The study area being relatively rectangular, the traditional plannar K function embedded in *CrimeStat 3.1* with rectangular edge effects correction was used. To test for significance, *CrimeStat 3.1* computes upper and lower simulation envelopes of the K function under complete spatial randomness. The confidence intervals provide a means to assess departures of the estimate of K(h) from its theoretical value. Nine hundred and ninety nine (999) simulations were run to estimate the confidence intervals. If the estimated univariate K function line is above the upper confidence interval, spatial dependence or clustering is present. In contrast, if it is below the lower confidence interval, the dispersed distribution is presented. The values between the two limits indicate a random pattern. According to the authors of *CrimeStat* software (CrimeStat, 2008), the relationship between K(h) and h is non-linear and typically increasing exponentially (Kaluzny *et al.*1998, cited in CrimeStat (2008, p.5.23)). Therefore, to display a more linear relationship, K(h) was transformed into a square root function, L(h) as in Equation 6-4 (after CrimeStat, 2008).

Equation 6-4:

$$L(h) = \sqrt[2]{\frac{K(h)}{\pi}} - h$$

6.3.3. Bivariate K-Function

The bivariate K-function has been used to testify the cluster inter-dependencies between two event patterns in space. The K-function can be estimated as:

Equation 6-5:

$$K(h)=\frac{A}{N^2}\sum_{1}^{i}\sum_{1}^{j}I(h_{ij})$$

where A is the area of the region, n is the number of parcels, h_{ij} the distance between i-th parcel and j-th activity centre or railway stations, the indicator function $I(d_{ij})$ is 1 if $d_{ij}<=h$, and 0 otherwise.

In this study, the bivariate K-Function analysis was estimated using R 2.6.2 (R Development Core Team, 2005) using the SPLANCS (Spatial Point Pattern Analysis Code) spatial statistics package (http://cran.ms.unimelb.edu.au/). R is free statistical software that performs spatial statistics. It requires specific package downloads for specific tasks. The bivariate K- function is defined as the expected number of points of pattern one (i.e. the residential development) within a distance *h* of an arbitrary point of pattern two (activity centres or railway stations), divided by the overall density of the points in pattern one. The bivariate K-function corrects for the edge effects using the toroidal shift technique (R Development Core Team, 2005). For presentation and ease of interpretation, the bivariate K-function was also transformed to L(h) (Equation 6-4:) as in the case of univariate K-function. The use of the bivariate K-function is to test the degree of clustering of infill development dwellings around designated activity centres and railway stations.

6.3.4. Multivariate Regression

The previously-mentioned analytical methods allow visualization and quantification of the spatial patterns of infill development (represented as points) and railway stations and designated activity centers. A multivariate regression model is developed to explore the relative influence of land parcel characteristics, socioeconomic factors and land use planning policies on the rate and extent of infill development in the City of Monash. Regression analysis offers a way to model, examine and explore spatial relationships as well as to better understand the factors behind observed spatial patterns (ESRI, 2008, Regression Analysis Basics). Regression analysis provides a way to fit the model with observed data, and a means to evaluate the importance of explanatory variables (Rogerson, 2001).

Many explanatory variables have been proposed and incorporated in urban growth and land use change models. Traditional urban models have focused on the site and neighborhood characteristics that have been assumed to influence the probability of land parcel development (e.g. Landis and Zhang, 1998). Site characteristics such as lot size, land value, and environmental constraints embedded in planning have been used to measure the land development capacity in urban growth and land use change models. Neighborhood-level factors such as population growth, land use mix, and socioeconomic characteristics have also frequently been used to measure the attractiveness of neighborhoods in urban growth or land use change models (e.g. see Zhou and Kockelman, 2008, Hu and Lo, 2007). Depending on the research objectives and questions, researchers will justify the choice of those above-mentioned variables.

This section explains the regression model used to examine the relative significance of site, neighborhood characteristics or planning policy as driving factors of City of Monash urban infill housing development. ABS Census Collection District (CCD) (Australian Bureau of Statistics, 2001 & 2006) geography was chosen as the spatial analysis unit. Multivariate regression models were employed in the empirical analysis in order to identify the links or interactions between infill development rates and the geographical, planning policy and socioeconomic variables. Such a multivariate regression model allows modeling of the relationship between a number of explanatory variables and a response variable by fitting a linear equation to observed data. The multivariate linear regression model is specified as (after Rogerson, 2001):

Equation 6-6:

$$Y=\beta_0+ \beta_1X_1+ \beta_2X_2+\ldots+ \beta_nX_n+\varepsilon$$

where:

Y is the number of infill development (2000-2006) in each CCD

$X_1, X_{2,\ldots,} X_n$ are independent variables, which are detailed in the following sections.

$\beta_{0,} \beta_1,\ldots, \beta_n$ represent the coefficient values for each corresponding independent variable

ε represents the error term.

The regression models are estimated by means of Ordinary Least Squares (OLS), computed using ArcGIS 9.3 (ESRI, 2008, Regression Analysis Basics). The OLS method estimates coefficient values from the observed set of response and independent variables to minimise the sum of the squared residuals (Rogerson, 2001):

Equation 6-7:

$$\min(Y- (\beta_0+ \beta_1X_1+ \beta_2X_2+\ldots+ \beta_nX_n))^2$$

Initial examination of the model with a set of independent variables (explained in the next section) found that the model residuals are not of a normal distribution (the Jarque-Bera Statistic test was significant at 0.05 level). Visual examination (using histogram, Q-Q plot and box plot) of model residual also confirms that model residuals are not of normal distribution. This violates one of assumptions when undertaking regression analysis. To correct for this, Rogerson (2001, p.146) suggested transformation of dependent variables. A logarithm transformation of the dependent variable was conducted. Because there are some CCDs without infill development, the dependent variable had one added before transforming into a logarithm. Thus, Equation 6-6 was transformed as follows:

Equation 6-8:

$$\mathrm{Log}(Y+1) =\beta_0+ \beta_1X_1+ \beta_2X_2+\ldots+ \beta_nX_n+\varepsilon$$

where:

Y is the dwelling yield in each CCD

X_1, $X_{2,\ldots,}$ X_n are independent variables, which are detailed in the following sections

$\beta_{0,}$ $\beta_1,\ldots,$ β_n represent the coefficient values for each corresponding independent variable

ε represents the error term.

6.3.4.1. Dependent variable

To measure the outcomes of urban growth management tool implementation, researchers normally use urban land area and urban density (Carruthers, 2002, Nelson, 1999, Howell-Moroney, 2007). In this City of Monash study, the number of new infill dwelling development between 2000 and 2006, (named dwelling yield) per 2001 CCD was used as the dependent variable. Some studies use grid cells (i.e. 1kmx1km) (Shen and Zhang, 2007), 100mx100m grid (Irwin *et al.*, 2003), or watershed unit (Brody et al., 2006) as a smallest spatial analysis unit. The use of the CCD as a smallest spatial unit of analysis has both advantages and disadvantages. First, the CCD (containing about 230 households) is the finest census data collection unit applied to aggregate household data (for the 2001 and 2006 census) and so the socio-economic factors that can be incorporated in the model. Second, each dwelling or property in the later year (i.e. 2006) can be represented as a spatial point. Thus, the counting of infill development within each CCD is easily conducted. However, as mentioned in Chapter 2, the CCD is an aggregated unit, the boundaries of which are subject to change. In the future (i.e. after Census 2011 is released), analysis can be taken at a mesh block scale, which is about four to five times smaller than a CCD (ABS, 2004). The mesh block is designed to allow scaling to any geography: administrative, political or management (ABS, 2004).

6.3.4.2. Independent variables

Table 6.2 lists the independent variables used in the multivariate regression model: proximity variables, policy and market variables, site characteristics, and socio-demographic variables. The choice of independent variables is derived from results of urban growth and land use change modelling research (e.g. Landis and Zhang, 1998), the history of urban growth and development patterns in the MMA and its current planning policies as discussed in Chapter 3.

