EVIDENCE-BASED SPATIAL ANALYSIS FOR IMPROVED URBAN PLANNING AND MANAGEMENT

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Abstract:
This paper exhibits methodologies for optimising municipal revenues within the confines of existing tax systems and revenue instruments, and for the testing of urban planning proposals aimed at uplifting the plight of the urban poor in South Africa. These methodologies employ quantitative and spatial modelling techniques and a wealth of datasets readily available to cities, without the need for costly, primary research.

Results indicate that cities in South Africa have significant scope for optimising their revenues without changing the tax system, introducing new revenue instruments or raising rates and taxes. This is possible through spatial overlays to locate properties not registered on the billing system, to identify incorrect billing relative to land use and to locate high value outstanding debtors.

The paper also demonstrates that planning for alleviation of urban poverty and the optimal functioning of cities based on accepted theory or winning recipes in different contexts are likely to entrench or even aggravate the very negative effects that planning wishes to eradicate, and in almost all cases will drain city coffers.

It then proceeds to offer a number of techniques and case studies demonstrating how urban planning problems and proposed solutions can be identified, assessed and refined. These include the identification and ranking of urban nodes, the identification of high-value investment areas and employment opportunities in city spaces, the testing of spatial development proposals and the development of spatially-based capital investment frameworks.

Key words:
Spatial modelling and analysis, bid rent, property rates, city revenue optimisation, spatial prioritisation, capital investment framework.

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Note: 1 South African Rand equals 0.098 US Dollar as at 16 November 2013
1. Introduction

1.1 The issue

The South African population is now largely urbanised. By 2011 68% of the country’s population resided in urban dwellings compared to 54% in 1996 (Quantec, 2013a). Urban poverty, as elsewhere in the global South, has become a real feature of South African cities. This is a matter of great concern to all spheres of government, to civil society at large, and of course, to those subjected to urban poverty. The dedication of all spheres of the South African government in eradicating this scourge is evident. Legislation has been comprehensive revisited to ensure that the country becomes a developmental state, all government policies and strategies are focussed, to varying extents, on poverty eradication, and various institutional mechanisms such as the Housing Development Agency have been created to ensure that pro-poor policies are implemented. There have been marked successes. Since the advent of democracy in South Africa more than a million homes have been constructed for the poor, and over 60% of city capital budgets over the course of the past decade have and continue to be directed at the poor through the creation of municipal infrastructure and social facilities. The majority of urban residents, regardless of income level, now enjoy high levels of access to infrastructure and community services.

Yet urban poverty not only persists, it is on the rise. Many causes for the rise of urban poverty have been identified, including the apartheid spatial structure that settled black people some distance away from economic centers and opportunities, the global trend of increasing urbanisation, influx of poor immigrants from neighbouring countries, the 2009 global economic recession and sluggish recovery since.

The contemporary approach to urban poverty alleviation in South Africa, in line with accepted theory, is premised on providing the poor with low income housing in developments sufficiently dense to ensure the economic functioning of Bus Rapid Transport (BRT) systems to allow the poor subsidised transport to Central Business Districts (CBDs) to secure and retain employment. In this approach the poor, depending on income level, either qualify for free house ownership or subsidised house ownership. All eight metropolitan municipalities have or are in process of implementing BRT systems. In short, compact cities are pursued. This approach has been further refined in the recently adopted Urban Networks Strategy (National Treasury, 2013a) that prioritises public sector capital spending in primary nodes and along development corridors that link primary nodes and poor settlements that meet minimum threshold targets in terms of population size and distance from the primary node.
Many organs of state, cities in particular, argue that they are unable to meaningfully address the plight of the poor given revenue constraints. The National Fiscus, following years of sustained increases in the funding of redistribution and upliftment programmes, and further pressured following the 2009 recession and subsequent dampened economic growth, is experiencing strain. The country’s consolidated fiscal framework projects expenditure at 32.9% of Gross Domestic Product, and a budget deficit of 5.2% (National Treasury, 2013b). Municipal ratepayers also feel the strain. Municipal service charges are increasingly becoming unaffordable (SACN, 2013). In 2009 poorer households spent between 10-14% on municipal services, and higher income households between 6-7%. By 2012 spending on municipal services increased to between 11-19% for poorer households, and between 8-9% for higher income households, depending on the exact basket of municipal services offered in each city.

