# Diffusion of Geographical Information Systems in local municipalities in South Africa

**Lydia MOUKANGWE and Edward KURWAKUMIRE, South Africa**

**Key words**: Geographical Information Systems, Local Municipalities, GIS Adoption, GIS Diffusion, Service Delivery, Local Government

## SUMMARY

Municipalities in rural areas have been lagging in the utilisation of spatial information systems for performing land administration and development planning applications. This has been worsened by having parallel systems of administration where local municipalities and traditional leaders concurrently administer the same land which often results in conflict. With the increase in diffusion of Geographic Information Systems (GIS) in urban areas for cadastre related applications, this study seeks to investigate if utilisation has extended to local municipalities in rural areas and the extent of diffusion. This study gathers empirical evidence to discuss the extent of use of GIS in local municipalities together with the different impacts that are being realised. The variables utilised were the application of digital land information in the improvement of public service delivery and in improving internal processes for land management. The results showed that despite high utilisation is GIS in urban municipalities, there is slow implementation in South African rural municipalities based on the Limpopo, Mpumalanga and Easten Cape study areas. The factors influencing the low adoption include budget constraints, limited technical expertise and data management capability and the lack of GIS and Land Management units within the municipal organograms. The absence of standardized protocols and organisational policies for interdepartmental collaboration and sharing of spatial data are additionally impeding the realisation of benefits from utilisation of spatial information systems. The adoption was measured against a systems development and benefits accrual model where most systems were found to be in the grassroot stage. Addressing the issues being faced by municipalities can enhance the utilisation of GIS technology which in turn improves service delivery capabilities. Additionally, a framework for adopting Spatial information systems based on cadastre and land management applications founded upon crowdsourced data sets and open-source processing platforms can improve GIS utilisation.

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## INTRODUCTION

Geographic Information Systems have a strong history of supporting decision making in local government according to geographical research with a few examples such as (Campbell, 2020; Jacquez, 1998; Melnick and Fleming, 1999; Pavlovskaya, 2018; Sui, 2014). As such, the Geographic information science domain has witnessed studies on the adoption and diffusion of GIS because of the GIS promises or benefits to organisations (Eria and McMaster, 2017; Nedovic-Budic and Godschalk, 1996). As GIS systems matured in organisations, it was found necessary to assess their performance coming from the fact that their implementation was through use of public funds and city managers had to be accountable to the citizens. This saw the emergence of evaluation studies in the GIS domain which largely focused on development of evaluation models and benefit assessment (Nedovic-Budic, 1999; Kurwakumire, 2014). In present day cities, GIS is supporting a wide range of activities within municipalities including disaster management (Penki et al., 2022), emergency and crisis mitigation (Goniewicz et al., 2021), asset and utility management. While developed countries have mature systems accruing such benefits, developing countries such as South Africa still have GIS's still in developmental stages, specifically in rural areas. In these areas, villages have transformed into small towns governed by local municipalities but still maintaining the administration of chiefs, which often is a cause of conflict in the land governance and service delivery processes. This paper studies the implementation efforts of GIS in local municipalities in Limpopo, Eastern Cape and Mpumalanga regions with a notion to identify the extent of use and benefits and the land administration functions being utilized. The rapid development of information technology and increased availability of spatial data has warranted municipalities to also adopt geographical information to enjoy its benefits in service delivery and social transformation as detected by GIS literature (Sigwejo and Pather, 2016).

While recent studies and discorses within geographic infromation science reveal rapid development of GIS technologies and icreased availability and usage of spatial data , benefit realisation however remains uneven due to the different country and organisational contexts within which GIS is adopted (Kurwakumire, 2014). Prior research has indicated that adoption does not imply usage and furthermore does not guarantee value creation in the operations of the organisation (Alzighaibi, 2016), but the benefits accrue with the maturity of systems within organisations as processes become aligned with geographical information workflows (Kurwakumire, 2014). In some cases there is no benefit accrual due to factors such as underusage and lack of experinec of utilising GIS in organisational operations (Keesee, 2025). As a resut, GIS maturity and benefits-accrual models are continlusly being applied in the

evaluation of impacts on the adoption and difusiom of GIS as the systems transform from grassroot to value-generating systems (Kurwakumire, 2014).

