URBAN-RURAL DEMARCATION WITHIN A METROPOLITAN AREA – A METHODOLOGY FOR USING SMALL AREA DISAGGREGATION

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ABSTRACT

There is ongoing debate with regard to the levels of service provision in urban and rural areas. However, progress with respect to the delivery of planned services can only be efficiently and equitably measured once benchmarks for different areas have been set. For this purpose, different settlement types need to be defined and spatially delineated.

While applying GIS-based service-access planning in eThekwini KwaZulu-Natal, it was agreed that the statistical results of spatially analysed backlogs in social-service facilities needed to be structured according to the varying urban and rural settlement types found in this metropolitan area. This paper explores the methodology that was developed in response and which enabled the demarcation of similar or comparable areas for use in policy development including the evaluation of facility standards for urban and rural areas.

Keywords: GIS methodology small area settlement-type disaggregation

Major advantages were found in being able to use both the area proportionality and the (population) weighted land-use type to disaggregate the population from the Planning Unit level (the latter being the most up-to-date and accurate population layer) to the much finer-grained hexagon layer. This allowed not only for detailed accessibility modelling, but also for fine-grained population disaggregation thus enabling a robust delimitation of urban, rural and dense rural settlement types within a metropolitan area.

INTRODUCTION

There is ongoing debate about the level of service provision in urban and rural areas. While applying GIS-based service-access planning in eThekwini Municipality in KwaZulu-Natal, South Africa during 2006 (Green, Morojele & vd Merwe 2006) the project team identified the need to present the statistical results on spatially analysed backlogs in social-service facilities in terms of the different urban and rural settlement types found in the metropolitan area. Few metropolitan areas are entirely urban and can include substantial rural or non-urban land or areas of fragmented urban development beyond the developed urban fringe (Demographia 2007).

In the case of eThekwini Municipality, the urban–rural divide and the density of population are contributing factors affecting the efficiency and effectiveness with which social services are provided. The eThekwini metropolitan area comprises highly built-up and industrialized areas as well as a large rural area on the periphery. The different settlement types thus needed to be defined and spatially delineated.

This paper explores the methodology developed for demarcating similar/comparable development areas with the view to policy development for measuring and monitoring facility standards in urban and rural areas. A regular set of hexagon zones was used to disaggregate population data from Planning Unit level with sufficient accuracy to enable demarcation of different settlement types by density. The process was initiated by a detailed apportionment of the population data weighted by the different land uses within the hexagons. This regular set of zones eliminates problems - such as those encountered in classifying urban and rural communes in Europe - where the size of communes relative to the population results in

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distortions and where urban clusters that may fall within some of the larger, more rural communes are not identified (Gallego 2007).

RATIONALE FOR THE NEW METHODOLOGY

Urban-rural distinctions in service delivery

The debate with regard to service-provision standards and the level of service required in urban versus rural areas is increasingly relevant. When rural and urban areas are within the same management area that is subject to restricted budgets, there is pressure to invest in infrastructure in a manner that achieves the greatest reduction in service backlogs. In South Africa, the rural components of a metropolitan area are generally historically disadvantaged as well as having typical features of rural areas such as low-density, dispersed settlement with unplanned/ informal road networks and a lower level of engineering and social-service provision than the more urbanised areas. This implies the need to impartially demarcate urban and rural areas in order to evaluate and measure service levels in terms of identified indicators for the different settlement types.

The distinction between urban and rural areas is becoming increasingly important for the purpose of service delivery and facility-accessibility analyses. Bibby and Shepherd (2004) indicate an evolving policy (implying an associated need for differentiated standards) with regard to service delivery in rural areas in England and Wales. This need for developing differentiated and context-specific standards is also evident in working with the service-delivery sectors within eThekwini and especially with the Rural Area-based Management (ABM) groups which were established to manage selected rural in a holistic manner.