1.2 Outline
This paper articulates innovative ways to enhance municipal revenue streams within existing tax systems and affordability limits that can contribute to finance efforts to alleviate the urban poverty problem. Existing tax systems and financing poverty upliftment requires redistribution of income. For purposes of this paper redistribution of income is assumed to be morally just and desired by society as a whole, and that both contributors and intended recipients expect optimal results with funds so made available. Furthermore, since the focus is on municipal revenue applied to urban poverty alleviation, it is assumed that funds earmarked for urban poverty alleviation are to be spend on shaping an urban structure that provides affordable and efficient accommodation and transportation to the poor, and decent access to employment opportunities. This begs the question as to whether urban planning is successful in the optimal utilisation of funds allocated to uplifting the poor.

This paper therefore also tests some policy and planning assumptions to addressing urban poverty in South Africa following an evidence-based approach that employs a body of available documentation and datasets, as well a variety of assessment methods and instruments, much of which includes the establishment of spatial relationships, modelling and analysis to provide a deep understanding of real issues and the identification of options for improving urban management.

1.3 Research material and methods

Materials
The study sought to optimise municipal revenue streams within the constraints of existing tax systems and to develop a spatial understanding of the current and probably future impacts of contemporary
approaches to urban poverty alleviation as expressed in municipal spatial development frameworks and municipal budgets.

Datasets employed for purposes of modelling, presentation and analysis were selected at the hand of the following criteria: (1) the nature of the datasets must respond to the research questions posed; (2) data must be commonly available to each South African city without the need to conduct primary research, to allow for easy replication of the chosen methodology; and (3) it must be possible to model and analyse the data spatially. Datasets selected included the cadastre set, road network, aerial photography, municipal immovable asset register, municipal budget, municipal billing system, the municipal property valuation roll, various land use management schemes in operation in various parts of the metropolitan area, register of development applications, socio-economic data from Statistics South Africa as well as shape files used in the development and presentation of the spatial concepts included in the municipal spatial development framework.

Approved planning documents for these municipalities were reviewed to understand and assess policy positions and planned initiatives.

**Methods of assessment**

Relational databases were constructed (see Figure 1) that enabled relational spatial modelling and analysis. A range of assessment methods were applied solve the research questions posed including (1) spatial accessibility analysis to determine access to municipal services; (2) land rent analysis which is a form of accessibility analysis used to model property values in distance from CBDs; (3) gravity analysis that assesses building massing and accessibility, the results of which indicates the existence or lack therefore of a spatial node and where it exists, the relative strength of that node; and (4) spatial overlays to assess municipal revenue, expenditure and outstanding debt spatially.

Spatial modelling, analysis and presentation of results were generated within the geographic systems’ environment.
2. How to get more from the same purse

2.1 The opportunity lies in spatial reconciliation of available municipal data and sound administration

How to raise municipal own revenues without increasing intergovernmental transfers, introducing new tax instruments or raising municipal rates and taxes? The simple answer lies in making the tax system as efficient as possible, but practice is often not so simple.

