The morphological / settlement pattern classification of South African settlements based on a settlement catchment approach, to inform facility allocation or service delivery

Abstract
South Africa, as a developing country, is faced with a number of challenges, one of which is the provision of social facilities in an equitable and sustainable manner. The problem is compounded by uneven and dualistic development arising from the apartheid era as well as geographical variations in respect to resource availability. This has resulted in a wide variety of development patterns and resultant settlement types ranging from well-developed neighbourhoods usually found within city limits to under-developed settlements in deep rural areas. Development patterns impact on the provision of social services as geographical dispersion and low density sprawl are major factors influencing the efficiency of service delivery. With the above in mind, it is of the utmost importance that a critical evaluation of settlement structure and patterns is undertaken to directly inform the manner in which social services are delivered in different settlement types.

Using the CSIR's accessibility analysis and facility location approach, the whole country was subdivided into service catchments for social service provision around the towns/settlements identified in the CSIR/SACN typology. Then, using other national datasets, the spatial distribution structure of the dwelling points that represent the distribution of buildings in each of the catchments was analysed and classified. This was done to better understand the morphological structure of each catchment, since morphology is important in understanding the character of spaces and as such is critical to the planning of facility location and distribution networks. Nine dominant settlement types were identified and these can inform decision making with respect to the best options available in the distribution of services so as to better match settlement distribution.

This paper briefly indicates the approach used to allocate the dwelling frame and SPOT building count data to a national set of service catchments. Following this, it discusses the process used to analyse and classify these catchments according to their morphology. It highlights the nine main types identified and then provides some detail on the most common environments where these catchments occur. It also addresses the implications for service delivery of each of the different settlement types.

Keywords
Settlement Morphology, Social Facilities, Location, Rural

1. Introduction

The delivery of services to citizens has always been one of the expected duties of any government. Good service delivery contributes to the improvement of standards of living and quality of life while poor service delivery undermines these. Most democratic constitutions around the world put pressure on governments to provide essential social services needed by its citizens. This is further emphasized by the United Nations through its Sustainable Development Goals. Since countries differ with regards to development, some countries are consequently doing better than others with regards to delivering basic services to citizens. Developing countries, in particular, still face major backlogs in service delivery, both in urban and rural areas. According to Wild *et al.* (2012), there is growing recognition that, despite considerable increases in resourcing, service delivery is still failing in many developing countries; and political and governance factors are some of the contributors to this failure. However, where delivery of services is occurring, a better understanding of the settlement morphology (the form/structure which settlements take) can improve how services are rolled out.

In South Africa, an often overlooked yet crucial component in service provision and distribution is the understanding of the varying settlement patterns and morphologies. Better understanding of these patterns can ensure that facility provision closely relates to residential development patterns. It is known that dense areas are more cost effective in terms of the provision of services than sparse areas. Analysing catchments around identified central service points enables facility planning to respond according to the unique character of each catchment thus making it possible to target and customise service distribution networks.

Over the past decade much research on service delivery, especially of social services, has focused on aspects such as facility population thresholds, distance thresholds and ranges, population density and service capacity, with limited attention given to the structure of settlement morphology in relation to the distribution and delivery of services. This is of particular importance in the case of non-urban settlements that did not develop in the same manner or pattern as conventional urban settlements that have defined places of high concentration. Thus, it is the purpose of this paper to evaluate and discusses the observed settlement patterns/morphologies in South Africa and how these different settlement configurations could affect the provision and distribution of services and; inform governments and other service providers in delivering services in different contexts.

To enable the analysis of areas, the project first demarcated the country into wall to wall catchments around service points. Following an analysis of each catchment according to its settlement dwelling pattern (morphology) was then performed. Each catchment was profiled and includes information such as where people live, how far they are to a closest town/node, population density per catchment and settlement morphology, amongst others, all of which are crucial for service delivery planning with the intention of informing planning standards for social facilities and service delivery in general.

The following section focuses on local and international literature on the matter of service delivery and settlement morphology.

