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Methods and Considerations for Determining Urban Growth Boundaries—an Evaluation of the Cape Town Experience

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Abstract Urban growth boundaries (UGBs) or “urban edges” as they are known in South Africa have been widely implemented by cities internationally with the intention of curbing urban sprawl. However, technical complexities and high levels of contestation frequently present challenges for their implementation. In particular, it is important to ensure that their demarcation includes appropriate land reserves to accommodate urban growth. Drawing the boundary too tightly can stifle economic growth and lead to land price increases, while including too much land within the UGB may result in unchecked urban sprawl and its associated environmental, social and financial costs. The aims of this paper are firstly to review international and local literature with reference to the merits and appropriateness of UGB policies and secondly to consider methods used by cities internationally to determine UGBs and describe the method used by the City of Cape Town to review its UGB in 2010. The Cape Town method evaluates land reserves against urban growth forecasts and is consistent with methods generally used by US cities. However, a number of adaptations for local and rapidly urbanising third world environments are outlined. The Cape Town method is evaluated with reference to the literature and lessons learnt are discussed. Key findings include the value of rigorous, defensible methods and clear policy guidelines in a contested environment, the value of integrating UGB reviews within broader land-use planning processes, the usefulness of information generated for broader urban planning processes and the utility of accurate information on past trends in moderating growth expectations.

Keywords Urban growth boundary · Urban edge · Cape Town · Growth management · Smart growth · Land use planning

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Introduction

Urban growth boundaries (UGBs) or "urban edges" as they are known in South Africa are planning mechanisms now commonly used in many countries to curb urban sprawl. An often overlooked consideration is that their administration presents challenges for local authorities. In particular, it is difficult to determine how much land should be included within the UGB to accommodate future urban growth and their demarcation and periodic review is technically complex and frequently highly contested (Brueckner 2001; Buxton and Taylor 2011; Knaap and Hopkins 2001). However, little is published on the ways in which cities have determined UGBs or the methods used to determine land reserves. The limited literature on this subject is largely restricted to developed counties.

The aim of this paper is two-fold. It firstly reviews the international and local literature on UGBs and, secondly, describes and evaluates the method used by the City of Cape Town (CoCT) to review its UGB in 2010. This paper focuses on quantitative considerations for determining UGBs and deliberations on the actual geographical demarcation of UGBs fall outside of the scope of the paper. The rest of this paper is structured as follows: "What Are UGBs?" section defines UGBs and their purpose, "Origins of and use of UGBs International" and "UGBs in South Africa" sections provide background on the adoption of UGBs internationally and in South Africa, and "Debates about Benefits and Drawbacks of UGBs in the Literature" section considers key debates in the literature regarding the merits of UGBs. The second part of the paper deals specifically with methodology for determining UGBs. "How Are They Demarcated and Adjusted over Time to Accommodate Urban Growth?" section reviews the literature for guidelines and methods for determining UGBs while "Context of the Cape town UGB," "The Method Used by Cape Town," and "Cape Town Results" sections outline the context, method used, and results of the 2010 Cape Town UGB review. The final section evaluates the Cape Town method in the context of the literature and discusses key considerations and challenges.

What Are UGBs?

UGBs are land-use policy mechanisms used by local authorities with the intention to contain or direct urban growth in order to protect non-urban areas and promote more compact and contiguous urban development. They involve the demarcation of a boundary around urban areas, beyond which urban land-uses are generally not permitted—thus directing development towards existing urban areas and limiting the total amount of greenfield land available for development (APA 2002; Dawkins and Nelson 2002).

They are generally implemented within a suite of "growth management" tools, aimed at improving the quality and environmental sustainability of urban areas, and are thus seldom implemented in isolation. Nevertheless, a wide range of objectives have been pinned on UGBs. For instance, they have been used to protect agricultural areas and stabilise agricultural land prices; protect environmental and heritage resources; encourage densification, infill development and a more continuous pattern of urban development; reduce travel distances and promote the use of public transport;

and encourage the efficient use of bulk infrastructure (APA 2002; CoCT 2012; Knaap and Hopkins 2001).

Origins of and Use of UGBs International

The concept can be traced back to Green Belts policies in the UK, first appearing in Ebenezer Howard's garden city scheme of the 1898 as well as influential plans such as Abercrombie's Greater London Plan 1944 (Thomas 1963). Early use of UBG-like policies has also been documented in Japan (Han et al. 2009).

However, UGBs have been popularised in recent years through the widespread acceptance of the "compact city" doctrine and the "new urbanism" movement that emerged in North America in the 1990s, largely in response to urban sprawl (Knaap and Hopkins 2001; Weitz 1999). The US state of Oregon played a leading role, passing legislation in 1973 requiring all cities to demarcate a growth boundary and set aside land for future growth. Other states including California, Maryland and Florida soon followed, although UGBs in these states were non-mandatory and local authorities were given considerable flexibility in their design. Consequently, a range of UGBs or related policies such as "Urban Development Areas" or "Priority Funding Areas" have been implemented in the USA. Today, there is widespread use of UGBs by US cities and UGBs enjoy the backing of key institutions such as the US Environmental Protection Agency and American Planning Association (APA 2002, 2009; Dawkins and Nelson 2002; Knaap and Hopkins 2001).

UGBs have also become popular in many other countries including developing countries. China recently passed legislation which makes "Urban Construction Areas", a similar concept to UGBs, mandatory for all cities (Long et al. 2013). In Saudi Arabia, national-level government oversaw the implementation of UGBs for 100 settlements in the 1980s (Al-Hathloul and Mughal 2004; Mubarak 2004). Other countries that have implemented UGBs include Australia (Buxton and Taylor 2011), New Zealand (Cadieux 2008) and South Korea (Bae 1998).