A South African metropolitan municipality will have between 168 802 to 682 629 cadastre entities. Many of these cadastre entities, in turn, may accommodate multiple tenants. Think for example of a skyscraper or shopping center, each with several to many tenants, each of whom should receive a municipal account. As a consequence a medium to large metropolitan municipality may have upwards of a million customers. To further complicate matters, different customers can have one or multiple municipal accounts for the same property, depending on whether they are property owners obliged to pay property rates, consumers of one or several municipal services, or both. Now a municipality potentially has millions of customer accounts.
<table>
<thead>
<tr>
<th>Metropolitan municipality</th>
<th>Size of municipal area (Hectare)</th>
<th>Number of people (2011)</th>
<th>Number of households (2011)</th>
<th>Gross Density (HH/Ha)</th>
<th>Gross Density (People/Ha)</th>
<th>Nr of cadastre entities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffalo City</td>
<td>253 616</td>
<td>755 200</td>
<td>223 569</td>
<td>0.88</td>
<td>2.98</td>
<td>173 271</td>
</tr>
<tr>
<td>Nelson Mandela Bay</td>
<td>195 902</td>
<td>1 152 114</td>
<td>324 291</td>
<td>1.66</td>
<td>5.88</td>
<td>248 635</td>
</tr>
<tr>
<td>Mangaung</td>
<td>628 429</td>
<td>747 432</td>
<td>231 921</td>
<td>0.37</td>
<td>1.19</td>
<td>168 802</td>
</tr>
<tr>
<td>Ekurhuleni</td>
<td>197 554</td>
<td>3 178 470</td>
<td>1 015 464</td>
<td>5.14</td>
<td>16.09</td>
<td>528 549</td>
</tr>
<tr>
<td>City of Johannesburg</td>
<td>164 536</td>
<td>4 434 827</td>
<td>1 434 861</td>
<td>8.72</td>
<td>26.95</td>
<td>618 503</td>
</tr>
<tr>
<td>City of Tshwane</td>
<td>629 830</td>
<td>2 921 488</td>
<td>911 532</td>
<td>1.45</td>
<td>4.64</td>
<td>428 573</td>
</tr>
<tr>
<td>eThekwini</td>
<td>229 124</td>
<td>3 442 361</td>
<td>956 706</td>
<td>4.18</td>
<td>15.02</td>
<td>457 739</td>
</tr>
<tr>
<td>City of Cape Town</td>
<td>244 506</td>
<td>3 740 026</td>
<td>1 068 564</td>
<td>4.37</td>
<td>15.30</td>
<td>682 629</td>
</tr>
</tbody>
</table>

Table 1: Selected South African metropolitan built environment data

Regardless of whether a municipal customer pays rates, tariffs or both, the basis of municipal revenue classification remains land use. But this again is not so simple. Metropolitan municipalities in South Africa formed following the restructuring of the system of local government in 2000, and really are collections of several local municipalities amalgamated into metropolitan structures. Each of these local municipalities had (often) outdated land use management schemes and different definitions of land use. Municipal property valuation rolls are prepared at four-year intervals, based on land use classification systems not necessarily aligned with that of land use management schemes. Land use in any normal town or city that has economic activity and/or population growth continually changes through new township development, sub-division, rezoning and approval of new business licenses and building plans. These changes and additions are updated once annually with the production of supplementary valuation rolls. This situation creates various issues relating to completeness of revenue, tax classification and timing of revenue.

Municipal revenue enhancement initiatives largely follow an accounting approach: an accountant analyses the debtor’s book, conducts debtor age profiling, and identifies customer accounts outstanding longer than an acceptable period, say thirty days. The account is then handed to a debt collections agent for recovery. This traditional approach does not optimise municipal revenue, at best it is merely good operating debtor management practice.

The proposed solution to municipal revenue optimisation entails:

1. Spatial reconciliation of data to ensure that all cadastre entities are accounted for at the actual land use;
2. Reconciliation between verified spatial data and the municipal property valuation roll (including supplementary rolls) to ensure that all properties are reflected in the roll and rated at the correct land use;
3. Reconciliation between verified spatial data and the municipal billing system to ensure that the correct tariffs are charged; and
4. Analysis of classification anomalies, properties not accounted for in the valuation roll and/or billing system, high value outstanding debtors and potential improvements in revenue-related policies to optimise land use classifications for revenue enhancement purposes.