As noted by Gallego (2007), a logical first step in any policy aimed at addressing backlogs in rural areas, would be to define which areas are rural and which are urban. In eThekwini, the settlement types had been neither defined nor spatially delineated. The project team was required to develop a robust spatially based methodology to delineate different settlement types (urban and rural) within the metropolitan area. In addition, it would have to be acceptable to the various stakeholders, not be constrained by administrative boundaries and be based purely on technical information that was independent of any political or area boundary issues.

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Data at different scales

Service-access planning, incorporating the use of the Flowmap tools as applied in the eThekwini municipal area, uses population distribution as a common basis for analysis for a range of facility types. A regular set of zones at a fine level of detail allows for analysis at a fine scale, however little data are generally available at such a small scale.

For the purpose of reporting a range of municipal statistics and population variables eThekwini is divided into Planning Units. The Planning Unit data available for the eThekwini region are however too aggregate for detailed planning of facilities including the spatial matching of supply and demand of facilities or settlement typology. Although these units are somewhat homogeneous, the land use within each and the sizes of the units vary considerably, making the direct use of population data unreliable from a density perspective. The most useful process proved to be one of disaggregating the data to a hexagon layer as this enabled the project team to establish a uniform size set of zones for the basis of comparison for service-delivery across the urban–rural continuum and also provided a more detailed distribution of population. Librecht et al. 2004 (Gallego 2007) made use of a similar regular grid for the purpose of demarcation, while others have defined homogeneous areas by clustering small basic units.

Spatial accuracy in identifying inequities

In terms of service equity, most of the historically disadvantaged and peri-urban neighbourhoods have a much lower quantity and/or quality of public-service provision compared to neighbourhoods closer to traditional city centres (CBDs) or affluent suburbs. Naudé, Green and Morojele (2001) have indicated how the extent of inequity is deceptively easy to measure in terms of aggregate indices of service availability per neighbourhood or suburb. Administrative boundaries are the traditional means of measuring facility needs and use the ratio of people per facility within a boundary disregarding the spatial relationship between users and the service points. This can lead to inaccurate reporting of service levels across planning units in terms of the presence of a service in relation to population as well as in terms of accessibility to the service within a stipulated time. Furthermore, line departments

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(Health, Education, etc.) often use planning areas with differing boundaries. Uncritical use of large-area based measures (e.g. number of clinics per 100 000 population) can lead to inaccurate reporting of service levels at the planning level.

To overcome some of these shortcomings, GIS and related network analysis tools can be used to produce disaggregated availability indicators by facility catchment and also statistics for any small areas (e.g. suburb, ward, postal code) for which disaggregate population or service-demand statistics can be obtained or analysed.

Reporting

Although the services-access planning approach uses a very fine grain of resolution and provides greater insight into the spatial aspect of accessibility. For statistical and comparative reasons the backlogs of facilities and the accessibility statistics for eThekwini Municipality additionally needed to be reported at an administrative sub boundary level and, more importantly, with respect to different settlement typologies. The purpose of this was to measure how the established urban areas compared to the peri-urban and rural areas of the eThekwini metropolitan area when it comes to the delivery of social services, and to align future facility plans with budget-planning processes for each administrative area.

Thus the administrative boundaries are only used for reporting results and not for analysis, the reason being that the larger and more irregular the administrative unit, the greater the likelihood that the unit measure will poorly reflect the accessibility of users to the service in question. Unit measures also give no consideration to transport networks or the fact that a facility and the population may be spatially separated by a river or other barrier, or that a closer facility may exist across an ‘invisible’ administrative border. In their paper Morojele, Naudé and Green (2003) formally outlined the distortions that result from aggregate facility measurements.

DEVELOPING A METHODOLOGY

The case study area and available data

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eThekwini Municipality is centred around the port city of Durban in KwaZulu-Natal and had 3.5 million residents in 2006. The municipal area covers approximately 242 000 hectares, of which 60–70% is rural and agricultural land. Providing municipal services and social facilities to these areas is extremely difficult and expensive.