UGBs in South Africa

In South Africa, UGBs took on a local flavour. They were popularised in the early 1990s by academics based at the University of Cape Town. In the context of the closing days of Apartheid, these academics were highly influential and created a then widely accepted vision for addressing the harm caused to South African cities by Apartheid as well as modernistic town planning (Watson 2002). UGBs featured prominently within this vision, which emphasised urban compaction and integration. Unlike North American UGBs, they were promoted more as design elements for spatially structuring cities. They thus initially tended to be conceptual in nature, and less consideration was given to the quantification of land reserves or mechanisms for their future expansion.

UGBs featured prominently in spatial plans for South Africa's largest cities from the 1990s, including the Cape Town Metropolitan Spatial Development Framework (CMC 1996) and the Gauteng Spatial Development Framework of 2000 (Horn 2010).

In Durban, UGBs where closely tied to infrastructure planning, especial costly wastewater infrastructure (Breetzke 2009).

Over time urban growth containment objectives were incorporated into key national and provincial legislation including the White Paper on Spatial Planning and Land Use Management (2001), Municipal Systems Act (2000), National Spatial Development Perspective (2003), Development Facilitation Act (1995), Gauteng Planning and Development Act (2003) and Western Cape Provincial Development Framework (2005) (Britz and Meyer 2006). This has encouraged the widespread establishment of UGB policies in South Africa.

Ironically, UGBs are currently being adopted by many South African towns and cities at a time of limited academic attention. The initial enthusiasm for urban compaction of the early 1990s has waned, giving way to more circumspect interest and the appropriateness of the "compaction–integration" vision of the early 1990s has been questioned. In addition, in sharp contrast to the international literature, little empirical work has been undertaken to investigate the effectiveness and benefits of growth management strategies in South Africa (Harrison 2002). Further, UGBs do not have a strong support base in South Africa, and the campaign for restructuring Apartheid cities has not retained popular support (Watson 2002).

Debates About Benefits and Drawbacks of UGBs in the Literature

UGBs and Land Price Increases

UGBs are most frequently criticised for causing land price increases. This is supported by several empirical studies that have found land price increases to be greater in UGB areas. It is argued that UGBs reduce the supply of developable land which, in conditions of inelastic demand, leads to price increases. Alternatively, it is argued that UGBs lead to fewer developers and uncompetitive practices (Brueckner 1990; Dawkins and Nelson 2002; Dowall 1981; Jun 2006).

Some supporters of UBGs agree, but argue that price increases are limited and acceptable. Dawkins and Nelson (2002) argue that prices increases are necessary in order to increase the desirability of redevelopment and infill development. Similarly, Buxton and Taylor (2011) contend that a good UGB should stabilise land prices outside of the boundary (i.e. reduce speculation) while not resulting in *unacceptable* price increases within the boundary.

A number of authors point out that most UGBs contain more than sufficient land reserves and thus should have limited effect on land supply. They note that policymakers are sensitive to the political consequences of constraining land supply for housing and economic growth and that UGBs can be expanded in response to higher than expected demand. In addition, UGBs are commonly implemented in conjunction with initiatives that encourage densification, infill developments and accelerated land release which act to increase land supply (Brueckner 2001; Buxton and Taylor 2011; Dawkins and Nelson 2002).

Some researchers believe that where land price increases do occur, they are primarily due to increased demand rather than reduced supply caused by the UGB. For instance, it is argued that the higher than national average price increases experienced in Portland are precisely due to success of growth management policies, including the UGB, in improving the land's amenity. This amenity includes better access to green space, better transport and lower energy consumption. Similarly, it is argued that high-income purchasers are attracted to the amenity of the non-urban areas or greenbelts created by UGBs, hence driving up land prices in these areas (Dawkins and Nelson 2002).

Other authors refute that UGBs necessarily lead to price increases and refer to empirical studies that have found little evidence of price increases in UGB areas (Jun 2006; Phillips and Goodstein 2000). Buxton and Taylor (2011) highlight the complexities and many variables that affect land markets and caution against drawing conclusions about the effects of UGBs based on generalisation from empirical studies.

Efficiency and Effectiveness of UGB

A more nuanced debate comes from the field of urban economics. Economists understand *excessive* sprawl as the consequence of market distortions. Brueckner (2007) outlines three sources of distortions: Firstly, commuters from peripheral suburbs do not pay the full costs of the transport and bulk infrastructure that they use; secondly, the full costs of road congestion are not priced; and thirdly, the benefits of open space are also not fully priced. Research from this field has generally supported urban containment strategies, including UGBs, as a means of correcting these market distortions (Bento et al. 2006; Pines and Sadka 1985).

However, many economists remain uncomfortable with UGBs and prefer market-based instruments, such as road tolling, development tariffs and fuel and parking taxes. UGBs are seen, firstly, as imprecise mechanisms that are difficult to set—capable of doing more harm than good if set too restrictively (Brueckner 2001). Secondly, economists remain sceptical about the interventionist nature of UGBs and the ability of state planners to determine the best location for development, preferring spatially neutral market-based mechanisms. Thirdly, UGBs leave congestion under-priced and do little to curb travel time and travel distances (Anas and Rhee 2006, 2007). Fourthly, several recent papers suggest that UGBs are ineffective relative to road tolling for controlling sprawl and promoting densification (Anas and Rhee 2006; Brueckner 2007). Fifthly, they do little to improve urban efficiency as they promote densification throughout the city rather than a density gradient, with densities decreasing with distance from urban centres, which is believed to be more efficient. It is further noted that UGBs may even lead to higher densities at peripheral locations adjacent to the boundary due to the higher land prices and amenity of the undeveloped land found there (Bertaud 2001; Brueckner 2007).

Nevertheless, many economists concede that, in practice, road tolling is often difficult to implement. UGBs are politically and administratively easier to implement, often only requiring an extension of existing land-use regulations (Brueckner 2001). The prevalence of UGBs attests to their popularity with policy-makers. This is emphasised by Turnbull (2004) who concludes that institutional practicalities outweigh the relative merits of the different policy mechanisms themselves.