2.2 Successes and scope for revenue enhancement

Buffalo City: raising revenue without increasing tariffs in an election budget

The Buffalo City Metropolitan Municipality required an additional R 70 million per month in revenue to finance its 2014/15 election year expenditure budget, with limited scope to increase rates and tariffs. Shortly before finalisation of the budget the municipal property valuation roll was updated, following the approach outlined in this paper. The exercise identified 2 275 additional properties for inclusion in the valuation roll, and property sub-divisions and consolidation were also dealt with. Additional property rate categories were created and a number of properties were reclassified. This resulted in revenue potential of R 847 million for the 2013/14 financial period, 25.48% more than the R 675 million property rates’ revenue originally projected for the same period, without raising property rates.

Ekurhuleni Metro: magnitude of incompleteness of revenue

The Ekurhuleni Metropolitan Municipality has an area of jurisdiction spanning 179 093 hectares. Matching of the municipal property valuation roll to cadastre data revealed that 42 934 properties (8% of all properties in the metro) representing 37% of the area have not been included in the valuation roll.

Using averaged values across the entire valuation roll, the market value of the properties omitted is R 519.56 billion, and the resulting loss in annual property rates revenue is R 8.87 billion. The potential revenue lost is about four times the total annual capital budget of the metro, or a third of the total metro annual budget.
**Emalahleni: picking high-value, low hanging fruit**

Emalahleni is a secondary city with a strong mining and ancillary economy. Its municipality was placed under administration in 2011, and could barely pay its salary bill, with essential service delivery expenditure curtailed. The provincial authorities requested an assessment of revenue enhancement potential. Analysis of the central business district revealed not only a high level of outstanding debt (see Figure 3), but that much of the outstanding debt can be attributed to a few large corporates, government departments and institutions who have the ability to pay for services. Additionally, one of the largest shopping centers in the province that at the time of assessment has been in business over some eight months, was not registered in the municipality’s billing system. Various other properties, including several townhouse complexes, could also not be traced in the billing system.

![DISTRIBUTION OF DEBT](image)

**Figure 3: Completeness of debtors and distribution of debt in the CBD of Emalahleni**

Further investigation in an adjacent industrial park revealed that sizable industrial entities are not listed in the municipality’s billing system, or consume less electricity and water than would an average household (see Figure 4).
2.3 Concluding remarks on urban municipal revenue enhancement

The few case studies presented in this paper demonstrates significant scope for municipal revenue enhancement through timely and comprehensive capturing of the tax base at the appropriate land use classification, after which normal debtor management practice applies. There are however also other positive spin-offs from such an exercise. The size and distribution of municipal debtors, when matched with land use data, can be used as proxy data to develop assumptions on the distribution of employment opportunities in a city. It also, together with economic data such as Gross Value Add by industry and employment by industry, informs planning decisions on appropriate land use configuration to support economic growth and employment creation. It furthermore also assists in developing appropriately nuanced levels and standards of municipal infrastructure services in physical space.

3. How well do we serve our urban poor?

3.1 General introductory observations

There is a wealth of literature that highlight intense debate on the best means to uplift the poor and to move towards sustainable urban development. The matter of most appropriate urban form often appears to feature at the center of this debate. It’s compact cities versus sprawl. Some, such as Neuman (2005), concludes that conceiving a city in terms of process over form is more likely to lead to the attainment of the goal of a sustainable city. Key stumbling blocks in attaining consensus appear to be differing normative frameworks and the lack of consensus on a crisp set of urban conditions that constitutes sustainability. Sanyal defines key challenges that urban planning must overcome to remain relevant,
including how to integrate spatial with socio-economic planning to develop solutions to urban problems, which is difficult given considerably different epistemological orientations, and the lack of robust descriptive and normative theories of planning practice.