Proximity variables: The latest strategic urban consolidation planning policy in the MMA, *Melbourne 2030*, is designed to focus new development on the vicinity of activity centres and the PPTN. Thus it is expected that the closer to the activity centres and railway stations, the more likely it is that infill development will occur. Proximity to major roads or freeways also enable residents to access other services or locations because of higher speed limit and less delay in traffics from traffic lights. In these terms, Table 6.2 lists a number of relevant proximity variables. They are coded as dummy variables. If any CCD intersects within a designated buffer (0 to 800m at each 200m interval) of activity centres, railway stations, or a major education centre (i.e. Monash University), or Monash freeways, it is assigned 1, otherwise 0.

Market variables: The median property sale data between 2000 and 2006 was purchased from the Department of Sustainability and Environment (DSE) (DSE, 2009). They are summarised at suburb level of aggregation. As each CCD falls within a suburb, the median property sale at each CCD was given the value of the suburb within which the CCD centroid falls.

Site variables: The site characteristic variables have also been reported as influencing the probability of land parcel development (Irwin et al., 2003a, Landis and Zhang, 1998a, Shen and Zhang, 2007). The areal weighted mean area (Area_AWM) (Equation 6-9 (Leit˜ao *et al.*, 2006, p.87)) of infill land parcels within each CCD was chosen to indicate land parcel characteristics: a bigger land parcel is much easier to subdivide, thus it has more potential impact on the extent and rate of infill development in each CCD. In addition, it is hypothesised that the ages of the suburban residential area has a positive impact on the infill development potential (Birrell *et al.*, 2005a). In 1997, the City of Monash Urban Character Study identified five residential area character types (A to E) indicating the period in which residential development was developed (City of Monash, 2004) (Figure 6.2 and Table 6.3). The total areas of each urban character class in CCDs (A_AR, B_AR, C_AR, D_AR, and E_AR) were chosen as independent variables for examination of the significance of residential area ages on infill development patterns.

Equation 6-9:

$$\text{AREA\_AWM}=\sum_{j=1}^{n}\left[a_{ij}\left(\frac{a_{ij}}{\sum_{j=1}^{n}a_{ij}}\right)\right]$$

where: AREA_AWM: area weighted mean;
n: number of infill land parcel within each CCD, and
a_{ij} is the area of infill land parcel (ij)

Table 6.2: Definition of explanatory variable used in the Regression Analysis

Category	Variable	Description
Proximity variables	200MACC(FRW,RAIL) 2_400MACCCen(FRW,RAIL) 4_600MACC(FRW,RAIL) 6_800MACC(FRW,RAIL)	Within 200meter (200-400 meter, 400-600 meter or 600-800 meter) of Activity Centre (Freeway, or railway stations) value=0 indicates that CCD is outside 200 meter buffer of Activity Centre (Freeway, or railway stations) otherwise value =1
Market variables	SALES00_06	Median property value change between 2000 and 2006 over 2000 property value
Site variables	Area_AWM (m^2)	Mean weighted area of infill development lots in each CCD
	A_AR, B_AR, C_AR, D_AR, E_AR (m^2)	Total area of estates (A-E) in each CCD
Socio-demographic variable	PopChange00_06	Population change between 2001 and 2006

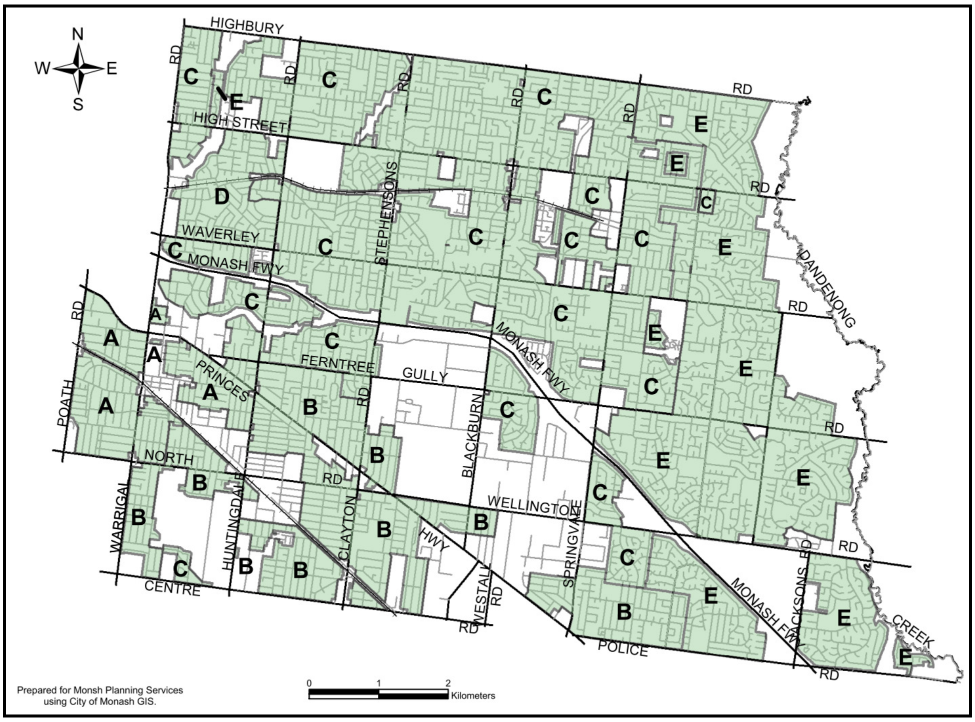


Figure 6.2: Monash City Urban Character (City of Monash, 2004). The neighbourhoods were classified and aggregated into five classes (A to E) based on time passed since original greenfield to suburb land parcel subdivision. Descriptions are presented in Table 6.3

Table 6.3: Monash Urban Character Class (City of Monash, 2004)

Ages of estates	Description
A	Pre WW1 and inter-war development on grid subdivision
B	Oakleigh- Clayton, 1945-165 development
C	Mount Waverley- Glen Waverley Area, 1945-1965 development
D	Jordanville - Chadstone area, public housing of the 1950s-1960s
E	post 1965 Glen Waverley - Wheelers Hill area, characterised by underground cabling, undulating topography and large allotments

Demographic (and sociodemographic) variable: According to Shen and Zhang (2007), the influence of population density on conversion of non-urban land use into urban land use is unclear. While population density can indicate demand for housing, high population density might have a negative correlation with housing development because there will be crowding and lack of open space. In this Chapter, the influence of population growth on the rate and extent of infill development is of interest. The population change variable was defined as the difference between total population between 2006 and 2001. This variable was determined for CCDs that did not change their spatial boundary between 2001 and 2006. Because the spatial boundary changed between census years 2001 and 2006 in 12 CCD out of 241 CCDs in 2001, two regression models were run

- Model 1: independent variable include all listed variables in Table 6.2 except population change variable
- Model 2: independent variables include all listed variables in Table 6.2, for all 229 CCDs

It is important to note that although the chosen set of independent variables does not include some socio economic and environmental factors (employment growth, the quality of schools in the areas, the frequency of the public transport as well as the proximity to the hazardous areas), the key determinants of land use change and urban growth have been included and considered in the models. These other factors would be a much more significant influence on the rate and extent of infill development in the City of Monash if the relative significance of "opportunism" factors (i.e. land parcel size and ages of estates) and urban planning factors (proximity to designated activity centres and railway stations) had not been so important.

6.4. Results

In this section, descriptive summary of infill development by urban character class (Table 6.4) and by buffers (400 meters and 800 meters) of each designated activity centre in the City of Monash (Table 6.5) is presented. It is followed by presentation of results from applying kernel density, univariate and bivariate K-function analysis, to quantify City of Monash patterns of infill development. Finally, the results of regression analysis using ordinary least squares (OLS) in ArcGIS 9.3 (ESRI, 2008, Regression Analysis Basics) are presented and discussed with the intention of elucidating City of Monash infill development patterns in relation to their driving forces (2000 and 2006).