Appropriateness of UGBs

UGBs may be inappropriate in developing countries where the urban poor are frequently accommodated in low-density settlements on the urban periphery. Such settlements allow poor households the space to conduct various livelihoods and survivalist activities including urban agriculture. In such conditions, UGBs can be inappropriate and difficult to implement. However, the urban poor may also benefit from UBG policies through the benefits associated with compact cities including better public transport and shorter commuting distances (UN-Habitat 2009; Watson 2009).

UGBs may be detrimental to economic growth and the financial viability of cities experiencing strong urban growth on the city edge (Harrison 2002). In addition, modelling conducted by Anas and Rhee (2006, 2007) suggests that UGBs are less appropriate in polycentric cities. UGBs may also be inappropriate in areas with insufficient levels of regional coordination as the implementation of an UGB may simply shift development to neighbouring administrative areas with less stringent development controls, resulting in "Leapfrog growth" (Turnbull 2004). In such circumstances, UGBs may serve to drive out lower-income households (Helling 2002).

Support for UGBs

Despite the above criticisms, UGBs have many supporters and are widely credited for containing sprawl. They appear to be particularly effective in directing urban growth to designated growth areas while protecting agricultural land and sensitive environmental areas from development (Abbott 2002; Buxton and Taylor 2011; Nelson and Moore 1993; Song and Knaap 2004). UGBs are also effective in preventing dispersed peripheral development. The role UGBs have played in curbing poorly regulated development and speculative sub-divisions in peripheral areas surrounding Saudi cities is clearly documented (Al-Hathloul and Mughal 2004; Mubarak 2004). In addition, UGBs have been credited for promoting infill development and higher urban densities (Abbott 2002; Al-Hathloul and Mughal 2004; Anas and Rhee 2006; Song and Knaap 2004; Weitz and Moore 1998), and Wassmer (2002) provides empirical evidence for the effectiveness of UGBs in curbing retail decentralisation. In several cities, UGBs have been closely tied to bulk infrastructure planning and have helped encourage efficient use of existing infrastructure and prevented unnecessary extensions, especially to expensive sewer networks (Al-Hathloul and Mughal 2004; Breetzke 2009).

How Are They Demarcated and Adjusted over Time to Accommodate Urban Growth?

As the purpose of UGBs is to promote a more compact form of urban development rather than prevent urban growth, they need to be demarcated so as to include sufficient reserves of developable land. However, the amount of developable land included in the UGB is critical. Drawing the boundary too tightly can stifle economic growth and lead to sharp land price increases. On the other hand, opening up too much land for development may result in unchecked urban sprawl and associated environmental, social and financial costs (Brueckner 2001; Knaap and Hopkins 2001). Surprisingly little research has been published on methods for determining appropriate land reserves and few practical guidelines exist. However, different cities have adopted a range of approaches to this problem.

Limited Quantitative Assessment

Many cities have implemented UGBs with no or very limited quantitative evaluation of land reserves or expected urban growth. Long et al. (2013) describe UGBs appearing in the spatial plans for Chinese cities as “artworks”, referring to their diagrammatic presentation and lack of reference to any quantitative assessment. This approach is surprisingly common and examples from South Africa include the Cape Town and Gauteng UGBs demarcated in the late 1990s, which were initially roughly determined with limited quantitative analysis and more accurately demarcated in subsequent years (Britz and Meyer 2006; CoCT 2003). In Saudi Arabia, large numbers of UGBs were implemented in conditions of limited information and technical support. Here a pragmatic approach was followed based on available information and existing subdivision approvals (Al-Hathloul and Mughal 2004).

Conventional Approach

The most comprehensive guidelines for determining UGBs come from the USA as outlined by the guidelines of American Planning Association (2002), Dowall (1981), Knaap and Hopkins (2001) and Knaap (2004). These authors advocate an approach that involves forecasting future land demands while monitoring land reserves to ensure sufficient land reserves for a set time period. Knaap (2004) describes detailed practical methodology for estimating both variables. They emphasise the importance of a reliable “land monitoring system” for determining when and by how much an UGB should be expanded. They draw attention to opportunities created by recent advances in geographical information systems (GIS) as well as the centralisation of development information in local government information systems, such as land-based taxation records and building plan approvals (Dawkins and Nelson 2002; Knaap 2004). Knaap and Hopkins (2001) argue that this land inventory-based system is more reliable than market-based mechanisms which can lead to unwarranted expansions immediately after an economic boom.

This approach is widely followed in the USA with most cities, including Portland, adopting rule-of-thumb guidelines for the provision of sufficient land to accommodate 20 years’ of urban growth, reviewed every 5 years (Knaap and Hopkins 2001). The American Planning Association guidelines (APA 2002) recommend that UGB planning be integrated with long-term land-use planning and propose generous land reserves, stipulating land sufficient to accommodate between 115 and 125 % of urban growth projected for the next 20 years and further that the growth projections be calculated at “minimum densities”. They argue that the extra percentages are required to allow for the “efficient and competitive functioning of real estate markets” and to prevent landowners from monopolising large parcels of vacant land.

Growth Simulation Models

A third approach is to use urban growth simulation models, such as cellular automata or artificial neural networks, to predict future growth. Using GIS and time series information gained from aerial photography or satellite imagery, these techniques use computer algorithms to recognise complex spatial patterns and predict future growth.

A number of recent papers have presented these techniques as a useful tool for setting UGBs, for example see Tayyebi et al. (2011a, b) and Long et al. (2013). However, to the best of my knowledge, these techniques have not been used in practise to demarcate UGBs.

Context of the Cape Town UGB

The "Urban Edge" was introduced by the Cape Town Metropolitan Spatial Development Framework (MSDF) where it featured prominently as a key element of its spatial vision (CMC 1996). Its alignment was subsequently refined and accurately demarcated and later extended to the city's coastal interface. Figure 1 shows its 2010 demarcation. It has been a strong informant of long-term infrastructural planning and has been successful in preventing development beyond the boundary, although this has been limited by its non-statutory status (CoCT 2003).