2. Literature Review

Fox and Meyer (as cited in Kanyane, 2010) argue that public service delivery is the provision of public activities, benefits of satisfactions; the range of public services provided relates both to public goods which are tangible and to services which are intangible. Service delivery is one of the important tasks of every government around the world and the provision of basic services is one of the determining factors of a progressive government. Governments are under pressure to provide these services to citizens as doing so leads to the betterment of the citizens' lives and also a step towards the global goal of poverty alleviation and equity as highlighted by the United Nations Sustainable Development Goals formulated in 2015 (www.un.org.). Given this pressure, there have been considerable efforts by governments all around the world to streamline service delivery; however, in developing countries, this has been somewhat thwarted by a number of issues relating to corruption, technical know-how, lack of effective policies, and so on. As noted by Wild *et al*. (2012), despite significant increases in resourcing, public service delivery is still failing in many developing countries. This slacking behind in service delivery has given rise to riots and strikes by citizens demanding what they believe they deserve.

Amidst all this continuing tension, what remains a core challenge is the provision of services in an efficient manner while not compromising on meeting the citizens' needs. Settlement morphology, although often overlooked, has a strong impact on the distribution of services. The continuum of space is not uniform and thus requires each area to be dealt with according to its unique structure/character. Settlement morphology can be defined as the distribution or pattern of the dwellings and other structures of human development within a defined catchment or demarcation. Over the years, little has been done to include settlement morphology as one of the informants to facility provision and distribution. As noted by Bidwell (2001), low density settlement morphologies create diseconomies of scale and extra distribution costs for the production of any good or service.

Providing services to these areas has proved to be economically challenging due to the sparsity of the settlements and this impacts negatively on the costs of providing infrastructure and services. This could explain why sparse areas have often been overlooked.

The Organisation for Economic Co-operation and Development (OECD) published a report in 2008 regarding the issue of servicing sparse areas in its member countries. According to the OECD (2008) report, the discussion on service delivery is not complete without a consideration of the dilemma of equity versus efficiency. Equity pushes for services to be equally available to both dense and sparse areas. Efficiency on the other side favours areas of agglomeration since it is in these areas that high levels of efficiency can be achieved. Since agglomeration in the sparse settlements is not common, this puts inhabitants in these areas at a disadvantage. The unconventional and generally uncoordinated settlement patterns usually present in areas such as these pose a challenge to service providers, but it is argued that the better the areas are analysed and understood – the better the planners can respond to needs of services across areas.

Thus, planners need more 'spatially smart' ways of thinking. "Principles of efficient and effective service delivery should be emphasised and maintained in every developing country and every state should ensure that such principles are successfully implemented by each responsible person" (Byaruhanga, 2011:9). Research has been conducted in an attempt to develop solutions to issues such as settlement morphology or structure with regards to service delivery. The questions that government is often faced with when planning especially rural development policies for services and infrastructure are, 'who gets what and where and how much of it?' Nleya (2011) states that public policy inherently involves value maximisation within constraints and that decision makers in services provision have to decide on what constitutes an acceptable level of access, quantity and quality, and ascribe a different weight to each of these three different components of the service delivery matrix. Thus, one can argue that value maximisation without a proper understanding of settlement structure is not as effective.

Looking at the South African context, Khumalo *et al.* (2003) argues that the process of municipal service delivery in South Africa takes place not only within the context of political and institutional reforms, but also within administrative and financial constraints. Given these constraints, there has been considerable progress as the government has been investing in knowledge dissemination and the creation/revision of guidelines through legislature to aid in planning decisions. This is evident by such legislature as the Municipal Systems Act of 2000 which places the IDP as the mandatory overarching plan for every municipality in the country. There have been good initiatives like the Rural Household Infrastructure Programme (RHIP) of 2009, among many others, which have indicated the government's effort to improve the livelihoods of rural inhabitants in South Africa. These initiatives, however, fall victim to the scarcity of a sound scientific based rationale for distributing and allocating facilities.

Farrant (2007) argues that to a large extent spatial analysis had been entirely absent from most social and infrastructural planning. Although, research into social facilities and infrastructure spatial analysis has been conducted in South Africa for the metropolitan areas of some provinces and a few municipalities, most small municipalities in South Africa still face difficulties with regards to spatial analysis for social and infrastructure planning. Small local municipalities often rely upon ward councillors to inform them about what communities need. This, however, creates an opportunity for imbalanced service provision as some councillors will have more say than others and or be more politically affiliated.

To support the sustainable distribution of social facilities, the Department of Rural Development and Land Reform (DRDLR) commissioned research in 2015 to develop differentiated standards for rural areas that would help address, but is not limited to, the morphological issues in relation to service provision in a range of rural areas. Prior to this project, a national morphological classification of areas to a settlement level has never been performed. This classification lets service providers plan on a settlement level as each settlement is unique. Thus, the work done will lay a foundation for future

work aimed at achieving efficiency in service delivery through an advanced understanding of settlement structure and pattern.