6.4.1. Descriptive analysis

Table 6.4 shows that a high number of infill developments occurred in the urban character classes B and C: 403 and 705 land parcels, respectively. The greenfield to residential conversion of areas occurred between 1945 and 1965 (Table 6.3). In comparison, just more than one hundred infill development sites occurred in the urban character class of A and D. Urban character class E recorded the lowest number of infill development sites.

Table 6.4: Summary of land parcel area of infill development sites by each urban character class

Urban character class	Mean (m^2)	Min (m^2)	Max (m^2)	Median (m^2)	Number of infill development
A	865.06	534.31	6597.43	734.88	106
B	776.87	418.47	3986.39	730.55	403
C	926.55	548.93	17103.24	759.73	705
D	722.62	475.55	1563.54	690.62	108
E	1516.59	642.91	4484.71	1121.47	43
Others					118

Table 6.5: Descriptive summary of infill development within designated activity centres in City of Monash (Phan *et al.*, 2008, p.27)

Activity centres	Count	Min	Max	Sum	Percentage of total infill development 2000–06	Percentage of total Dwelling addition 2000–06
Within a 400m buffer						
Glen Waverley	23	2	25	76	1.55	1.99
Clayton	28	2	6	75	1.89	1.76
Oakleigh	0				0.00	0.00
Mount Waverley	13	2	3	28	0.88	0.56
Brandon Park	5	2	3	12	0.34	0.26
Monash University	0				0.00	0.00
SUM					4.65	4.58
Within a 800m buffer						
Glen Waverley	103	2	25	248	6.95	5.44
Clayton	73	2	6	177	4.92	3.90
Oakleigh	30	2	27	97	2.02	2.52
Mount Waverley	46	2	3	96	3.10	1.88
Brandon Park	10	2	3	23	0.67	0.49
Monash University	39	2	4	100	2.63	2.29
SUM					20.30	16.52

Notes: Summary of infill developments by number of dwellings (count of land parcels sub–divided, minimum, maximum and the sum of newly extant dwellings), percentage of total added dwellings by infill development, and percentage of total infill development within the 400m and 800m buffers around each activity centre.

Table 6.5 shows that infill development is more concentrated around the Glen Waverley Principal Activity Centre (PAC) and the Clayton Major Activity Centre (MAC) than around the other four activity centres. Additionally, infill development around all activity centres only accounts for a small to moderate proportion of all infill development between 2000 and 2006 (4.6% and 16.5%, respectively at 400 and 800 meter buffer).

6.4.2. Kernel Density

Figure 6.3 shows that infill development occurred in a wide geographical range of the City of Monash locations. Clearly, the cell value of kernel density surface depends on the window size. In Figure 6.3, three kernel density maps are presented. Figure 6.3a is kernel density map of window size equals to the average distance of 10 nearest infill development sites. Figure 6.3b is a kernel density map of window size which equals to average distance of 30 nearest infill development sites. Figure 6.3c is a kernel density map of window size which equals to a default setting of window size in ArcGIS 9.2. As indicated in the legend, the pattern of number of dwellings/ha can be represented via a colour ramp. It can be seen from Figure 6.3 that the maximum value of kernel density surface with window size of mean distance of 10 nearest infill dwellings is 53.34 dwellings/ha as compared to that of 16.90 dwellings/ha if window size is determined by the mean distance to 30 nearest infill dwelling developments. The kernel density pattern and maximum density values (around 17 dwellings/ha) in Figure 6.3b is very similar to that which displayed when the default setting in ArcGIS is used. Figure 6.3 reveals that out of all designated activity centres in the City of Monash, Glen Waverley PAC and Clayton MAC were amongst the zones of highest density of infill development between the period 2000 and 2006. In contrast, the kernel density map indicates that very few infill developments occurred around the Brandon Park Major Activity Centre (BPMAC). Dense infill development also occurred around the City boundaries Figure 6.3. Around two railway routes across the City, some dense infill sites have developed, with most of them being near the Glen Waverley PAC and the Clayton MAC.

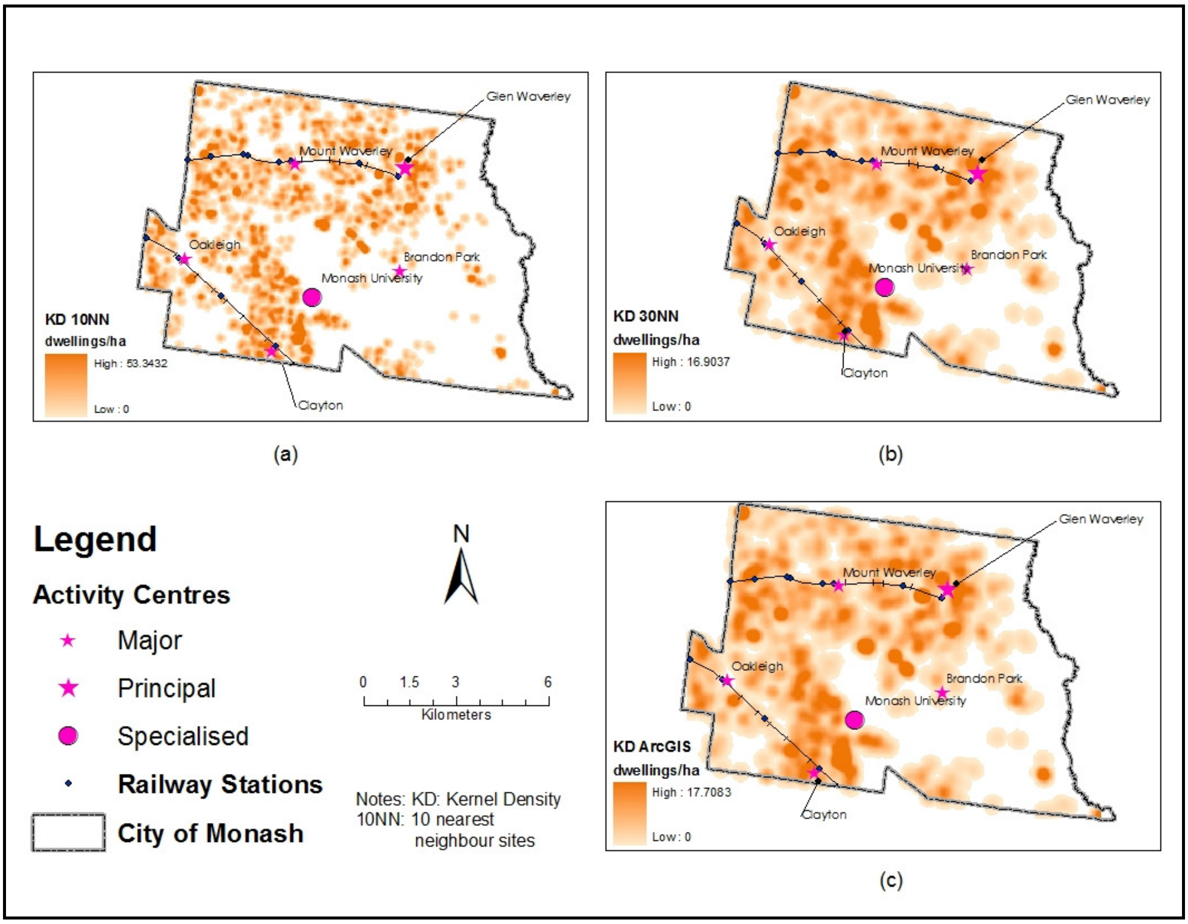


Figure 6.3: Kernel density of Monash City infill development sites (2000-2006). The window size equals to the mean distance of 10(c), and 30(a) nearest neighbour sites, and was assigned by default in ArcGIS (b)

6.4.3. Univariate K-functions

Figure 6.4 shows that the L envelope of random data (999 permutations) is much less concentrated than that for infill sites. This indicates that it is highly unlikely the residential intensification was due to chance. In other words, infill development sites are clustered together.