Methods for defining urban areas differ from country to country but land use and population density are often the two most influential factors in determining if an area is urban or rural (Demographia 2007). Several European and North American countries define urban areas as having 400 people per km^2, while in Australia urban centres are clusters of 1 000 or more people living at a minimum density of 200 people per km^2. Some countries also use census district density or one km^2 grids whilst for certain European countries continuous urban types of land use (with no more than a 200 m break) is the determining factor and satellite photography is used for the demarcation of such urban areas.

Both land use and population data were available for eThekwini. It was therefore decided to combine this information at a fine-scale to attempt to establish a defensible demarcation of the different settlement types in the area at a still to be determined density.

CREATING A SPATIALLY ACCURATE DEMAND SURFACE AT A HEXAGON LEVEL

Updating population data

Where small-area statistics are not available, GIS tools can be used to disaggregate the population data from larger areas to a smaller set of zones nested within or partially contained in these zones. This disaggregation of population, for example, is usually undertaken based on a proportional allocation of the underlying land area.

In eThekwini, population data at Planning Unit level (406 units) had to be used. This population data was based on South Africa's Census 2001 data at enumerator area level that had been aggregated to Planning Unit level. For future planning, the Planning Unit data was adjusted by municipal staff to reflect 2006 population levels. The process involved meetings with local planning and housing offices with respect to obtaining information on major residential developments and low-cost housing development between 2001 and 2006.

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Informal and traditional settlement areas were updated using eThekwini Water Service's most recent dataset - digitized from aerial photography - depicting water-service connection points.

Creating the hexagon layer

To create the hexagon layer, the surface of the study area that would serve as the demand surface was tessellated. This process resulted in 5 816 hexagons of 41.6 ha each (side length 600 m) across the eThekwini metropolitan area. Since the Planning Units that contained the population data are not uniformly developed/ homogeneous a methodology had to be developed to disaggregate the population data to the hexagons with great accuracy, as it was to be used for both:

- classification of settlement types based on population density, and
- as a spatially detailed demand-base map for accessibility modelling to determine service-facility backlogs.

The methodology for the weighted population disaggregation

It was decided not to depend solely on area proportionality in the disaggregation of the population and other GIS layers that could assist in the allocation were evaluated. A data layer was available of the underlying land use. Since the underlying land use is strongly correlated with population density and, since each Planning Unit comprised two or more different land uses, it was necessary to find a way of allocating the population from the Planning Units to the hexagons based on the area proportion **and** the land uses contained in the hexagon. The scale of the available data did not allow for a standard GIS allocation with a high level of accuracy.

The demand for facility use is based on the population or a subgroup of the population; for example, people living in households earning less than R3 500 per month or those in a specific age group. Thus, the need existed to estimate for each hexagon the number of people as well as those in each different income, or age groups, as well as any related attribute data. A solution was found through the development of an Excel lookup table / spreadsheet that allowed for the disaggregation of the population data weighted according to the population-carrying properties of different land-use types. The lookup table was geo-referenced and

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linked back to the spatial layers in the GIS system. The population lookup table that was developed was linked to the Planning Unit, land-use and hexagon layers.

Calculations

To undertake the calculations the following information was known:

- Inside each hexagon zone the number of hectares per land-use type.
- Each hexagon zone is assigned to some specific Planning Unit (PU).
- Inside each Planning Unit the number of people belonging to each population class is known.

An *a priori* estimate was made regarding the relative propensity of any hectare of a specific land-use type to attract or support population.

A table was developed to allow a range of land-use weights to be tested for undertaking the population allocation according to the land use–population relationships. The related spreadsheet in the excel workbook allowed for the balancing of the disaggregated population at Planning Unit and total metropolitan level.

The spreadsheet enabled the disaggregation of the population data taking into consideration the underlying land-use layer. It allocated the population as well as the relevant social information, e.g. age and income, to the hexagons. In the process, the underlying land-use type, land area extent and population were used to achieve a weighted proportional allocation. The methodology that was developed thus accommodated the uneven development within the Planning Units and ensured that the population was allocated to those land-use types that support population. The resultant map (Figure 1) was validated by the eThekwini project team in terms of their local knowledge and formed the basis for most of the demand scenarios.