A similar morphological study was carried out in the United Kingdom (UK) but mainly focusing on population density in the rural areas. The Countryside Agency of the UK carried out a study in 2004 in which it claimed that the lack of geographical detail in distinguishing rural areas was an obstacle to the targeting of rural policies pertaining to service delivery (The Countryside Agency, 2004). For this reason it distinguished rural areas from urban areas using spatial analysis. As the government in England and Wales classified rural areas as having between 1 500 and 10 000 inhabitants, the agency recognised the shortfall in the definition through its lacking a spatial context. It could be that 9 000 people live within a $2km^2$ or a $50km^2$ area and surely the two cannot be treated the same even though the population may be the same. The former can be considered to be densely populated while the latter is sparse and therefore this information is critical for policy makers.

The Countryside Agency developed a grid covering England and Wales with 1 hectare cells (100m by 100m). To determine dwelling density, it used the Royal Mail's postcode addresses. The postcode addresses showed where houses were and this information was overlaid on the grid. Dwelling density was calculated by determining how many postcode addresses were in each one hectare cell in the grid. This density information was then constrained to the existing municipal boundaries. The result was that policy makers not only knew how many people lived in certain areas, but that the different densities of the areas were also available to aid in decision making. This assisted in the distinction between urban and rural areas. With such information, governments are able to develop specific policies like 'clustering of facilities' based on population densities within areas that are classified as remote or disjoint. In some instances, sharing facilities across boundaries was encouraged based on density information.

This approach, however, differs slightly from the one adopted in this study. For one, the Countryside Agency set out to distinguish between urban and rural areas while this approach seeks to classify each settlement catchment regardless of its location. This is because there are settlements in rural areas in South Africa that are as dense as urban areas. Thus, a classification of an area as rural does not tell the whole story. The approach followed in this study also adds the distance factor to the morphology, i.e. how many people live between 10km to 15km of a node/ service point. This morphological classification was performed on already defined catchments around potential service points.

The following section presents the research question and is then followed by a discussion on how the settlement catchment classification approach was used to classify every area in the country based on its morphology, population, economy, and so on.

3. Objectives /Research Questions

Can a better understanding of settlement morphology contribute to a better balance of equity and efficiency for public service provision throughout SA?

4. Approach & Methodology

Being that this research reported on here is but a single component of a larger project, it is necessary to firstly contextualise the process that took place prior to the settlement pattern analysis and classification that was undertaken.

In order to classify the pattern of a 'settlement' the first step was to define the 'boundaries' or the extent of the service areas around towns so as to enable the analysis of settlement patterns within a defined space. The analysis took abstracted concepts from Christaller's Central Place Theory (King, 1984) and principles of accessibility. Using the assumption that people would travel to the nearest central place / settlement that can provide the service or function they need, several datasets were used in unison, analysed and processed using Geographic Information Systems (GIS) spatial analysis

functions to create service catchments. The datasets used to undertake the demarcation included the following:

- The CSIR/South African Cities Network (SACN) functional settlement typology town points (CSIR)
- National Roads dataset (AfriGIS)
- ESKOM SPOT Building Count Points dataset (ESKOM)
- 1x1km grid of South Africa (CSIR).

With the above datasets and theoretical assumptions in mind, the first step was to create the service catchments. The goal was to assign every square kilometre grid cell in the country to its nearest town/settlement point based on the road network. The data was inputted into a routing solving operation to create an Origin-Destination (OD) distance matrix. The OD matrix finds and measures the shortest distance paths along a road network from multiple origins to multiple destinations. In this case, the centroids of the grid were used as the origins and the town points as the destination and the road network and each grid-cell was attributed to a town. Once all cells where attributed to the nearest town, the grid was dissolved to create catchments around each town, with the assumption that people located within that catchment would receive at least lowest order service from their closest town/node that was the central place in that catchment.