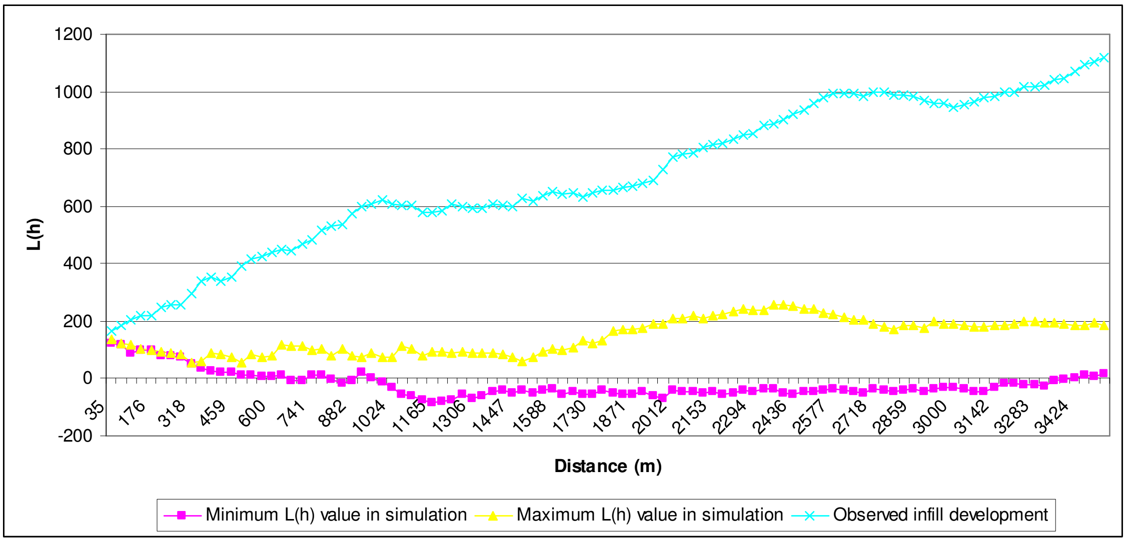


Figure 6.4: Rescaled univariate K function of City of Monash infill development sites (2000-2006), 999 simulation, rectangular edge correction, L is calculated for each of 100 distance intervals, L(h)=sqrt[K(h)/pi]-h (Equation 6-4).

6.4.4. Bivariate K-functions

The observed line (solid line) is within the 95% confidence interval bounds (dash lines) (Figure 6.5), meaning the events have no significant deviation from being random in pattern with respect to the random shift and simulations. The result of a bivariate K-function application shows no clustering of infill development around activity centres at a short distance. However, and as Figure 6.6 indicates that there was clustering between residential infill development and railway stations between 600m and 700m of railway stations in the City of Monash (2000 and 2006).

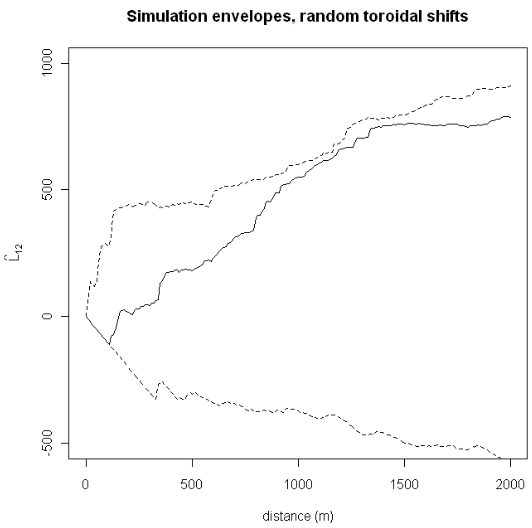


Figure 6.5: Rescaled bivariate K-functions (L) of infill development sites and designated activity centres

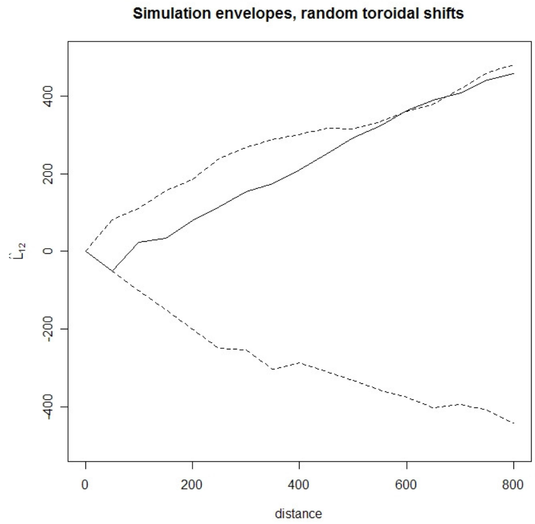
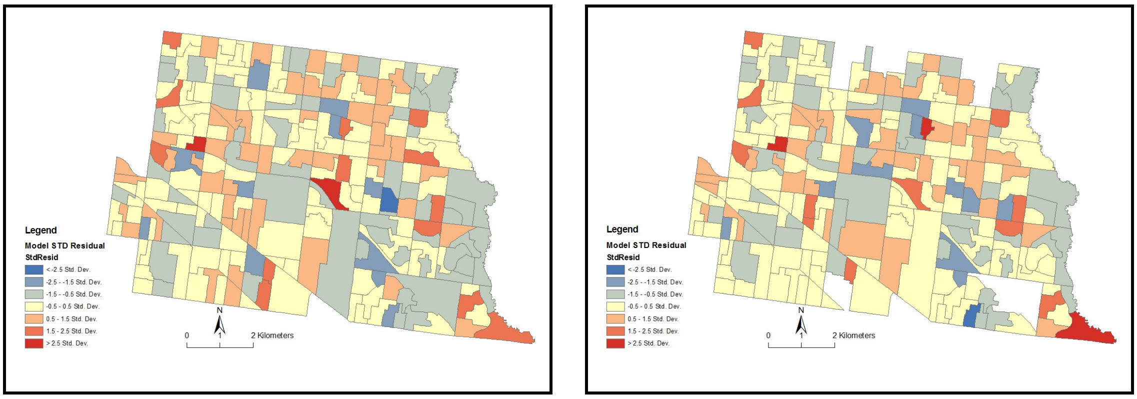


Figure 6.6: Rescaled bivariate K-functions (L) of infill development sites and railway stations

Notes: Upper and lower confidence intervals are in broken lines and estimated bivariate K-function is in solid line

6.4.5. Multivariate Regression Analysis

Table 6.6 shows the results of applying OLS regression for City of Monash infill development data. Results include model performance R squared values, and four statistics tests, which are used to check whether the model meets the OLS model assumptions. The Koenker (BP) statistic is significant (p-value <0.05). The global Moran Index is -0.016 (p-value =0.749) at the search threshold of 862.764 meters (model 1) and 0.019 (p-value equals 0.502) at the search threshold of 1000 meters (model 2). These results altogether indicate that the model residuals are not spatially autocorrelated (ESRI, 2008, Regression Analysis Basics). The selected independent variables explain the moderate significance of infill development (adjusted R squared equals to 0.49 in model 1 and that in model 2 is 0.55). Figure 6.7 shows the standard deviation of model residual by CCD. The red areas are model over-predicted while the blue areas are under-predicted (ESRI, 2008). The only a few CCDs with blue colours (1 CCD in model 1, 2 CCDs in model 2) or red (1 CCD in model 1 and 2 CCDs in model 2) in Figure 6.7 indicate that using selected independent variables, both model and model 2 predict well the number of infill development sites by CCD.



(a) Model 1 (b) Model 2

Figure 6.7: Standard deviation of model residual by CCD. CCDs in red are over-predicted with regards to the number of infill developments. In contrast, CCDs in blue are under-predicted with regards to the number of infill developments. The analysis was undertaken using set of independent variables listed in Table 6.2

To check the multicollinearity[20] of independent variables in a regression model, a variant inflator factor (VIF) is used. As seen in Table 6.6, the VIF of all independent variables are all smaller than 7.5, suggesting that there is little sign of multicollinearity of predictor variables in the model (Rogerson, 2001, ESRI, 2008). The Jarque-Bera Statistic tests in both models are not statistically significant, suggesting that the model residuals are of normal distribution. To sum up, the transformation of the dependent variable meets all assumptions of regression analysis. The transformation also increases the model performance (R squared and adjusted R squared values). The expected signs of independent variables are also revealed.