The UN Habitat (2009) notes the emergence of a number of new and at times overlapping approaches to urban planning, such as strategic spatial planning, use of spatial planning to integrate public-sector functions and planning to produce new spatial forms such as compact cities and new urbanism. It recognises the positive qualities of these approaches, but notes that emphasis is directed at process, often to the detriment of outcomes. It further cautions that there is too much focus on the directive aspects of planning, with insufficient attention given to underlying regulatory and financing systems, and the relationship between planning and such systems. It also notes that planning has not yet resolved the best means on dealing with the major urban sustainability challenges of the 21st century, including rapid urbanisation, poverty and informality. The following sub-sections consider planning approaches in South African urban spaces in specific.

3.2 Settlement and transportation

Burdett and Sudjic (2011: 290) state that rapid urban growth in Johannesburg has outpaced transport infrastructure. Johannesburg over the past twenty years, like most of the larger metropolitan areas in South Africa, expanded its spatial footprint far beyond the requirements of natural population and economic growth (see Appendix A). In its first 120 years up to the advent of democracy in South Africa, the city grew its footprint to 737 045 955 m². In the 20 years since, the city expanded its footprint by 181 864 944 m². In short, it grew by 20% (see Figure 5). This growth is largely the result of government-led large-scale low income housing developments at the urban periphery. Reasons for the choice of location include the nature of the low income housing subsidy that requires a single detached dwelling on its own stand of defined size, availability of large tracts of inexpensive land at the periphery, and administrative preference for larger developments.

These low-income township developments have, by and large, been planned without taking transportation arrangements into account. As a result the urban poor spend up to 30% of disposable income on transportation, and for many, the prohibitive cost of transport outweighs the benefits of minimum wage.
3.3 Getting the urban poor to places of employment

Applying the urban networks’ strategy to the Tshwane metropolitan area

Contemporary urban planning thinking in South Africa recognises the concepts of a hierarchy of nodes and of hierarchical connectedness. The Urban Networks’ Strategy intends to link previously disadvantaged areas with a minimum population threshold of 40 000 people each and that are located within a radius of 7.5 km of the CBD of a city. Capital investment will then be focussed on qualifying townships, and on the corridors that link these townships and the CBD. How likely is this strategy to succeed in uplifting the plight of the poor? Consider Tshwane, the capital city of South Africa.

None of the poor townships meet the requirement of being situated within 7.5 kilometers from the CBD (see Table 2). In the event that these parameters are ignored and a fully subsidised BRT system is implemented linking these townships to the CBD, the annual operating cost of the system would amount to about R 6.95 billion. This translates into an annual subsidy of R 68 082 per unemployed person, which is more than double minimum wage, or over 40% of the total revenue budget of the city.
<table>
<thead>
<tr>
<th>Townships</th>
<th>Population</th>
<th>Distance from CBD</th>
<th>Unemployment</th>
<th>Cost of BRT</th>
<th>Subsidy cost per person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric</td>
<td>nr km</td>
<td>nr R R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hammanskraal</td>
<td>21 345</td>
<td>40,2</td>
<td>3 228</td>
<td>1 768 800 000</td>
<td>547 955</td>
</tr>
<tr>
<td>Mahopane</td>
<td>110 972</td>
<td>36,7</td>
<td>17 694</td>
<td>1 614 800 000</td>
<td>91 263</td>
</tr>
<tr>
<td>Atteridgeville</td>
<td>64 425</td>
<td>13,8</td>
<td>10 320</td>
<td>607 200 000</td>
<td>58 837</td>
</tr>
<tr>
<td>Laudium</td>
<td>19 102</td>
<td>11,3</td>
<td>720</td>
<td>497 200 000</td>
<td>690 556</td>
</tr>
<tr>
<td>Eersterust</td>
<td>29 676</td>
<td>15,6</td>
<td>3 642</td>
<td>686 400 000</td>
<td>188 468</td>
</tr>
<tr>
<td>Mamelodi</td>
<td>334 577</td>
<td>20,9</td>
<td>57 591</td>
<td>919 600 000</td>
<td>15 968</td>
</tr>
<tr>
<td>Nelmapius</td>
<td>56 111</td>
<td>19,4</td>
<td>8 853</td>
<td>853 600 000</td>
<td>96 419</td>
</tr>
<tr>
<td>Total</td>
<td>636 208</td>
<td>157,9</td>
<td>102 048</td>
<td>6 947 600 000</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>90 887</td>
<td>22,6</td>
<td>68 082</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDP thresholds</td>
<td>min 125 000 - 200 000</td>
<td>7,5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2: Reaching out to the poor in Tshwane**