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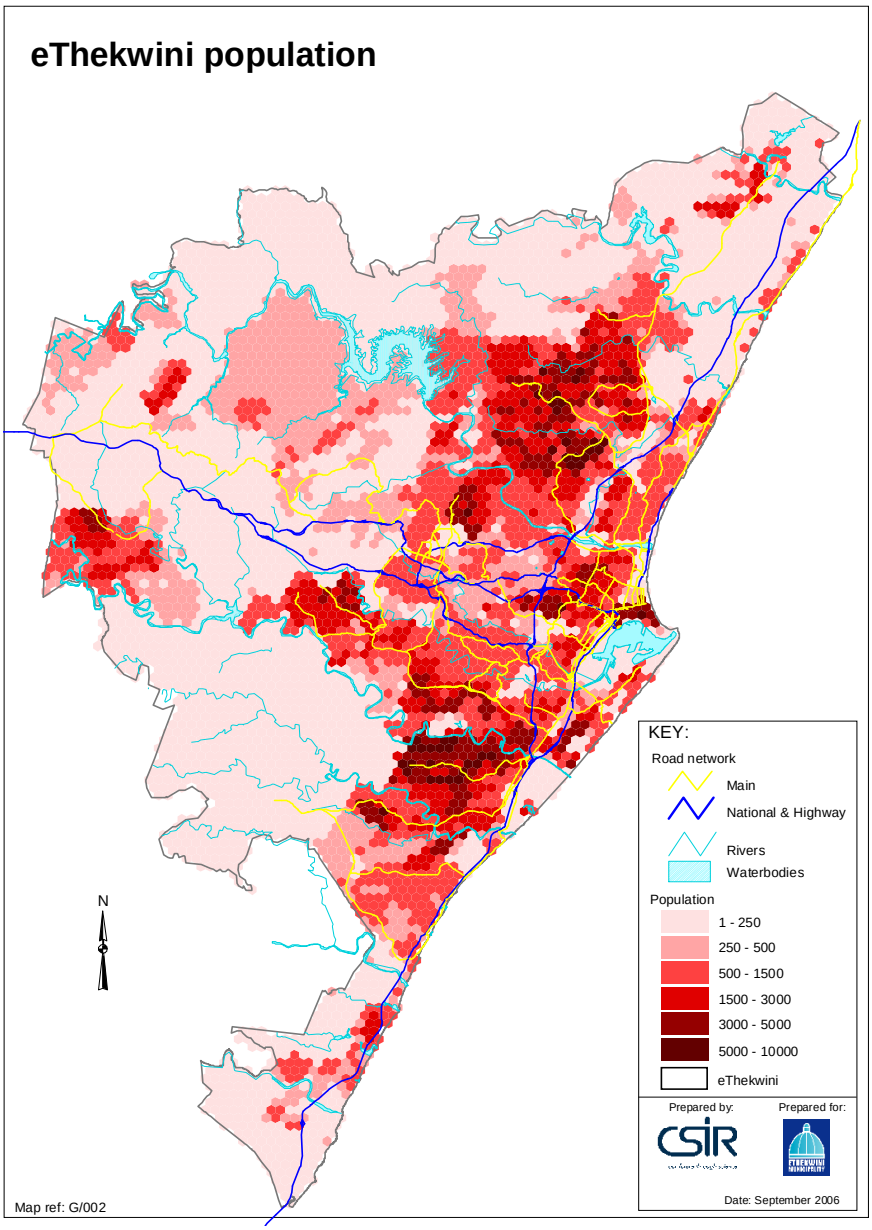

Figure 1: Number of people per hexagon within eThekwini

CLASSIFICATION OF SETTLEMENT AREAS

Using the fine-grained population map that is spatially the most accurate reflection of development and population distribution in the eThekwini metropolitan area, a series of map views that use different population-density cut-offs (person per hexagon/hectare) were developed. It was finally agreed that in this context the urban cut-off was best represented by 250 people per hexagon or six people per hectare.