Regression analysis results show that proximity variables are not the most important factors in driving the degree of infill development. Except for 6_800MACC variable in model 1, none of the four buffer variables (activity centres and freeway) are not statistically important determinants of the location of infill development in the City of Monash between the period 2000 and 2006. Results also show that the number of infill development within each CCD negatively correlates with the buffer variables around activity centres; however it was only found statistically significant within 600 to 800m of activity centres (in model 1). Zones within 400 meters of Monash University, and 600 to 800 meters of railway stations are found to be statistically positively significant with the number of new infill developments in each CCD. The number of infill

[20] One of the assumption of multiple regression model is there is no multicollinearity among the explanatory variables, meaning that the correlation among the explanatory variables should not be high ROGERSON, P. A. (2001) *Statistical Methods for Geography*, London, Sage..

developments in each CCD is found to be more positively influenced at 600-800 meters of railway stations than for the three other closer ring buffers as indicated by its higher coefficient value than those in other proximity to railway stations.

Table 6.6: Ordinary least squares (OLS) regression estimates for infill development in City of Monash, 2000-2006[1]

	Model 1		Model 2	
Variable	Coefficient	VIF	Coefficient	VIF
Intercept	-2.571281*	--------	0.440218	--------
AREA_AWM	0.000058*	1.061876	0.000044*	1.108477
200MFRWY	0.190855	1.459996	0.043678	1.713402
2_400MFRWY	0.138886	1.232123	0.126516	1.337525
4_600MFRWY	-0.307475	1.164440	-0.232789	1.273867
6_800MFRWY	-0.164388	1.113928	-0.240532	1.132425
0_400MMU	0.859530*	1.345069	0.892038*	1.373620
4_800MMU	0.178509	1.222242	0.248568	1.199364
0_200MRAIL	0.527258*	2.002363	0.346486	2.033525
2_400MRAIL	0.639670*	1.748625	0.438500	1.781353
4_600MRAIL	0.571042*	1.227201	0.334433	1.249503
6_800MRAIL	0.797994*	1.337593	0.647138*	1.393538
0_200MACC	-0.048136	1.595950	-0.015888	1.561445
2_400MACC	-0.252505	1.331704	-0.171216	1.359160
4_600MACC	0.222182	1.210503	0.014187	1.250717
6_800MACC	-0.372055*	1.341939	-0.238352	1.384673
A_AR	0.000004*	2.047827	0.000006*	1.967608
B_AR	0.000008*	2.889331	0.000007*	3.016465
C_AR	0.000004*	3.109615	0.000004*	2.897485
D_AR	0.000007*	1.672401	0.000006*	1.713414
E_AR	0.000000	2.382982	0.000001	2.289349
SALES00_06	0.000016*	2.367031	0.000001	2.226989
PopChange00_06			0.005969*	1.264599
Number of Observations	241		229	
Degrees of Freedom	219		206	
Akaike's Information Criterion (AIC)	625.74		561.62	
R squared	0.541364		0.598364	
Adjusted R squared	0.497386		0.555471	
F-statistic	12.309674*		13.950100*	
Wald Statistic	321.642889*		439.022541*	
Koenker (BP) statistic	52.732851*		36.803025*	
Jarque-Bera statistic	4.502379		4.239011	

* Statistically significant at the 0.05 level.
VIF: Variance Inflation Factor

The property sale price change (2000 and 2006) (SALE00_06) variable has positive coefficient status in the two models, and is statistically significant (p<0.05) only in model 1 (see Table 6.6). Site variables (the ages of land development estates) in the model have less of an influence on infill development (indicated by their lower coefficients) compared with their status according to the market variable (model 1) and the proximity variables. However, almost of all site variables are statistically significant (p<0.05). The ages of land development estates (time since greenfield to suburb conversion) (A, B, C, and D) are all positively statistically significant ($p<0.05$) in relation to the number of infill developments in each CCD. The higher standardised coefficient value of class B neighbourhood (Figure 6.2) correlates with time since greenfield residential development. In addition, the average weighted area of land parcel in each CCD was also found to be significant, which indicates that land parcel area influences the appeal to (re)developers of potential infill development sites. In terms of socioeconomic and demographic variables, the population change variable is positively associated with a significantly greater number of infill developments ($p<0.05$) (model 2).

6.5. Discussions

This Chapter has demonstrated that the applications of various spatial statistical techniques to spatial patterns of infill development reveal factors influencing residential urban form change. The utility of these analytical approaches to exploring infill development patterns and driving factors is discussed as follows.

6.5.1. Spatial patterns of infill development

First, the kernel density K-function analysis allows visualisation of the intensity of City of Monash infill development. Secondly, the application of the univariate K-function shows that infill development/residential intensification sites are significantly spatially clustered. This is consistent with economic theory of urban development, in which the cluster of residential development patterns is perceived as the way to take advantage of existing infrastructures or concentrate population enough to justify essential infrastructure and services improvement (Irwin *et al.*, 2003). In the future, application of univariate K-function conducted for different temporal periods can provide a comparison of the spatial pattern of infill development over time. In essence, the spatial dependence of infill development over time can be compared in terms of how much they deviate from "random" patterns and at which distance the spatial cluster occurs. Thirdly, the results of deploying the bivariate K-function technique show that 2000-2006 City of Monash infill development sites are not significantly statistically clustered around designated activity centres, but they are significantly statistically clustered within the distance of 600 to 700m to railway stations. This information provides insight not only about the spatial location of infill development sites, but also their relative distribution compared with other public infrastructure and services, i.e. designated activity centres (in planning policy) and railway stations. This result also implies that infill development (by 2006) had not yet located within designated activity centres as the strategic urban planning policy *Melbourne 2030* was designed to promote.

Results of kernel density and bivariate K-functions analysis show that there has been a low level of infill development around activity centres (2000-2006). These results support previous studies using descriptive summaries of the number of infill developments within the 400 and 800 metre buffers of designated activity centres (Phan *et al.*, 2008). Such a low proportion of infill development around activity centres might be attributed to the incomplete nature of implementation of structural plans for MACs. Currently, major components of activity centres are retail shops, restaurants and service functions with some of them, for instance the BPMAC, offering bus transit, and others (Clayton or Glen Waverley) offering both railway and bus transit (Yamashita *et al.*, 2006). There are more residential re-development clusters within 600 and 700 metre of railway stations as opposed to designated activity centres. This is in accord with dominance in the pattern of eminently redevelopable 1960s "quarter-acre-block" residential developments (City of Monash, 2009). Birrell *et al.* (2005b) named this pattern of infill as "*opportunistic*" infill development. Such (re)development has also been reported in the United States (Landis *et al.*, 2005), in which the probability that land parcels will be (re)developed is more likely to have been influenced by economic value of return on property investment rather than by the planning policy outcomes. By using regression analysis, the "opportunistic" infill development hypothesis was explained and better understood.

6.5.2. Contributing factors of infill development

To enhance the contribution derivable by analysis of geographical, planning and socioeconomic parameters on the spatial distribution and intensification of infill development sites, deployment of the regression analysis model was undertaken to confirm that proximity to designated activity centres (ranging from 0 to 800 meter at 200 meter interval) is not statistically significant as an independent variable in accounting for the 2000-2006 infill development pattern. However, the urban character variables (the total areas of residential land classified as A, B, C and D), and the 600 to 800 meter railway station buffer zone and the zone within 400 meters buffer around Monash University, are found, along with land parcel area, to be positively statistically significant with dwelling yield. These results indicate that land parcel characteristics, especially land parcel size and time since greenfield residential development influence the number of infill developments in each CCD. This also indicates that the implementation of compact city policy to 2006 has yet to be seen to direct infill development around public transport network (e.g. railway stations) or designated activity centres.