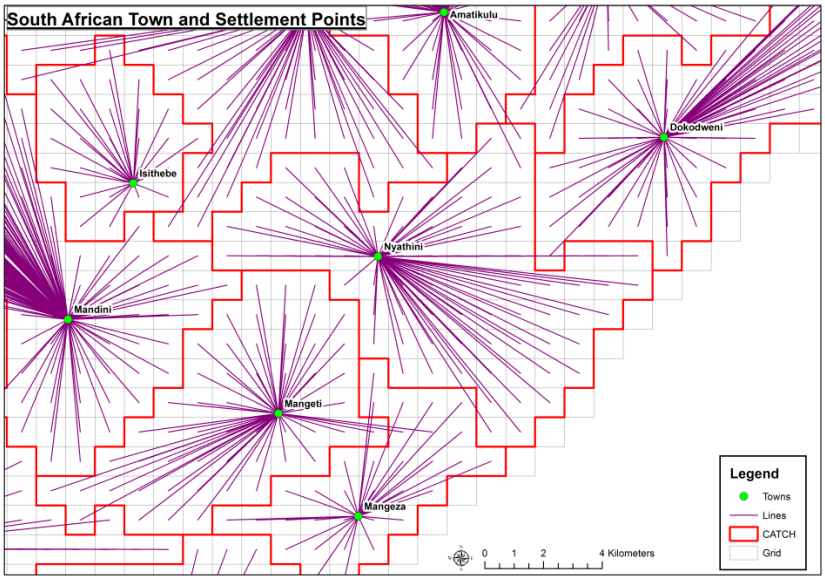

Figure 1: Creation of settlement catchments around places of concentration

Having created the catchments around all the towns, the SPOT Building Count (SBC) was overlaid on the catchments to begin the morphological/settlement structure analysis. See the figure below.

Figure 2: Updated SBC base layer (Source: Mudau 2010)

The SBC is a points dataset that maps the locations of building structures across the entire country, and is constructed through a process whereby:

'All the dwellings and building structures are mapped by points. Where up to date cadastral exists, one point per cadastral rule was applied to capture dwellings in urban areas. The townhouse group is represented by a point per cadastral portion. In rural areas, each building structure is mapped and represented by a point. All individual buildings structures around resorts and mines are mapped by points. All the mapping and classification of the structures are done through image interpretation and no field work has been conducted at this stage of the project.' (Mudau, 2010: 50)

The points dataset was used as a proxy for dwellings, and this along with satellite imagery was used to visually inspect, interpret, identify, analyse and classify the structure of settlements within each of the catchments in the country. Having approximately 12 000 000 points, it is one of the most comprehensive and widely used building count datasets in the country, and is thus the most appropriate and complete dataset that could be utilised to undertake this type of classification. An interpretive approach was employed in the morphological classification in each area through visual inspection, pattern analysis and interpretation of observed building and settlement patterns in each of the catchments.

Several other processes and datasets along with the building point dataset where used as control checks. A population and distance grid of $1km^2$ was created, this grid contained the distance of the centroid of the grid to the town point in the catchment and the population total in each cell. This grid was used to evaluate population densities in the catchment to evaluate whether it was fairly distributed, centralised or scattered. The distance attribute was used to evaluate the distance from the central point and how this related to the distribution of the population in the catchment. Google Earth satellite imagery was also used in instances of uncertainty which also added to the accuracy of the classification.

This process was undertaken for all catchments, and the results are presented in the next section of the paper.

5. Analysis Findings

Following the classification of all 1 328 catchments as set out in the methodology in the previous section, 9 major morphological classes where identified. Figure 3 below graphically depicts the 9 classes that were identified and classified through the analysis.