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The urban–rural divide within the eThekwini metropolitan area is clear; however, within the rural periphery there are several isolated pockets of higher-density settlement, surrounded by what is essentially traditional subsistence agriculture and scattered traditional dwellings. Thus, instead of demarcating only two settlements types, namely Urban and Rural, a third type was identified - Dense Rural.

Although currently lacking the normal range of urban functions and being surrounded by farm and tribal land, the Dense Rural areas are geographically extensive and densely developed dormitory settlements with a higher level of service delivery and access than the surrounding low-density, dispersed settlements of the rural areas. Barring the relatively high density, these areas have few higher-order commercial and employment characteristics typical of a true urban area. The areas are not contiguous to the urban area and can hardly be considered suburban. Thus, notwithstanding the mainly rural nature of these areas, it is necessary to strive to provide social-service facilities at the same level here as for urban areas due to the number of people present.

The three settlement types were defined as follows:

- Urban – more than six people per hectare and contiguous to the CDB core
- Dense Rural – more than six people per hectare, but disjoint from the major urban area
- Rural – peripheral to the city, with large areas where the population density is less than six people per hectare.

Using the above criteria, the spatial extent of each settlement type as defined was demarcated, as shown in Figure 2.

From a development and service delivery perspective, these settlement types formed the basis for comparing the service-delivery levels of social facilities within the eThekwini municipal boundaries and for developing appropriate policy responses to service access. The comparison of land areas covered by different settlement typologies shows that only about 40% of the municipal land area can be considered urban, 10% is made up of densely populated rural settlements, and the remainder mainly comprises sparsely populated rural and farming areas. The sparsely populated rural areas have a significant impact with respect to service delivery,

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specifically within the context of budget constraints and rapid growth mainly as a result of migration into these areas and, to a lesser extent, natural population growth.