6.6. Conclusion

Spatial statistics and spatial modelling can assist decision makers to better understand the spatial patterns of infill development, and to examine the factors determining the nature of its evolving spatial patterns. Point-based spatial statistics techniques, such as kernel density estimation, univariate and bivariate K-functions allow visualisation and quantification of the spatial patterns of infill development in the period 2000-2006. Spatial modelling techniques, such as multivariate regression, facilitate integration of different social economic and geographical variables in a model so that their relative influence on the number of infill developments in each CCD may be derived. Empirical findings from the regression model show that there are several factors that influenced residential infill development or residential intensification. In the City of Monash, between 2000 and 2006, land parcel size and the time since greenfield residential development, together with particular proximity to railway stations (600 to 800 metre buffer) were found to be important determinants of the patterns of infill development. Proximity to freeway and activity centres (within 800 meter buffer) was not significant factors on infill development. This study herewith is conducted for a particular suburban LGA in the MMA; however it is certain to apply to other LGAs in the MMA due to the availability and consistent format of spatial datasets held under the Victorian Spatial Data Infrastructure policy and the ABS data collection protocols.

7. CHAPTER 7: CONCLUSION

7.1. Introduction

This concluding chapter begins by outlining the study contribution to the wider body of related scientific knowledge. It is followed by a section describing main conclusions in terms of the study aims and objectives. The significance and implications of the findings are also discussed. The final section of this chapter makes suggestions for future work.

7.2. Advances presented in this study

This study contributes to both the conceptual and technical aspects of urban planning, monitoring, and evaluation with special reference to the current strategic urban consolidation planning policy *Melbourne 2030*. In particular, it contributes in:

Conceptual terms:

- Providing a framework for spatial data integration in mapping residential intensification so that stakeholders can share data (that they should be in any case maintaining), in ways that ensure that decision support need no longer be reliant only on analysis of aggregated data.

and ***Technical terms***:

- Demonstrating an detail-intensive integrated approach to mapping changes in urban residential form due to on-going urban consolidation
- Demonstrating how, after relevant data quality testing, current data archives can be deployed via data integration such that decision support systems in use today can be improved enough to be used in monitoring urban form change at land parcel scale (as presented in Chapter 4)
- Demonstrating the capacity of this detailed approach to provide quantitative information about the relative significance of the various residential urban form types that arise from those differences in age and distance from the Central Business District that can be found across the MMA (as presented in Chapter 5)
- Exemplifying the utility of spatial data integration for supporting multiple approaches to describing and quantifying urban consolidation. Thus new approaches to monitoring not only widen the range of queries for which decision makers can expect answers, but also offer solace to decision

makers wary of using the results of hitherto traditional (aggregated) analyses. Models using these latter are inherently unable to support queries referring to the main management (decision-making) unit: the land parcel. The hitherto dominant models built with aggregated data and descriptive analysis of urban consolidation can now replaced by detailed models, to which all stakeholders can relate and the decision support systems can deploy.

7.3. Achievement of aim and objectives

This study aims **to explore relationships between urban consolidation theory, policy, and practice of the compact city using the MMA as a case in point**. Outcomes were designed to be useful for urban study scholars, urban planners and policy makers and advisors seeking to understand and monitor the progress of urban consolidation implementation. Clear implications emerge from pursuit of this aim, the success of which is best assessed in terms of the study objectives. Some of the implications refer to scope for decision support up-grade and some to scope for future work.

Objective One: *To develop a GIS-based land parcel framework for automatic and systematic identification of residential intensification that can be applied for all local government areas (LGAs) in the MMA, which will produce outputs that can be used further for quantifying spatial patterns and spatial modelling.*

In reference to the concept of urban consolidation as applied in the MMA, and the spatial resolution offered by previous studies, this objective was achieved. It is now not only theoretically possible to offer the implementers of *Melbourne* 2030, decision support at a far more detailed spatial resolution than hitherto, but also demonstrably feasible. As shown in Chapter 4, spatial datasets from both local government areas and state government data archives can now be assembled for the necessary data integration. Key vector datasets include cadastre and address points. Together, these provide the spatial extent and spatial location of each dwelling. Data cleaning was shown to be essential in the context of Victorian spatial data flows. This ostensibly expensive barrier to implementing the detailed geography was overcome by automation via macro-programming embedded in GIS softwares. Spatial query and analysis facilitated by the same software allows change detection: identifying dwelling spaces in the previous year improved by an increase in dwelling numbers in a later year. Method validation was conducted by on-screen comparison with aerial images acquired for the most-close-to date to that of the relevant vector datasets. The framework developed in this objective is tested and exemplified in four LGAs, representing different geographical regions: in the middle suburbs and fringe regions of the MMA (Phan *et al.*, 2008, Phan *et al.*, 2009a, Phan *et al.*, 2009b). Since the datasets have become available and accessible from LGA offices and with the availability of GIS softwares in-house in many Victorian urban planning offices, it is now possible to implement this method for other LGAs. Similarly, the approach can be applied to other metropolitan areas with the same spatial data availability and attributes.

This study demonstrates a unique approach for mapping urban infill development in the Australian spatial data and policy context. It used an existing spatial dataset: address point data as an indicator of dwelling presence, whereas two previous studies in Australia used the aspatial attributes attached to development applications (e.g. Holloway and Bunker, 2003) or attributes attached to building permits (e.g. Buxton and Tieman, 2004) to identify the presence of dwelling or building development. In contrast, the mapping approach pioneered in this study complements the current DPCD monitoring attempt in urban development program (UDP) monitoring. When integrated with UDP outputs, data integration supports the generation of a closer settlement style indicator determination suitable for *Melbourne 2030* policy implementation monitoring and evaluation (as demonstrated in Chapter 5).

Objective Two: *To evaluate the conformity of development patterns to state planning policy (Melbourne 2030) objectives regarding development vis-à-vis activity centres and liveability measures*

This was achieved by developing the closer settlement style geography (in Chapter 5) to describe and compare the contribution of different development types of residential intensification or urban consolidation in different LGAs. First, an approach was designed which utilizes GIS and outputs from Objective One to describe quantitatively the contribution of each of three different development types (the closer settlement style indicator) as mentioned in *Melbourne 2030*. This first attempt to clearly show how to derive spatially detailed housing indicators represents a demonstrably useful addition to monitoring tools. Derivation of information is at land parcel scale as opposed to previous approaches (e.g. DPCD, 2007, Buxton and Tieman, 2004), which are characterised by spatial aggregation to Census Collection Districts (CCDs), suburbs or LGAs. The use of the land parcel as the smallest spatial unit of analysis allows scalable aggregation for generation of LGA geographies, while at all times greater detail can be called for to test to the extent to which any aggregation hides significant geographical variation.

Although the proposed approach was only exemplified for four selected LGAs, their geographical variation both in terms of the distance from/to the Central Business District (CBD), and the ages of successive urbanisation development demonstrates its strength and applicability. Therefore, the approach can be applied to the remaining 27 LGAs in the MMA. Thus, the practice of housing policy implementation in *Melbourne 2030* can be compared with plan outcomes. Compliance-based plan evaluation for the whole MMA can be undertaken.

Additionally, the closer settlement style indicator can enhance the understanding of variation in housing policy implementation amongst LGAs. As presented in Chapter 5, residential intensification varied spatially LGA by LGA. In a typically long-standing suburb (City of Monash), on sites that were greenfield four to five decades ago, dispersed infill development accounted for the majority (60%), of the new dwellings (followed by strategic development: 40%). In contrast, in the fringe cities (Whittlesea and Casey), greenfield development accounted for the biggest proportion of new dwellings: just above 68%. In the City of Casey, strategic development was of moderate proportion (26.2%) and dispersed infill development made the smallest (5.43%) contribution during the time period under study. The contribution of these two development types in the City of Whittlesea was the other way around, with dispersed infill development accounting for 22% compared with a strategic development contribution of 9.85% (Phan *et al.*, 2009b).