It included generous amounts of developable land, and initially little thought was given to its possible expansion and no policy was in place to guide how and when this should happen. However, by 2008, towards the end of a sustained property boom, the City was increasingly criticised for unnecessarily constraining land supply, and planners were frequently called upon to justify its delineation. Critics included private developers, who by 2008 had established a lobby group specifically to engage with the CoCT.

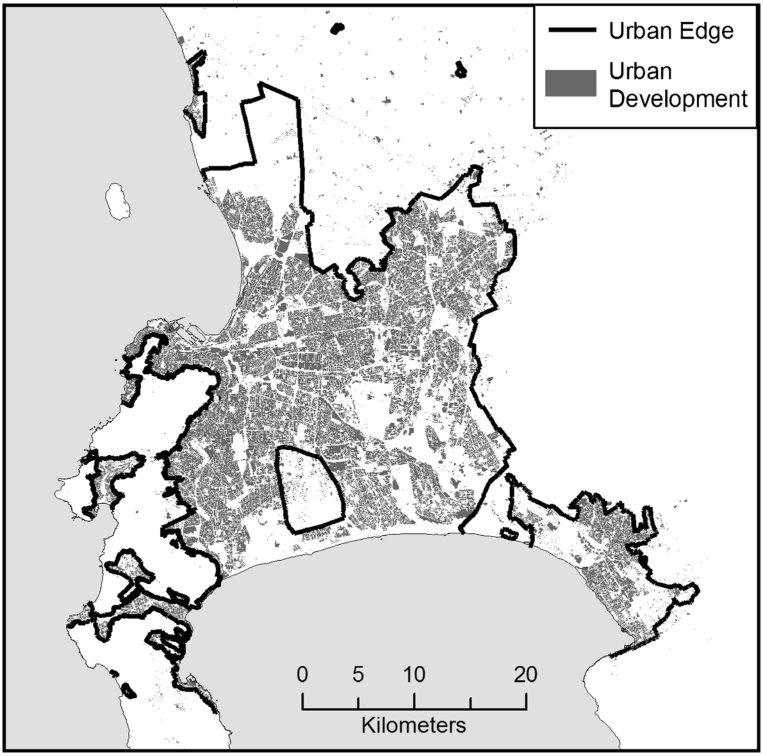

Fig. 1 Map showing the Cape Town UGB (Urban Edge) and urban development in 2007

Housing practitioners, on the other hand, were concerned that the UGB was frustrating efforts to secure adequate land for state-subsidised housing. Planners were keenly aware that urban expansion driven by private development as well as state-subsidised housing had substantially reduced land reserves within the UGB since its demarcation in 1996. There were also strong indications that urban intensification, as envisaged by the MSDF, was not occurring (CoCT 2003). This, together with the development climate at the end of the property boom, heightened fears that the city was running out of developable land. Given the high levels of urban poverty and lack of adequate housing in the city, planning officials were concerned not to be seen to be responsible for constraining economic growth or inflating land prices. Planners, torn between not wanting to abandon the densification objectives of the 1996 MSDF and risking constraining economic growth, thus required a reliable way of estimating remaining land reserves and evaluating the time period for which sufficient reserves exist.

Provincial government has established guidelines for the demarcation and adjustment of UGBs that are arguably considerably more stringent than those generally applied to US cities (PGWC 2005a, b, 2009b). These caution against providing too much developable land within an UGB, arguing that this is as detrimental as providing too little, and further recommend that the densification of existing urban areas and infill development should be relied upon to accommodate a portion of anticipated urban growth. However, the guidelines are in places inappropriate for Cape Town, the only large city in the province. For instance, the criteria for enlarging UGBs include the following: "…the urban edge must restrict the outward growth of urban settlements until such time as average gross densities of 25 dwelling units or 100 people per hectare are achieved" (PGWC 2009a, pp 8–54). This is problematic for Cape Town which has substantially lower gross densities.

The Method Used by Cape Town

The Cape Town method essentially addresses two questions: firstly, how much developable land is there within the urban edge? And, secondly, how fast is the city likely to grow? These questions are covered in "Estimation of Developable Land Reserves" and "Forecasting Urban Growth" sections, respectively. It follows the conventional American method as outlined by Knaap (2004) and the American Planning Association's guidelines (APA 2002), although, it includes a number of innovations and adaptations to a developing world environment.

Estimation of Developable Land Reserves

The Identification of Undeveloped Land

The first step was to survey all undeveloped and "under-developed" land. All land was considered irrespective of its suitability for development, although wetlands, proclaimed nature reserves and land outside of the existing UGB were excluded. Properties were categorised into categories such as agricultural land, under-used land, vacant land, public open space, parking areas and sports fields. This database was updated periodically by inspecting aerial photography, and the information was captured manually by property in GIS. This led to the identification of 61,780 undeveloped properties, accounting for of 47,583 hectares of land, as shown in Fig. 2.

Various other CoCT information sets, such as land valuations records, building plan approvals and property zoning, were used to either flag properties that may have changed in status or for verification purposes, although the manual method of updating proved to be time efficient and accurate. Valuation records were found to be insufficient for distinguishing between vacant and partially vacant land and generally less accurate than the interpretation of aerial photography. It also proved necessary to ensure that GIS property boundaries were up-to-date to at least the time of the aerial photography. In Cape Town, it was possible to source property sub-divisions, approved by the city but not yet finalised, which helped to reduce the time lags in the GIS data.