Source (population and unemployment): Statistics South Africa 2011 Census

But assuming the funding could be found, and BRT arrangements put in place, would the poor find work in the inner city? Bid rent theory, the skills profile of urban poor, spatial economic data and the function of the inner city suggest not. The economic sectors absorbing high levels of labour are largely situated outside the inner city. Four out of every five jobs have preference for locations outside the core city (see Figure 6). The remainder of jobs are largely those offered by various spheres of government. Increasing the supply of labour to the inner city will not increase the demand on government’s side.

*Figure 6: Location of jobs in Tshwane*

Source: Quantec formal and informal employment per industry 2011
Current urban planning in Ekurhuleni will not improve the plight of the poor or functioning of the labour market, and is not financially viable

The municipal low income housing programme largely locates development at the urban periphery of the metropolitan area, with some smaller developments adjacent to established towns within the urban structure (figure 8). These can be grouped into four main historically disadvantaged areas situated along the urban periphery, considered to be pockets of poverty, and one smaller area, located centrally in the metropolitan area (figure 7). The planning intent is to link these disadvantaged areas to major economic centers and corridors through the introduction of an Integrated Rapid Public Transport Network (IRPTN). The municipal spatial development framework identified over 200 spatial structuring elements consisting of central business districts, train stations and corridors. Minimum density targets of 100 housing units per hectare for the spatial structuring elements were established to ensure sufficient ridership and viability of the IRPTN. Phase 1 of the IRPTN, indicated in figure 8, will link the disadvantaged areas in the north and south to main economic centers in between to ensure access to employment opportunities.

This plan has intuitive appeal to many urban planners and politicians alike. It aims to provide public transportation to the poor to strong CBDs, to link significant nodes with each other through an expanded
public transport network, and to introduce minimum densities. But how does its proposals stand up against spatial and quantitative assessment? To connect poor areas to all concentrations of employment opportunities would require a public transportation system spanning 343 kms, at an annual operating cost of R 13.7 billion – more than 50% of the total budget of the city and seven times the transport subsidy allocated to the city. Average densities in the previously disadvantaged areas, CBDs and around passenger railway stations all fall far short of the densities required for a viable transportation system. There is not sufficient demand for low income housing in the next 25 years’ to achieve the density targets, and supply arrangements would not be able to cope. The cost of achieving the required density in high-rise housing solutions has been estimated at equivalent to 213 years’ of the current total capital budget of the city, and at the current rate of housing delivery it would take 462 years’ to supply sufficient housing. This situation is aggravated by the fact that the municipality is committed on projects to develop large-scale low income housing developments at the urban periphery for the next 15-20 years, with some infill projects adjacent to major centers. Projects where large-scale housing demand manifests are prioritised for in-situ development, hence the location of these projects are not well aligned with the spatial structuring elements identified for the IRPTN (Boshoff and Fourie, 2012).

Phase 1 of the IRPTN will also not meaningfully improve access to employment opportunities. Within the core economic triangle alone (Kempton Park, Boksburg, Benoni and Germiston), the areas to which the urban poor are to be connected to for improved employment access, 41 411 people are informally employed and 31 575 are unemployed. This indicates the inability of the core economic triangle to absorb labour.