Accessibility analysis tools were applied to closer settlement, style by style, to derive measures of proximity to public hospitals and schools. In Chapter 5, the accessibility indicator was demonstrated for two services, schools and public hospitals, using both Euclidean and road network distance. Similar approaches can be applied for other services as long as their databases have been collated and made available. Adoption of such a measure provides a quantitative approach for comparing the accessibility of different development type areas to public services. Accordingly, the particular social amenity and liveability measures referring to residents living in these development types can be derived and compared. Results in Chapter 5 show that, on average, residents in greenfield development areas are further away from public hospitals and schools than are those in areas of dispersed or strategic (re)development areas.

The utility of urban form metrics (dwelling density, proportion of cul-de-sacs, proportion of impervious surface area, dwelling development types, and favourable journey-to work-criteria to work) was explored in development tract (DT) analysis. In terms of the geographical variability referred to in the previous paragraph, four typical development tracts, one in each of in four LGAs, were selected for exemplification. It was found that urban form characteristics varied between each development tract type. Especially, it is highlighted that dwelling density in the greenfields was under 15 dwellings/ha. Clearly promotion of the other closer settlement styles is more compatible with the spirit and purpose of the *Melbourne 2030* policy.

These results will have implications for further work in a number of fields. First, the derivation and application of the closer settlement style indicator will benefit both local and state urban planners in their efforts to understand, at a given time, the status of urban consolidation implementation. Thus monitoring and evaluation of residential urban form and related land-use planning matters can be better supported. For instance, update or amendment of the planning policy and estimation of the capacity of each LGA in supplying housing for the growing MMA population can become better informed than hitherto. Secondly, in terms of site suitability analysis and impact assessment, accessibility indicators can be used to bring detail to planning for the deployment of new public services, especially within the fringe cities. For example, it can be used to examine the suitability of proposed sites for development area installation of new services, such as schools or bus stops in the greenfield development areas. Comparison of accessibility indicators before and after the establishment of new service locations will reveal if any changes or improvement(s) may/have occur(ed). Thus, decision makers can be assisted in choosing the suitable locations during new service development. Therefore, the indicator-based evaluation approach as demonstrated in

Chapter 5 adds rigor to research in implementation evaluation, particularly with the context of *Melbourne 2030*.

Objective Three: *To explore and examine the drivers of urban form changes: infill development using spatial statistics and spatial modelling*

The spatial patterns and process of infill development were examined in detail using a case study in a suburban LGA, the City of Monash (in Chapter 6). It was conducted by using GIS for data manipulation and output presentation after deployment of spatial statistics. The statistical software tools (*Crimestat 3.1* and R) used in this study have been well accepted and freely accessible and so, now that the existence of the necessary data streams has been proven, can be taken into routine analysis by decision support teams in LGAs or by consultants. Using spatial statistics, spatial patterns of infill development were initially visualised and then spatially quantified. This is the first study in Australia incorporating spatial statistics (specifically, the point-based spatial statistics approach) as a specific application to urban infill development studies. It was found that infill development patterns were clustered together. Relative proximities of infill developments to designated activity centres and railway stations were also examined. Infill development was found to be clustered within 600 and 700 meter of railway stations in a statistically significant way but no statistically significant clustering (at the given radii) around designated activity centres was found. Such information is useful for urban studies scholars in understanding the process of infill development, and for urban planners intent on reviewing the merits of such infill development as has occurred *vis a vis* the policy preference for development within activity centres and near principal public transport networks (PPTN). The mapping approaches demonstrated in this study could be deployed in any review about the implementation of urban consolidation policy, LGA by LGA.

A regression model was developed for application to CCD geography to examine the influence of socio-economic, geographical and planning policy variables on spatial location and extent of infill development. The analysis was conducted using tools in

ArcGIS 9.3[21] (ESRI, 2008). Results showed that land parcel sizes and the age of land development estates (time since land parcel subdivision of greenfields) have a statistically significant relationship with the number of infill developments in the CCD. This finding supports a previous observation by Birrell *et al.* (2005a). Also, the relationship of population change with residential urban form change by infill development was positively statistically significant. However, proximity variables for railway stations and Monash University only showed partial influence on infill development whilst proximity measures to designated activity centres and freeways did not suggest significant influence of these variables on the infill development pattern. This information suggests that mechanisms other than those at present governing residential urban (re)development permit application appraisal might be needed to promote infill development within designated proximity to activity centres and railway stations.

7.4. Suggestion for effective implementation of Melbourne 2030

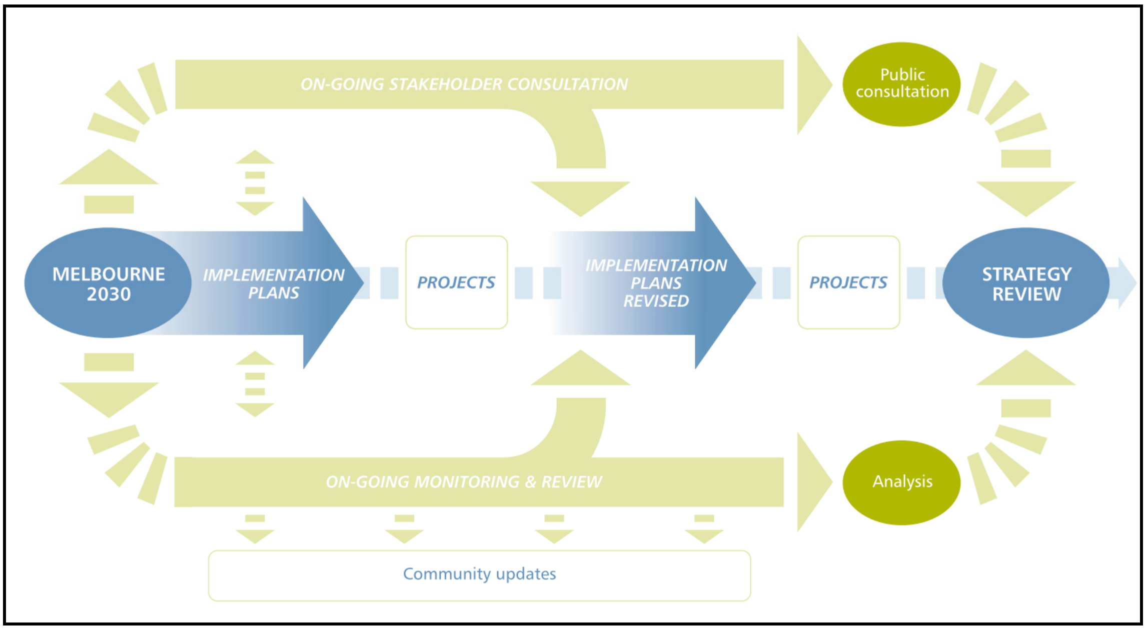


Figure 7.1: Process for implementation, monitoring and review of Melbourne 2030 (DoI, 2002c, p.170)

Melbourne 2030 provides a summary of a process for its implementing, monitoring and review as presented in Figure 7.1. The Government will work with local government,

[21] Alternatively, it can be conducted in freely downloadable softwares such as Geoda 0.9.5-i5 ANSELIN, L. & THE REGENTS OF THE UNIVERSITY OF ILINOIS (2004) Geoda 0.9.5-i5.. However the test of regression model assumptions is not integrated in Geoda 0.9.5-i5