In this study, we borrow concepts from e-government evaluation in the discussion of public sector GIS in the local government context. The paper concludes with the improvement of the GIS maturity model to cater with recent developments in technology, data and service needs, municipal sustainability issues and the need to solve global challenges. However, despite evolving these needs and global developments, rural municipalities in South Africa are still experiencing slow diffusion of GIS technology.

## THEORETICAL FRAMEWORK

The goal for local government operations is citizen satisfaction, hence its use in local government evaluation (Sigwejo and Pather, 2016) for stimulating social changes through better service delivery. Similarly, systems that can connect or feed into e-government such as GIS play a major role in aiding citizen satisfaction. Additionally, government GIS should improve capabilities of disaster management to improve the safety of the public. When no such decision support systems exist, then participatory GIS provides an alternative to disaster management Penki et al., 2022).

Rural communities are often segregated in terms of digital service delivery due to the digital divide they face due to inadequate access to technology and communications infrastructure by municipalities (Qureshi et al., 2017) which negatively influence accessibility of services. Communities should be viewed as part of the users as GIS can be viewed as a socially constructed technology (Schuurman, 1999) that can additionally stimulate social change (Pavlovskaya, 2018) as required of government information systems (Sigwejo and Pather, 2016). When technology is accessible, building human resource capacity through training is required (Qureshi et al., 2017) for government implemented information systems to result in improved service delivery.

These challenges are not unique to rural areas but also to urban municipalities in developing countries. Some implementation and adoption issues include insufficient infrastructure and inadequate trained personnel (Penki et al., 2022). Despite this, Alzahrani et al., (2021) emphasises the need to study the factors influencing GIS adoption as they provide solutions to improving implementation, as this spatial information system is a crucial technology in the public sector that provides geospatial data essential for daily government operations (Valachamy et al., 2020).

## METHODS

This study utilized an online questionnaire survey created through google forms to develop an understanding of the adoption of geographical information systems in local municipalities. Purposive sampling was utilized in identifying municipalities in Limpopo, Eastern Cape and Mpumalanga regions and in identifying respondents that interact with GIS and spatial data in

their daily operations. The survey was based on the following municipalities: Sekhukhune District Municipality, Makhuduthamaga Local Municipality, Elias Motsoaledi Local Municipality, Ephraim Mogale Local Municipality, Sarah Baartman District Municipality, City of Johannesburg, Dr. JS Moroka Local Municipality, Steve Tshwete Local Municipality. The survey comprised of closed questions for gathering information on the nature of GIS use and its adoption within the municipality as an institution. The questionnaire link was distributed through emails of the relevant technical personnel accessed through purposive sampling as the respondents directly operating on the GIS. The survey results were then analysed to identify common patterns in the adoption across provinces. While this study utilised a questionnaire survey as utilised in related studies such as Kurwakumire (2024), Alzighaibi (2016) and Alzahrani (2024), similar studies in the domain of e-government evaluation such as (Sigwejo and Pather, 2016) utilised interviews and focus group discussions to collect information for assessment as they are also instruments utilized in evaluation research. The submitted responses were interpreted through the analytics embedded within google forms.

## RESULTS AND DISCUSSION

Seven local municipalities were surveyed in the Limpopo, Mpumalanga and Eastern Cape regions. An urban metropolitan municipality in Gauteng province was also surveyed to provide a different perspective on how urban and rural environments are faring regarding GIS adoption and use. The respondents were from various offices in the domains of development planning and GIS both at technical and supervisory roles. This was essential, as qualified personnel are essential for successful implementation, operation and the broader diffusion of GIS. However, 90% of the respondents emanated from the development as opposed to either Land surveying or GIS sections which is a challenge currently in local municipalities. The Local municipalities have failed to establish separate surveying and GIS sections. These sections are normally embedded within the development planning sections and, in most cases, managed by town planners rather than GIS specialists and land surveyors.