Assessment of Undeveloped Land

However, information on undeveloped land on its own is insufficient for determining developable land reserves as it includes substantial quantities of land that could arguably be better used for non-urban purposes such as environmental, agricultural or green public open space. A further consideration was that Cape Town, like other South African cities, has excessive amounts of vacant or underutilised land. This is

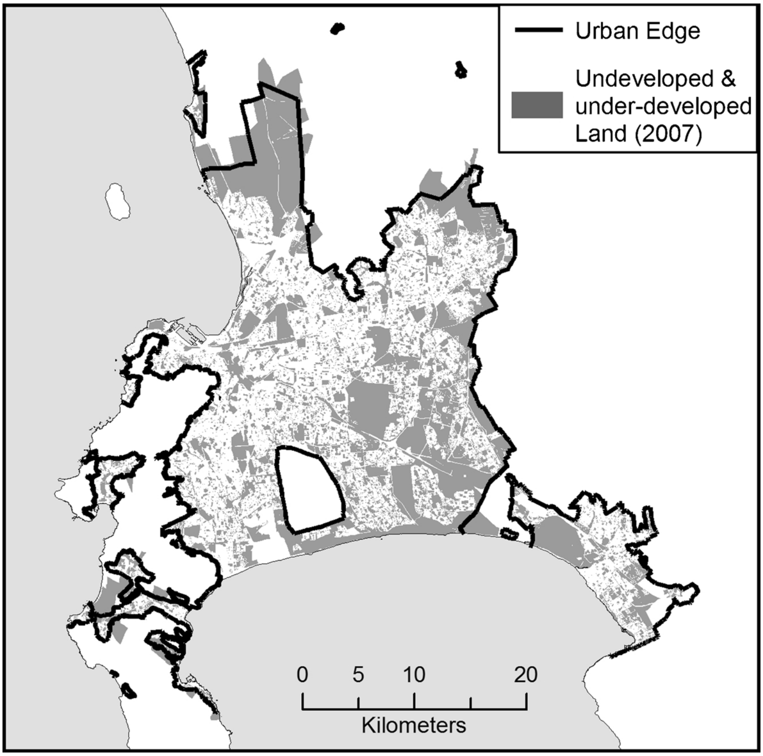

Fig. 2 Undeveloped and under-developed land identified in Cape Town for 2007

frequently owned by state enterprises with limited interest in improving the land (CoCT 2003). Examples include the Wingfield and Youngsfield sites, both are large, sparely developed former airfields owned by the South African National Defence Force. Although this land is underused, central and eminently suitable for further development, it cannot necessarily be considered part of the city's developable land reserves.

Thus, in 2008 and 2009, the city undertook a further information gathering and assessment exercise. As it was impractical to assess all 61,780 properties listed in the database, larger and more strategic sites were selected for further assessment as follows:

- Information on large-scale developments was obtained from planning officials or the developers' consultants. This information was usually readily available as it is required for land-use approval processes. Information captured included proposed land uses, number of dwellings, densities, aggregated floor areas and phasing, Similarly, information for large planned subsidy housing developments was obtained from the City's Housing Department.
- Sites larger than 1 ha were selected for assessment by area-based planning officials. Each site was assessed in terms of percentage of the site available for development, suitability for different land uses, residential density (if proposed for residential use), stage in the development approval processes and the likely timeframe for its development, taking in to account, all known development constraints. GIS information including bio-diversity, agricultural data and aerial photography was made available to assist with assessment and strategic sites were debated further. Remarkably, a total of 22,153 sites were ultimately reviewed by planning officials.
- Vacant serviced residential and industrial plots were identified using GIS and a combination of information including zoning, valuations information and aerial photography. These two land types were prioritised as they account for a significant amount of land. A total of 12,260 residential sites (718 ha) and 491 industrial sites (163 hectares) were identified.

A key feature in this assessment was the degree of overlapping and competing land demands. Mapping of biodiversity-sensitive areas blanketed much of the city's remaining undeveloped land, and it was not uncommon for the same property to be earmarked by different CoCT departments for competing urban, agricultural and environmental use. What proved to be particularly useful was that the land assessment process was integrated into a high-profile spatial planning process that culminated in the approval of Cape Town Spatial Development Framework (CoCT 2012). The spatial logic of the plan helped identify which land should be prioritised for development. The planning process also helped provide the necessary channels for interrogating information and debating competing land demands with staff from various CoCT Departments. However, substantial public comment was also obtained through a public input process linked to the Cape Town Spatial Development Framework (CTSDF). In addition, the CTSDF provided the impetus to improve GIS information and the land assessment process benefitted from a number of parallel studies including a study of agricultural land and an extensive "field verification" survey of environmentally sensitive land.

Use of an Automated Model to Process Land Assessment Information

To provide a richer understanding of undeveloped land in the city, additional information, including information on land ownership, zoning, land-use and informal settlements, was sourced and linked to the above described "undeveloped land" and "land assessment" information. Due to the volume and heterogeneity of the data, an automated procedure was developed to help process these data and arrive at estimate figures for developable land. In essence, the model used algorithms to prioritise more reliable information sources, to work from assumptions when information was incomplete and to allow for various parameters and calibrations to be set. In general, key information such as expected future land-use, residential densities, percentage of the site available for development and expected development date was available for larger sites, while assumptions on the timing and type of development for smaller sites with incomplete information were made using what information was available. For example, depending on the parameters, an assumption could be made that a higher proportion of privately owned, serviced land would be developed by a certain date than non-serviced land owned by state institutions.

The model also estimated the proportion of land required to be set aside for road reserves, social facilities, infrastructure and open space. This proportion varies greatly depending on the site. In general, large rural tracts of land require a large proportion of the site to be set aside while individual vacant residential plots and small city blocks do not require any land to be set aside. This was calibrated from careful GIS analysis of existing urban areas of the city. The final step was to estimate the carrying capacity of the land in terms of dwelling units, although this was not used in the final assessment. The model was run multiple times using different density assumptions and model parameters. This included parameters set for expected densification within existing residential areas and the proportion of land to be set aside for facilities and infrastructure. This proved useful for testing the sensitivity of the model and exploring different development scenarios.