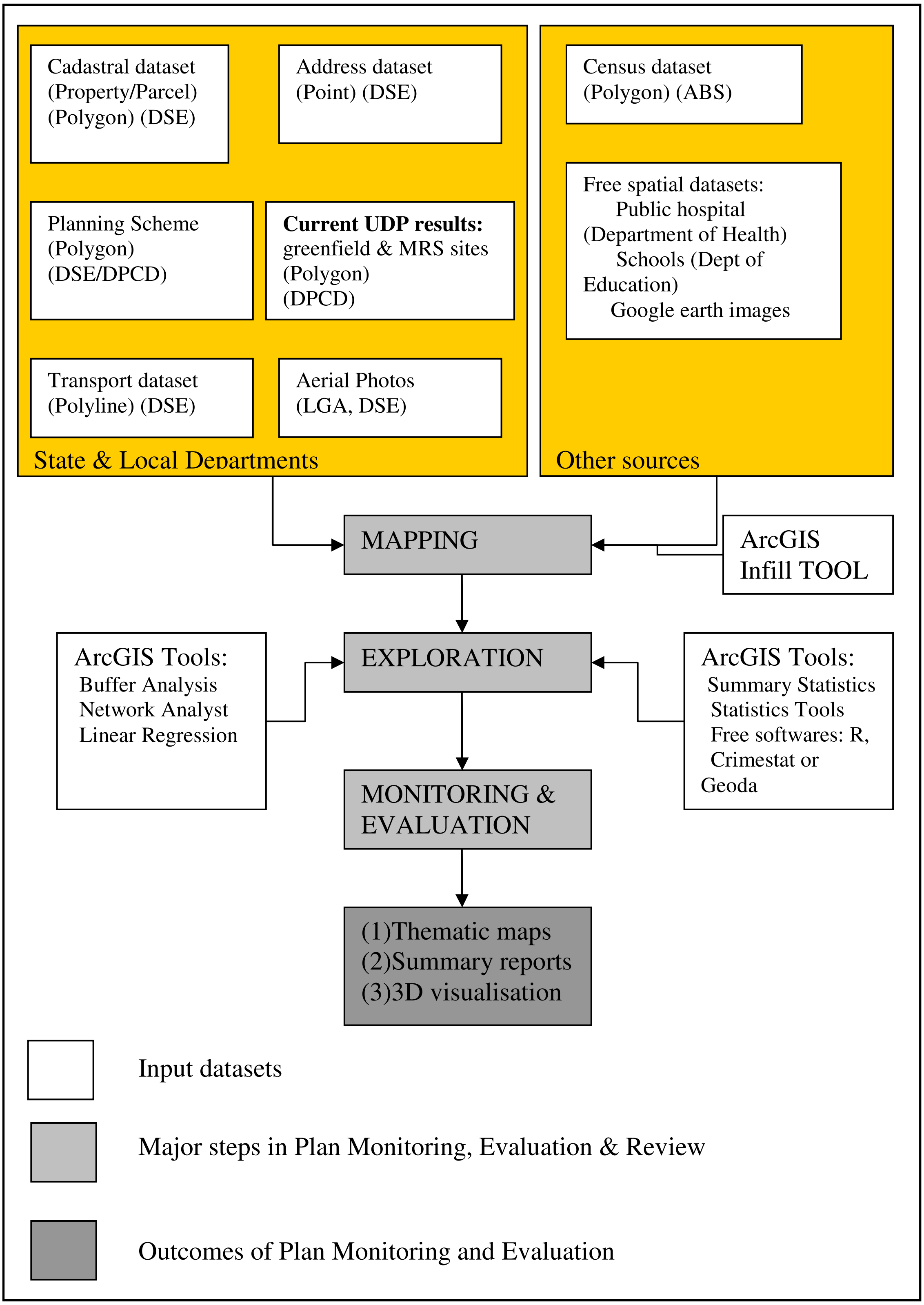


Figure 7.2: Detailed process flow path suggested to support monitoring and evaluation of urban compact city policy *Melbourne 2030*

the private sector organisations and other key stakeholders in plan monitoring and review (DoI, 2002c). An assumption behind the diagram is that stakeholders and decision makers can have access to information derived from monitoring residential urban form change. The overall process flow path to support monitoring and evaluation of urban compact city policy implementation *Melbourne 2030* as identified in this study is presented in Figure 7.2. As can be seen from Figure 7.2, the process features three major steps: (1) data collection, (2) data analysis, and (3) outcome presentation. Urban planning professionals consider these steps as crucial components of plan evaluation (Oliveira and Pinho, 2009). By integrating results from the current urban development program (UDP) (by DPCD), Figure 7.2 also indicates that the proposed flow path complements to current plan monitoring program.

Data collection is acquired from different agencies and departments, and so a commitment in data sharing is mandatory if this data and information flow path is to be deployed. Data analysis, as presented in the study Chapters 4 to 6 includes mapping, objective plan policy monitoring as well as exploration of driving factors accounting for observed development patterns. A spatial data handling approach to *Melbourne 2030* monitoring and evaluation in terms of housing development as presented in this study and its potential in supporting current planning decision support in Victoria is demonstrated. The implied improvement on current plan monitoring and review can be achieved if new process flow paths compatible conceptually with that shown in Figure 7.2 can be adopted. Although the data flows refer to dispersed databases, and other data gaps or access problems (typical of those noted elsewhere, see Talen (1998)) it has been shown that in the Victorian context, these constraints can be overcome. The way is open for building consensus around adoption of this data process flow path for MMA urban form pattern change monitoring.

7.5. Suggestions for future work

This section discusses some of the implications of the study in terms of further opportunities for research into the relationship between urban consolidation theory and practice.

Accounting for temporal scale patterns

This study examined residential intensification over a six-year period (between 2000 and 2006). It refers to the latest datasets available when the project was formulated in early 2007. Using methods pioneered in this research, future study can incorporate data covering a longer time period. Thus, the spatial location of residential intensification in the post-implementation stage of urban planning policy *Melbourne 2030* can be continually monitored, analysed and understood using data and information flow paths like those shown in Figure 4.7. For a postscript to the 2000-2006 study of Monash City, refer to section 4.8.1.

Accounting for a larger sample of development tracts and incorporation of other variables

Only four development tracts within development sites (representing brownfield and greenfield sites) were studied in detail during the attempt to augment the study of urban form changes and variation. Future work should cover a larger number of development tracts and possibly incorporate behavioural variables, such as modes of transportation or travelling times as well as energy consumption measures. Thus correlations between different urban forms and car-dependence and energy consumption might be better elucidated. Again, the new approach refers to mapping with greater detail than has been seen before among the decision support systems for *Melbourne 2030* evaluation and monitoring

Accounting for different housing types

This study classified residential intensification patterns in relation to public services, in middle MMA and outer growth areas. Future study might record the housing type attributes associated with each land parcel: single houses, semi-attached and/or multiple storey townhouses and units (as in case studies from Sydney by Holloway and Bunker, 2003) so that the contribution of each building type on residential intensification can be understood and compared, LGA by LGA.

Further exploration of the regression analysis methodology

This study examined the influence of different socio-economic and geographical variables on infill development at the CCD scale. Future study might be conducted at the land parcel scale provided that median property appraisal value and land development estate age data can be accessed at this scale. For example, ABS: mesh-block data is due for release in 2011. Studies in New Zealand show the potential benefits of incorporating mesh-block data among socio-economic datasets used in urban consolidation studies (Ghosh *et al.*, 2007).

7.6. Concluding comments

The results of this study can be deployed in urban consolidation monitoring and evaluation of urban form in the MMA. These results have local, state, and national significance and contribute to urban compact city research at the international level. The techniques applied, including GIS-based mapping, spatial analysis of residential intensification, statistical analysis of infill development and deployment of a spatial regression model were found to be feasible and practical for deployment in MMA urban residential urban form monitoring, and can be applied to future studies in any metropolitan area with similar data archives and data maintenance procedures. Such a successful data integration approach calls upon the necessary data access and collaboration inherent in decision support that calls on data from many sources. Adoption is more likely if the benefit from application of the decision support up-grade tools and methods of interpretation offered herewith can be shown to advantage all stakeholders like LGA representatives, community associations, and state government authorities. Accordingly exemplification is called for not only of the techniques but also of the successes in establishing the necessary data sharing and in exhibition of results via 2D and 3D visualisation for stakeholders.

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9. APPENDIX

The author’s peer-reviewed publications are inserted in this section. They are presented in the format of published journals and conference proceedings.