Employment by industry analysis as well as skills level data are useful in understanding whether job opportunities are located in urban centers. Some 36% of the total formal Ekurhuleni workforce is semi-skilled or unskilled (Quartec, 2013b). The dominant employment industries are manufacturing (18%); wholesale and retail trade (21%); finance and related services (21%), and various spheres of government (26%). Improving the access to employment opportunities will not stimulate the demand for labour in government services. Manufacturing tends towards heavy industrial in Ekurhuleni and mostly locates outside of urban centers. According to McCann (2010), bid rent theory predicts that wholesale, characterised by small margins, the need for large land lots and access to major road networks, will locate at the urban periphery. Retail will be located in both the CBD and across the urban fabric, whilst services will place a premium on CBD locations. So where are the jobs?

**How to locate job opportunities – the Ekurhuleni case study**

Accessibility is an important characteristic of metropolitan areas and is often reflected in transportation and land-use planning goals (Handy & Niemeier, 1997). First introduced by Hansen (1959) (Andres
& Michael, 2011), gravity modelling has been used extensively to investigate the determinants of relationships in trade, capital investment and migration between origins and destinations, commodity flows, traffic flows, residence-workplace trips, market area boundaries etc. (Beenstock & Felsenstein, 2012). In general terms, gravity models state that the interaction between two centres is in direct proportion to their size and in inverse proportion to the distance (at a certain power) between them, taking into account additional factors in the spatial impedance (such as speed) required to travel to each of the destinations (Constantin, 2004).

The formula for conducting a gravity analysis is provided below. The formula assumes that accessibility at building \( i \) is proportional to the attractiveness (weight) of destinations \( j \) surrounding \( i \), and inversely proportional to the distances between \( i \) and \( j \) whereas:

- \( Gravity^r[i] \) is the Gravity index at building \( i \);
- \( W[j] \) is the weight of destination \( j \);
- \( d[i,j] \) is the geodesic distance between buildings \( i \) and \( j \); and;
- \( \beta \) is the exponent for adjusting the effect of distance decay (Andres & Michael, 2011, p. 10)

\[
Gravity^r[i] = \sum_{j \in G - \{i\}} \frac{W[j]}{(\beta d[i,j])^\beta}
\]

The gravity type index thus captures both the attraction of the destinations (\( W[j] \)) as well as the spatial impedance of travel required to reach those destinations (\( d[i,j] \)) in a combined measure of accessibility (Andres & Michael, 2011).

In reality, conducting gravity analysis can be constrained or limited by the availability of data. The locational aspect of the data is often available (for example the location of employment activities).
Attribute data used to measure the weight of the destination is sometimes more difficult to obtain (for example the number of employment opportunities at each specific employment activity). Yet despite the data limitations, gravity analysis provides urban planners with invaluable analytical means to measure specific spatial occurrences and to rank these occurrences in some form of hierarchy. The results of gravity analysis in Ekurhuleni show some interesting and startling results. The center of building massing in several instances have shifted outside the historic boundaries of CBDs. More importantly, several new strong nodes and some corridors have formed with higher gravity rankings than that of the traditional CBDs, indicating that the latter are in decline, that capital formation is targeted elsewhere and that employment opportunities migrated outside of CBDs.

With regards to the question of the location of retail employment opportunities, Figure 10 indicates the location of shopping centers in Ekurhuleni. The decline in the CBDs of the nine main towns have led to the rise of the shopping center phenomenon that created more, and in several cases, stronger nodes that act as a counterforce against the revitalisation of the old CBDs. The CBDs collectively comprise 2 170 ha and market value of R 19.9 billion. The 258 shopping centers only consume 140 hectares, but boast an impressive R 3.7 billion’s worth of market value. As a result the market value of shopping centers average R 2 857/m² compared to the R 1 619/m² of the CBDs. The value of properties in an 1 km radius around shopping centers is a notable R 122 842 million. Between the shopping centers and an 1 km radius
the Municipality receives R 1 095 million per annum in property rates, compared to R 175 million in the CBDs. Employment opportunities are spread more evenly across the metropolitan space that holds the benefit of bringing more job opportunities closer to many people, but also counters the demands of an effective public transportation system that ideally requires fewer but denser points and routes.