A key feature of the model was that it remained relatively simple and used commonly used software, Microsoft Excel and ESRI ArcMap GIS. This allowed the exercise to be conducted internally by city officials without the assistance of external consultants. This facilitated on-going updating and improvement over a 2-year period as well as greater understanding and acceptance of the results.

Forecasting Urban Growth

This section addresses the second question: How much land is required for urban growth? While America guidelines (APA 2002; Knaap 2004) recommend that land demand forecasts be based on population and economic projections, this approach may not be valid for South African cities. Figure 3 shows population projections for Cape Town developed by Dorrington (2000, 2005). These indicate declining growth rates which could lead to assumptions of a slower urban expansion rate in the future. However, this may not be necessarily true for Cape Town for the following reasons. Firstly, the development of state-subsidised housing contributes to approximately 12 % of all urban growth in Cape Town.[1] It can be argued that this expansion is driven by state

[1] Author's calculation

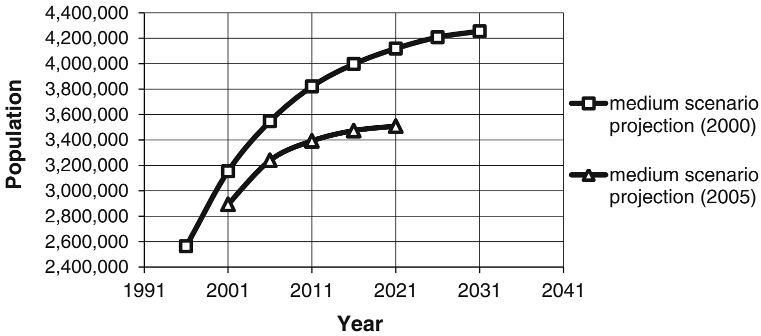

Fig. 3 "Medium scenario" population projections for Cape Town (2001–2031 and 2006–2021) (Dorrington 2000, 2005)

housing budgets and housing policy rather than population growth given the large housing backlogs in the city. Secondly, Cape Town's urban density patterns are highly polarised (Turok et al. 2010). Approximately 20.5 % of households are accommodated in informal settlements or in "backyard shacks" (Statistics South Africa 2011) often at extremely high densities while formal residential developments are mostly low density. This would complicate forecasting urban expansion from population projections.

In order to obtain more robust estimates, we used two methods, one based on past urban expansion and one based on residential growth. This allowed for cross-verification of results using two different methods and independent information sources.

Forecasting Growth Based on Past Trends

This method estimated future land required assuming that the city would continue to grow at rates observed in the recent past. The average growth rate for the past 20 years was calculated using measurements obtained from the survey of undeveloped land. Measured in hectares, this included all urban land-uses including housing, industry, schools, clinics, infrastructure and informal settlements, however, excluded parks, open sports fields, public open space and roads.

Figure 4 shows that growth between 1988 and 2007 was more or less linear, averaging at approximately 650 ha/year. Interestingly, this rate appears to have remained stable through economic cycles including the property boom of 2000 to 2008—possibly due to the long timeframes required for property development.

Forecasting Based on Residential Land Development Scenarios

Residential land uses, by area, account for the majority of urban land use (approximately 70 % in Cape Town[2]), and its growth was subject to greater uncertainty due to possible changes in state-subsidised housing policy. There was thus a concern that forecasts, based on past trends, could underestimate potential residential growth. Therefore, a second forecast was undertaken in order to explore potential residential

[2] Ibid.

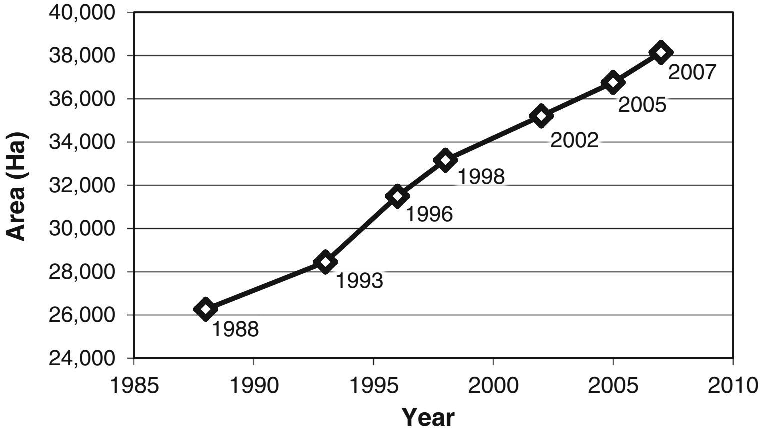

Fig. 4 Growth of the urban extent of Cape Town in hectares (1988–2007)

expansion. This was based on a disaggregated model for informal settlements, state-subsidy housing and private sector housing growth.

Informal Settlements Growth in informal settlement was estimated as follows: Informal dwelling counts, obtained from CoCT aerial photography-based surveys, were used to extrapolate an informal dwelling growth rate as indicated in Fig. 5. This projected growth rate was applied to the total land area used for informal housing in 2008 to obtain a projected informal growth in hectares. Nevertheless, informal settlements account for a relatively small amount of urban expansion considering the number of people accommodated in such settlements.