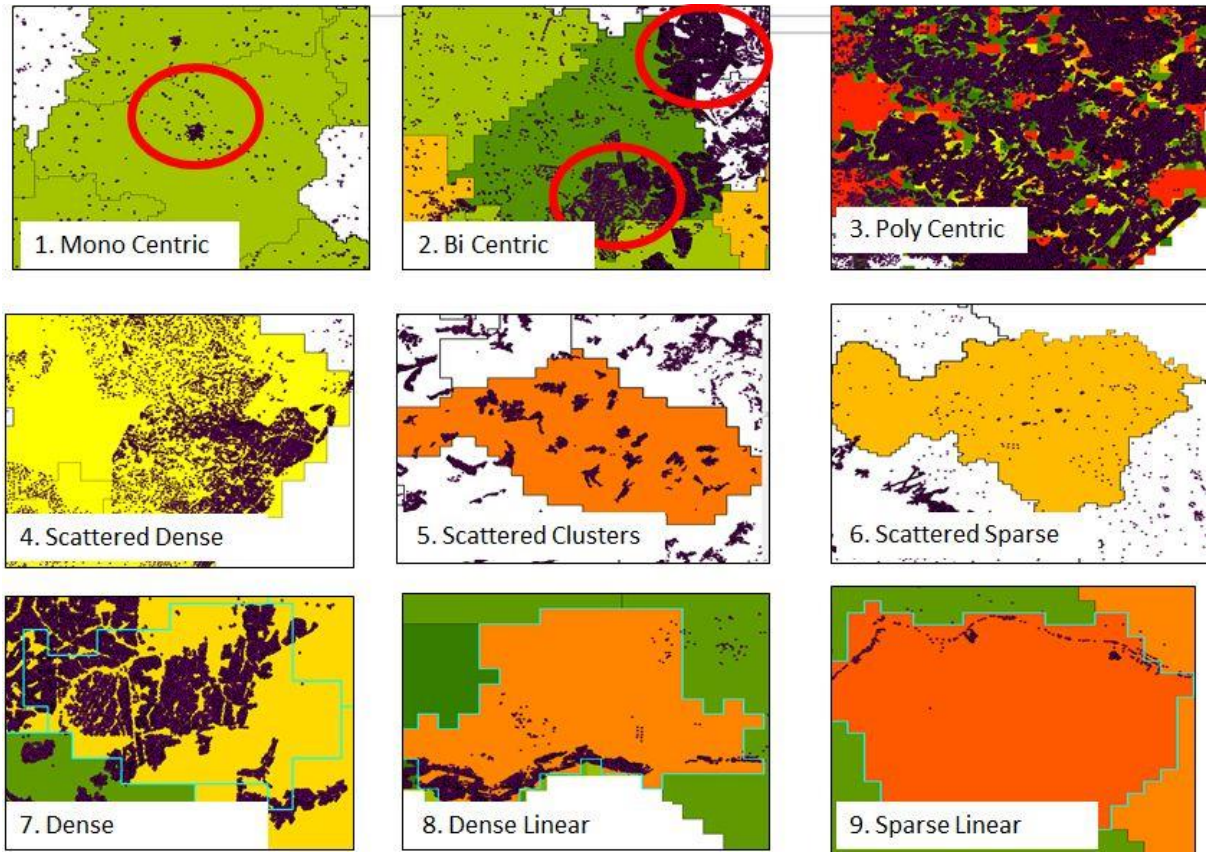

Figure 3: Nine identified morphology types

The key characteristics of each of the nine morphological types and examples of town / settlement catchment areas that these patterns where found in are as follows:

a) **Mono Centric** – Has only one distinct concentrated settlement in the catchment (e.g. Aliwal North, Beaufort West, Cradock)
b) **Bi Centric** – Has two distinct concentrated settlements in the catchment (e.g. Paulpietersburg, Virginia, Moruleng)
c) **Poly Centric** – Has more than two distinct settlements in the catchment (e.g. Johannesburg, East London, Durban)
d) **Scattered Dense** – Has a continuous dense point settlement coverage structure (not as dense as cities but also not too sparsely populated, in many instances with a density of over 100 people per km^2) (e.g. Hlabisa, Coffee Bay, Sterkspruit)
e) **Scattered Clusters** – Has clusters of non-uniform and non-continuous dense settlements across the catchment (e.g. Libode, Jericho, Hartebeesfontein)
f) **Scattered Sparse** – Has sparsely scattered settlement points irregularly distributed across the catchment (e.g. Riebeek East, Ogies, Alexander Bay)
g) **Dense** – Largely composed of continuously dense settlement with no distinguishable centres or town points (e.g. Lusikisiki, Driekop, Scottburgh)
h) **Sparse Linear** – Has a linear pattern of sparsely populated settlement; this may mean it has developed alongside a river, coast or road (e.g. Leerkrans, Kanoneiland, Gouritsmond)
i) **Dense Linear** – Has a linear pattern of densely populated settlement; this may mean it has developed alongside a river, road or coast (e.g. Jeffreys Bay, Mutale, Ga-Rakoma)

It is important to note that this is not the classification of the town / settlement node that the service area / catchment were developed around, but the evaluation of the total pattern of settlement in the catchment area. This information along with information about the number of people that potentially live within different distances from the main town becomes critical when planning for an area and the populations in its hinterland. As stated earlier, an often overlooked yet crucial component in service

provision and distribution is the understanding of the varying settlement patterns, and a better understanding of the settlement morphologies can improve how essential services are rolled out.