Six out of the 7 local municipalities are utilizing GIS reflecting diffusion of the technology in rural municipalities. Municipalities are taking advantage of the increased accessibility of both information and communication technologies and geographic information. Usage within all sections of the municipalities is still limited with 60% of the municipalities reporting partial integration with other departments. GIS use is restricted to the development planning sections. There is also no integration with municipal systems such as the development planning process, billing or building planning approval. The municipalities have standalone systems, and the GIS is not being utilized to its full potential. Even in the urban metropolitan municipality, there exists partial integration with other sections, meaning that promises of GIS are still not being fully realized. GIS is not utilized daily but rather on ad hoc basis.

Six of the even rural municipalities have had staff trained (see figure 1) in operating GIS through

there in need of continuous skills development and possibly in-house training. Currently the municipalities are dependent on external trainers, some of which do have municipal GIS background, which impacts the effectiveness of the training. These results are consistent with findings from (Penki et al., 2022) who cited inadequate training facilities.

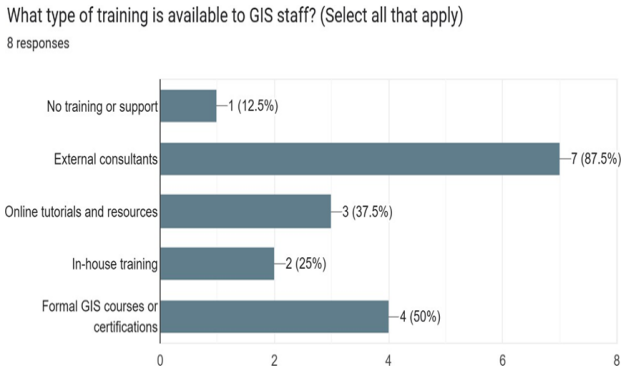

Figure 1: Capacity Building

Expansion of GIS to becoming independent sections is hindered by lack of dedicated budgets according to 70% of the responses. Departments hence face challenges of using legacy hardware sometimes without adequate computing power for some geoprocessing operations. The utilized software (see figure 2) is primarily ArcGIS, GQIS and Google Earth with QGIS being preferred as it is freeware and without any bearing on the budget and with lower system requirements in terms of computing resources.

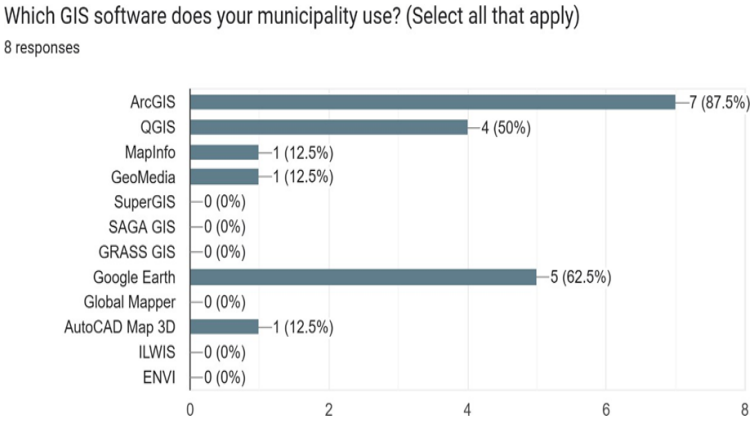

Figure 2: GIS Software

Data access is still an issue of concern. While the national land information infrastructure has nationwide data of the cadastre, the scale and update frequencies are different for urban and rural municipalities. For local municipalities the cadastre is of poor quality due limited coverage and being outdated with only 4 municipalities capable to updating their datasets on an annual basis. This impacts decision making as datasets are incomplete and dated.