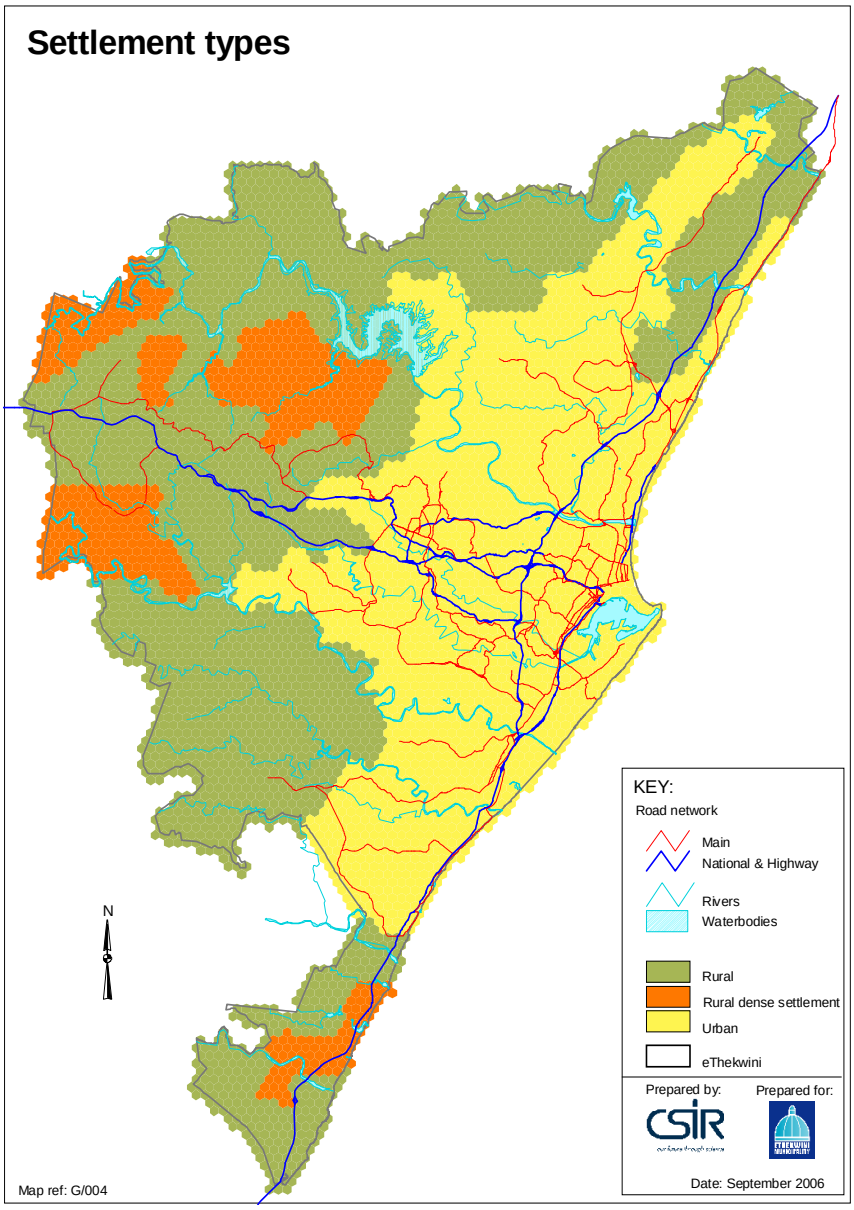

Figure 2: Three settlement types in eThekwini

APPLICATION OF SETTLEMENT TYPOLOGY TO FACILITY BACKLOGS

Some results from studies commissioned by the eThekwini Municipality, to evaluate access to facilities, are used to illustrate the application of the settlement typology in evaluating facility

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backlogs (Green & Morojele 2001; Green, Morojele & vd Merwe 2006). The accessibility assessment projects produced facility-utilisation statistics for each settlement type per facility.

As an example, the analysis for the provision of library services illustrates the varying levels of service provision for Urban, Rural and Dense Rural areas and is summarised in Table 1.

Table 1: Population served by libraries per settlement type within 15 minutes using a public transport trip

Access by settlement	15 min public transport		
	Urban	Dense Rural	Rural
Average travel time (min)	6,7	9,7	10,4
Population served	2 135 394	94 533	54 096
% population served	74,2	28,4	18,5
Land area covered (ha)	71 457	4 157	21 907
% land area covered	71,5	16,9	18,7

Table 2: Library backlog based on universal 15 minute travel time for all persons

eThekwini	No of facilities	Capacity	Population	Unserved population	Backlog* No. of libraries	Spare capacity
	84	3 100 000	3 501 751	1 246 119	20.7	844 370

* based on library capacity of 60 000 (large facility)

Based on the number of unserved people living more than 15 minutes from a library at least 20 libraries are needed while there is still spare capacity (Table 2). If longer travel times are acceptable - especially for those outside the urban area - most of the existing spare capacity can be utilised and the backlog reduced to only 10 libraries of 60 000 capacity. This could be supplemented through library outreach programmes at schools in rural areas.

If backlogs in facility provision are calculated assuming the same level of service in all settlement types, the backlog is significant. The facility-provision standards for different settlement types continue to be debated.

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CONCLUSION

From a GIS perspective the ability to use both the area proportionality and the (population) weighted land-use type to disaggregate the population from Planning Unit level (the latter being the most up-to-date and accurate population layer) to the much finer-grained hexagon layer held major advantages. It allows not only for detailed accessibility modelling, but also for the fine-grained population disaggregation that enables a robust delimitation of urban, rural and dense rural settlement types within the eThekwini metropolitan area. This methodology has thus contributed to improved accuracy and, as a result, has enhanced confidence in the project recommendations.

The methodology used is felt to be robust and to provide a technical solution to accurately disaggregate data and classify settlements types. It is important to eliminate subjectivity from the classification so that it does not become open to political influence. This is especially important if the demarcation impacts on the accessibility of services and the levels of service provision.

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