6. Research Contribution

These 9 types were added to the catchment profile and will be an assessment informant for planners on where and how to allocate facilities based on the distribution of population. These nine types also informed the adaptation of planning standards for rural/sparse areas throughout the country, thus laying a foundation for service delivery that is not only based on equity but also on efficiency.

Prior to this study, a morphological classification of all settlement catchments has never been performed. The results presented in this study pave a way for further and more detailed research pertaining to settlement morphology and service delivery.

7. Research Limitations

The limitation in the research relates to the fact that the available points dataset that was used does not take into account the type of building, i.e. high rise/ single dwelling/ residential / commercial building or the population per dwelling; it is purely based on observed building patterns.

8. Discussion & Concluding Remarks

The settlement catchment approach used is based on familiar concepts like 'the central place' which means that people are more likely to travel to their closest point of service to get their needed services. The point of service then has a catchment with people who are closest to it – this is its market share. Knowing how many people are within a catchment is important. However, one needs to go further to find out how people are distributed within a certain catchment. As previously alluded to in the literature review, the inclusion of morphology in an area classification can lead to a better understanding of the area which will then lead to a more informed decision when distributing facilities in that area.

8.1. Implications of morphology on service delivery

The table below indicates that almost 48% of all the towns/settlements in South Africa are classified as monocentric (see 6th column from the left). This monocentric morphology is widely distributed across small and larger catchments. The very first column in the table shows a ranking of towns/settlements in orders from 1 to 10, Order 1's being the largest towns (city/metro) and Order 10's being a small town catchment. Mono Centric, Bi Centric and Poly Centric catchments make up 57% of all town/settlement catchments in the country. This means that the distribution of service or social facilities in these areas should potentially be considerably more efficient in comparison to the other types of morphologies. In addition to these, Dense catchments (2.2%) also make it possible to achieve greater efficiencies in the distribution of services as dwelling units are close together.

Table 1 Number of catchments within identified morphology types

Town Order	Catchment Count	Cumulative Catchment Count	Avg Density/ km2	Cumulative %	01_MonoCentric	02_BiCentric	03_PolyCentric	04_ScatteredClusters	05_ScatteredDense	06_ScatteredSparse	07_Dense	08_SparseLinear	09_DenseLinear
1	6	6	1 342.42	36.40%	0	0	6	0	0	0	0	0	0
2	7	13	369.94	41.59%	1	0	6	0	0	0	0	0	0
3	44	57	193.91	50.40%	35	3	5	0	1	0	0	0	0
4	128	185	99.95	61.63%	87	9	7	7	10	2	3	0	3
5	27	212	371.29	67.51%	9	5	6	2	4	0	1	0	0
6	67	279	201.89	73.67%	19	2	5	15	15	2	6	0	3

7	257	536	119.96	87.37%	87	19	7	57	61	5	16	0	5
8	270	806	74.25	94.85%	121	26	4	59	34	18	4	0	4
9	262	1068	43.14	98.58%	150	7	1	40	23	32	0	0	8
10	261	1328	19.75	100.00%	124	9	3	15	6	89	0	4	2
Total	1328		0.00		633	80	50	195	154	148	30	4	25
					47.63%	**6.02%**	**3.76%**	**14.67%**	**11.59%**	**11.14%**	**2.26%**	**0.30%**	**1.88%**

The other types of morphology being those of scattered, clusters and sparse catchments present a great challenge to service delivery. In these catchments, a much greater understanding of the local residential pattern, mobility, income levels and age breakdown is required. In these places, middle order facilities (such as 24-hour clinics, Home Affairs offices) can be located at the central node – depending on the threshold and average travel distance. However, with respect to lower order facilities (such as schools and clinics) which have a much smaller service reach, a good interpretation of the morphology can help to ensure the correct placement of facilities close to residents while avoiding 'white elephants' where there is not sufficient demand. The morphology is also extremely useful to plan service points for mobile and periodic services.

The classification of catchments according to morphology, amongst other classifications, has a direct impact on how facilities are planned for and distributed in each catchment. The findings supported the narrative that services cannot be uniformly provided across settlements by merely considering the population and density as is the conventional thought. What the morphological classification of catchments allows planners to do is to plan according to a very localized context. Not all rural areas are the same, and with a detailed classification of morphology down to a settlement level, it is possible to have more insight into the context of each area throughout the country. This knowledge results in a more people orientated approach to planning while also allowing for greater efficiencies from the service provider's perspective.