3.4 What these examples tell us
The case studies offered in this paper expose several flaws in urban planning in South Africa, which is surprising since the profession has the necessary theoretical foundation and quantitative techniques to avoid the following pitfalls. The dominant flaw is the automatic assumption that inner cities or CBDs are the strongest nodes with the greatest labour absorption capabilities, apparently based on the historical strength of such nodes. The second major flaw is the assumption that the supply or labour will be sufficient to increase employment in a particular spatial location, without consideration of the match of the skills profile of the unemployed and the economic function of the spatial location to which labour is to be supplied. Last, but no less important, insufficient consideration is given to the benefits and costs of locating and transporting the poor in relation to the needs of the local economy.

3.5 Towards rigorous planning: spatial modelling and prioritisation in Ekurhuleni
Recognising the value of spatial modelling and analysis, and appreciating the sheer magnitude of funding required to finance pro-poor urban interventions, the metro aggressively rationalised the number of spatial structuring elements in its spatial development framework.

A key paradigm shift was the realisation that the metro is not able to spread its capital investment across the municipal space each year: if the capital budget is equally divided across land within the urban edge, then the available capital budget is around R 15 000/ha, not even enough to provide infrastructure services to one low income house.

It therefore adopted a spatially-based capital investment framework that directs its capital budget towards protection of its current revenue streams.
streams through investment in infrastructure upgrading and renewal in the spatial structuring elements (e.g. nodes and corridors) that yield high net revenue for the municipality’s coffers (see Figure 11), and towards providing municipal infrastructure and community services to under-serviced areas (see Figure 12).

Identifying high-revenue generating areas were determined by spatially overlaying the Municipality’s billing system on cadastre data. The accessibility index presented in Figure 12 considers the weighted access to all municipal services and identifies both priority intervention areas where service provision is below acceptable norms and where low income housing projects are underway.

Much of land in Ekurhuleni carries high construction cost premiums due to factors such as dolomite and shallow mining activity. A cost surface map was constructed of the metropolitan space that identifies and ranks areas according to the level of cost premiums to be paid for development to be undertaken (see Figure 13).

Furthermore, the 5,065 land parcels previously identified for low income housing developed were spatially assessed based on access to municipal infrastructure services (both bulk and reticulation), municipal amenities and other public sector goods (e.g. the availability of schools and classroom capacity), and the cost of providing such services where capacity does not exist or is insufficient. Ratings were allocated to all land parcels that enables spatial targeting and prioritisation (see Figure 14).
This again signals a paradigm shift from selecting the largest land plots for housing development towards well located plots with the least infrastructure and associated capital cost implications.

Together these various spatial instruments allow the Municipality to make more informed, considered capital investment decisions towards sustainable city growth, optimal allocation of scarce financial resources and finite land, and towards uplifting its urban poor.

These instruments as a collective, whilst proving valuable in gaining a deeper understanding of the city and in supporting informed urban planning decision-making, do however not provide all the answers. Whilst shedding light and providing answers to some questions, they raise even more questions, such as which is the best spatial and transportation logic and structure for the city, how to allocate land and zone land, and how to balance and time investments in economic growth versus poverty alleviation. These questions, in turn, force urban planners and decision-makers to apply their minds to understand issues, problems and opportunities, and to develop and test feasible options.

4. Conclusions

Cities are highly complex and evolving structures. Planning for alleviation of urban poverty and the optimal functioning of cities should not be based on accepted theory or winning recipes in different contexts only that may inadvertently entrench the very effects that planning wishes to eradicate. Robust spatial modelling and analysis employing datasets commonly available to cities prove to be invaluable for gaining a deep understanding of city spaces, and the design and testing of urban development
solutions. Spatial analysis likewise supports the optimisation of municipal revenues within the confines of existing revenue instruments, structures and client portfolios, creating much needed revenue to finance city economic growth and poverty eradication.
Appendix A: Growth in South African city footprints

BUFFALO CITY CITY DEVELOPMENT OVER TIME

CITY OF CAPE TOWN CITY DEVELOPMENT OVER TIME
References