State-Subsidy Housing Based on subsidy housing delivery for previous years as well as budgetary constraints, it was reasonable to assume that a maximum of approximately

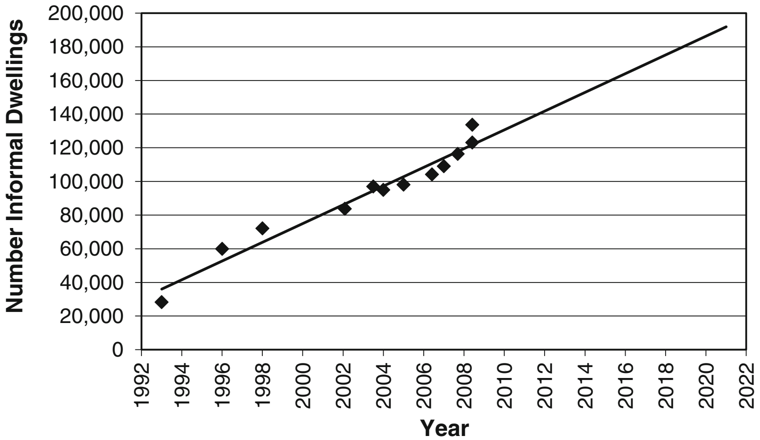

Fig. 5 Informal dwelling counts (1993–2008) and extrapolated growth

10,000 houses per year would be built. However, a change in housing policy to include site-and-service housing delivery had been mooted. If implemented it would dramatically increase the amount of land required for subsidy housing. In order to assess the impact of such a policy change, two scenarios were developed with input from officials from the CoCT's Housing Department.

The first scenario was based on current housing delivery and current housing budgets. It assumed that 10,000 subsidy houses with an average property size of 100 m^2 would be delivered per annum. The second scenario assumed a change in housing delivery policy and is based on a scenario outlined in the CoCT Housing Department's Five Year Integrated Housing Plan (CoCT 2009) where one third of the housing budget is spent on subsidy housing while the remaining two thirds are spent on site and service. This assumption translates to 2,500 subsidy houses and 17,000 site-and-service sites per annum. It was further assumed that this policy change would take effect from 2016. Figure 6 shows the results of these two scenarios.

Private Sector Housing Information on past trends was obtained from an urban growth model developed by the CoCT's Strategic Development Information and GIS Department in 2008. This model estimates formal housing (both private sector and subsidy housing) growth using a number of CoCT sources including electricity connections, solid waste registration and building plans information. Annual subsidy housing delivery figures were used to exclude subsidy housing, and private sector housing growth was then extrapolated using an average growth rate as shown in Fig. 7.

This was translated into a land consumption rate for private sector housing growth using an average net residential density of 30 dwelling units per hectare. This density was decided upon after reviewing the densities of a number of recently developed residential areas and is a deliberately conservative (low) density compared to recently developed areas on the West Coast that achieve much higher densities. It was further assumed that 90 % of future residential units would be developed on "green-field" sites and the remaining 10 % on previously developed land through sub-divisions, re-developments and the development of second dwellings (granny flats).

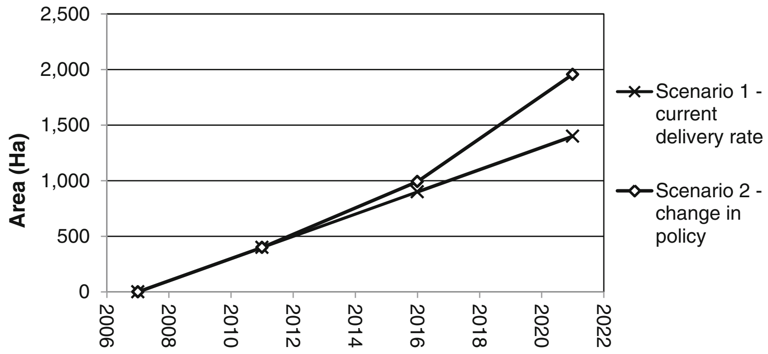

Fig. 6 Estimated hectares land required for state-subsidy housing (2007–2021)

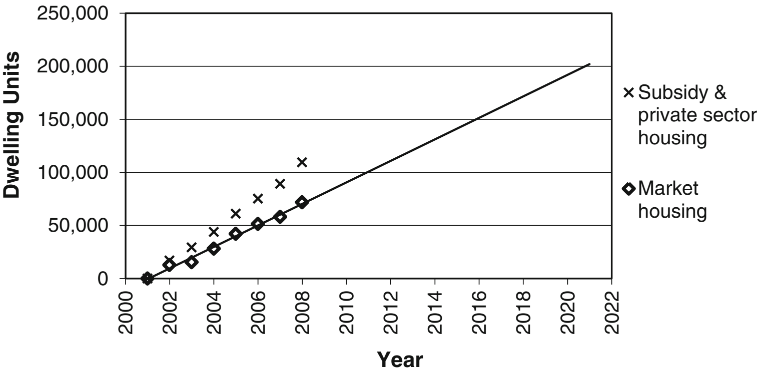

Fig. 7 Estimated private sector housing developed (2001–2008) and extrapolated growth

Cape Town Results

High and low developable land reserves scenarios were calculated for 2021 by running the land assessment model, as outlined in "Estimation of Developable Land Reserves" section, using two sets of carefully chosen parameters. Parameters for both scenarios were conservatively chosen to reduce the risk of overestimating land reserves. The results were then compared with the two growth forecasts as outlined in "Forecasting Urban Growth" section. Figure 8a compares estimated land reserves with the growth forecast on the basis of past growth trends, while Fig. 8b compares estimated *residential* reserves with the residential growth scenario with the assumed change in the subsidy housing policy.

Figure 8a, b show that estimated land reserves, even using the low scenario, exceeded forecast land requirements for both forecast methods until at least 2021. This even held true for an assumed change in the subsidy housing policy. Based on these results and on the understanding that a further review would be conducted within 5 years, it was concluded that there is sufficient land availability for development within the UGB and that the UGB should not be expanded.

Discussion

This paper has outlined the methods used by the CoCT to estimate developable land reserves and forecast land demand and has demonstrated how this was of value for the review of Cape Town's UGB. This section reflects on lessons learnt and key points arising from comparisons with methods and guidelines in the literature. The innovations and adaptations to local conditions of this method may have application for other developing world cities.