The practical impacts of the morphology for any order of place are evident. Consider having two catchments that have the same number of people (say 9 000) within each, knowing how large each catchment is (the land extent) and how people are distributed in each catchment is key to providing an optimal number of services for both these hypothetical areas. For example, if you wanted to put a clinic in one of the areas you would be able to tell if the whole catchment population warrants a clinic and of what size. Morphological information would also be able to identify the most central place where everyone would have approximately equal access to the clinic. All this information is attributed to each catchment. If one of the two catchments happens to be mono centric, which typically is a small town surrounded by a sparse hinterland (e.g. farmlands/forest/desert), one would not have difficulties in planning for the placement of social facilities or services. This is because the town/settlement is the only inhabited place within the larger catchment and thus all the facilities would have to be placed at the central place.

However, if the second town/settlement catchment was classified as scattered clusters, for instance, the approach adopted for placing facilities would differ. This is because this time there will not be an apparent single place of concentration within the catchment. To overcome this challenge, one would have to look for an area of the greatest population density and adapt the size of facility to match the area of greatest density within the catchment, an area that is more central and equally accessible to the rest of the catchment. This information is crucial for services that involve the deployment of mobile units like health clinics. With the morphological information, the Department of Health, for instance, can determine where to place a fixed facility from which mobile facilities can be deployed.

In one of the case studies undertaken for the project, a team of researchers travelled to Butterworth to study the varying morphologies within the Butterworth catchment. Butterworth has a holiday resort development by the sea in Mazeppa Bay and during the field trip it was discovered that people in the vicinity of the holiday resort were being served by a mobile/satellite clinic. There was a fixed wooden

structure where people gather around when the mobile clinic with medical equipment arrives on a predetermined day. The wooden structure itself has no equipment besides a bed. Within the Mazeppa Bay catchment, there is a district hospital from where these mobile clinics are deployed. If the Department were to look at deploying another mobile service, the morphological information would be important to inform decisions about the most suitable location and also to determine the frequency of the service based on the number of people in the target location.

Another important attribute included in the morphology classification of catchments is that of the number of people within distance bands from a catchment's central point. Its practical applicability comes into play when deciding what size a facility should be and who will be served by it. With the morphological information, any service provider will be able to know how many people are within 5km of the main node, for example, within the catchment; and from this information they will be better positioned to carry out service provision in a more efficient and specific manner.

The implications of this morphological classification of catchments on service delivery are extensive. Governments and other decision makers will now have rationale based information to support their decision making with regards to the placement of facilities. This information has been prepared for catchments across the country. This morphological information is also incorporated into a planning application guide; this provides a step by step guide on how to apply planning standards for social facilities placement/distribution, thus assisting decision makers in making informed decisions and better serving communities.

For convenience, all this morphological information has been freely made available to the public in the form of an online portal, accessible here: www.socialfacilityprovisiontoolkit.co.za. This means that all decision makers who have internet access and are interested in getting morphological information about the areas they are planning for, can freely access this information from the online portal.

8.2. Conclusion

Service delivery is one of the duties of every government around the world. Rural areas have been relatively overlooked and development has been focused mainly on urban areas. Since the United Nations put pressure on governments by identifying common global goals and making some services basic human rights, every government has been trying to pay attention to the deficit in basic services in both urban and rural areas. However, these efforts have been met with challenges as the absence of sufficient information, like understanding and adequately responding to settlement patterns, has undermined service provision. This is exacerbated by limited financial resources.

In light of this challenging task of delivering services efficiently to rural areas, scientifically sound methods have been applied to try and balance the needs of communities with efficiency (given the finite financial resources of every government). Internationally, there have been various methods of addressing this through the use of various spatial analysis techniques. This project adopted an advanced approach to analysing spaces which puts emphasis on the morphology of settlements as this is viewed as the key informant in service delivery for any area. The analysis identified nine types of settlement morphologies common in the South African landscape. With this information, service providers and planners can be better positioned to achieve efficiency in the distribution of services while not neglecting equity. The morphological information was an important input to the creation of a planning application guide which is designed to assist planners in planning for service delivery and addressing any morphological challenges.

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