Value of the Methods Used

A key success of the methods used was that they provided a rigorous and defensible method for reviewing the UGB. The relatively simple nature of the method afforded a reasonably high level of transparency, and it provided planning officials with the

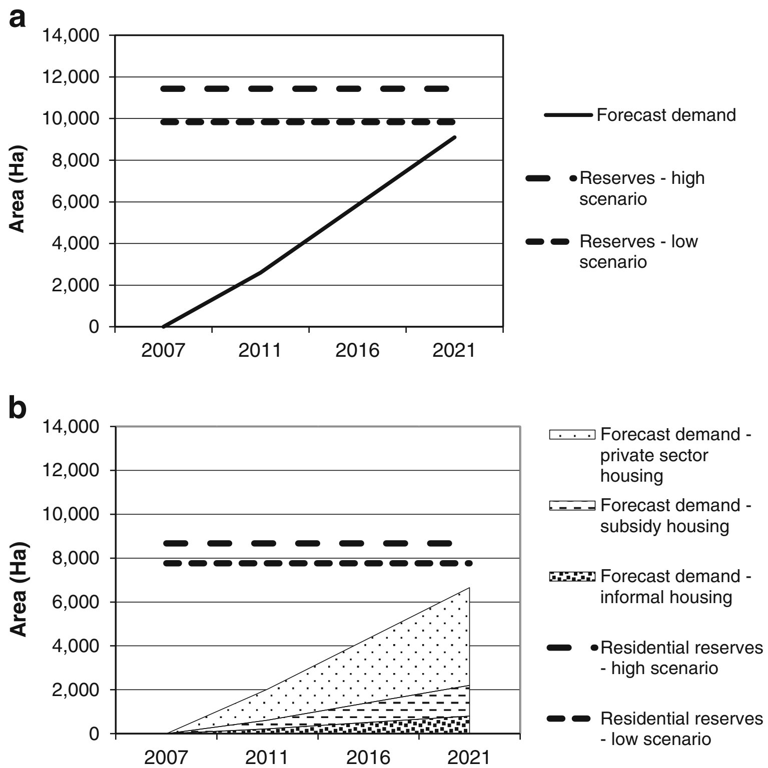

Fig. 8 **a** Forecast land demand based on past growth compared with developable land reserves within the UGB. **b** Forecast land demand based on residential growth scenario compared to residential land reserves identified within the UGB

necessary grounds to resist pressure for further relaxations of the UGB. This is a common theme in the literature with many authors referring to high levels of contestation (Abbott 2002; Buxton and Taylor 2011; Knaap and Hopkins 2001). A key lesson learned is the value of clear and upfront policy on the timing and method of UGB reviews.

The thoroughness and level of detail of the land assessment exercise is an indication of the planning officials' sensitivity to critics of the UGB. However, analysis of the data suggests that for future reviews, sufficient accuracy may be obtainable from a less comprehensive land assessment, as a large portion of the land ultimately came from a small number of relatively large development sites.

Integration with Broader Planning Programmes

The review of the UGB was integrated within a broader, high-profile planning process which culminated in the approval of the Cape Town Spatial Development Framework in 2012. This proved to be highly valuable for a number of reasons. Firstly, it provided channels for debating competing land demands both within the CoCT as well as through a public input process linked to the CTSDF. Secondly, the public interest generated by the CTSDF process was beneficial for the UGB review. Input from environmental groups and rate-payers' associations provided a useful counterbalance to that of property developer lobby groups. Thirdly, the SDF process provided the impetus for interrogating, understanding and improving the quality of data. In some instances, extensive surveys or additional studies were undertaken to improve the quality of GIS input data.

These aspects are highlighted in the literature and our experience supports the value of using these approaches. The American Planning Association guidelines (APA 2002; Knaap 2004) stress the integration of UGBs with long-term regional planning and the establishment of a "land monitoring system", while Knaap's (2004) detailed step-by-step guidelines and suggestions for the use of multiple data sources and avoiding gross data errors resonate strongly with the Cape Town experience.

Innovations of the Cape Town Method

The Cape Town method included a number of innovations and adaptations to local conditions. Past urban growth trends, which were found to be relatively stable through several economic cycles, were used to help forecast land demand. This proved useful in moderating high growth expectations made towards the end of the property boom. In a further innovation, the rich knowledge of area-based planning officials was utilised, and a quantitative land-assessment model was developed to process this information. This was valuable for evaluating the vast amount of undeveloped and under-developed land within urban areas of the city. In addition, land-based forecasts were used instead of population projections, as is proposed by American guidelines, due to the city's urbanisation rate, housing shortages and the nature of the city's density patterns.

Comparisons to Urban Growth Simulation Models

Urban growth simulation models are proposed in the literature as a method for establishing UGBs (Tayyebi et al. 2011a, b; Long et al. 2013), although to my knowledge this has not been applied in practise. Based on the Cape Town experience, these techniques may well be useful and should provide a richer understanding of urban growth patterns. They should also be of particular value in settings where limited land information is available.

However, these techniques differ significantly in approach. The established American approach focuses on evaluating land reserves, facilitating long-term land-use planning processes and proactively steering growth towards more compact patterns of development. In contrast, simulation models use past development patterns and probability to predict future urban patterns.

A number of possible limitations should also be considered. The highly technical nature of these techniques requires specialist skills that would need to be outsourced. This may discourage iterative planning and data interrogation processes which typically involve negotiation and frequent data updating by internal staff over an extended time period. A simpler model should also be more transparent and easier to understand by a wider audience, which should facilitate greater confidence and acceptance of the results.

Other Uses: Spatial Population Projections

The extensive land information collected as well as the land assessment model proved to have important other uses. The model was adapted to generate future spatial population scenarios for various future time periods. These were an input to several other planning processes including transport modelling, long-term water and sanitation infrastructure planning and the assessment and planning for social facilities. This functionality is well described in the literature (Al-Hathloul and Mughal 2004; Knaap 2004) and was confirmed by our experience.

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