70% of the municipalities posed difficulty in accessing data sets, which is partly due to lack of an integrated spatial data infrastructure and meta data catalogue in South Africa. Spatial Data

sets are available within the custodian organisations but the metadata pertaining to where to find the data is unavailable.

Municipalities are experiencing benefits (see figure 3) improved decision making, spatial planning, and service delivery. These responses resonate with the promises and benefits of GIS in local government documented in literature by (Nedovic-Budic, 1999) even though there is no evidence of the social change discussed by (Sigwejo and Pather, 2016).

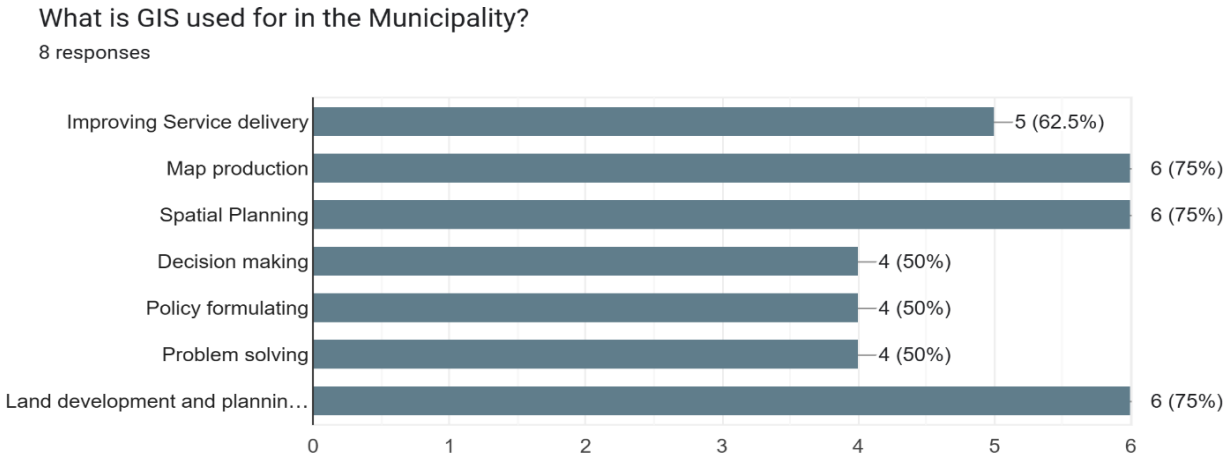

Figure 3: GIS Benefits

These findings are partly consistent with the work in Alzighaibi (2016) where customer service improved, however the authors could not establish whether GIS improved the efficiency of decision making and introduced cost savings. This, however, could be an issue of GIS maturity where the benefits will be experienced as the systems matures transforms with time.

## A SPATIAL DATA ENRICHMENT MODEL

One key element that affects benefits accrual is availability of input spatial data for use in different municipal operations. This is a stumbling block especially in local municipalities as the existing official datasets are not as detailed as citywide spatial data and, in most cases, not up to date. While small scale topographical maps are available, the large-scale municipal maps that are relevant for the day-to-day running of the municipalities are often incomplete. Due to poor funding, rural municipalities again struggle to outsource data collection. Due to these reasons, we propose a diffusion model based on utilization of official or authentic spatial data sets that emerge from the GIS unit within the municipality, contracted private companies and the surveyor general's office. Parallel to these data sets is volunteered geographic information (VGI) collected from non-profit organisations and the general public as it is an alternative and effective way of obtaining vast amounts of spatial data (Ahmad et al., 2022). The VGI needs to go through some quality control processes and value addition to merge it with existing spatial data even through it may be in the form of description with a course resolution of sometimes geotagged photographs and locations generated from social media applications. This VGI can

close gaps on areas with insufficient data while providing the municipality with information for decision making. In the end, the spatial data is warehouse and made available to the large spatial information user community as depicted in figure 4.

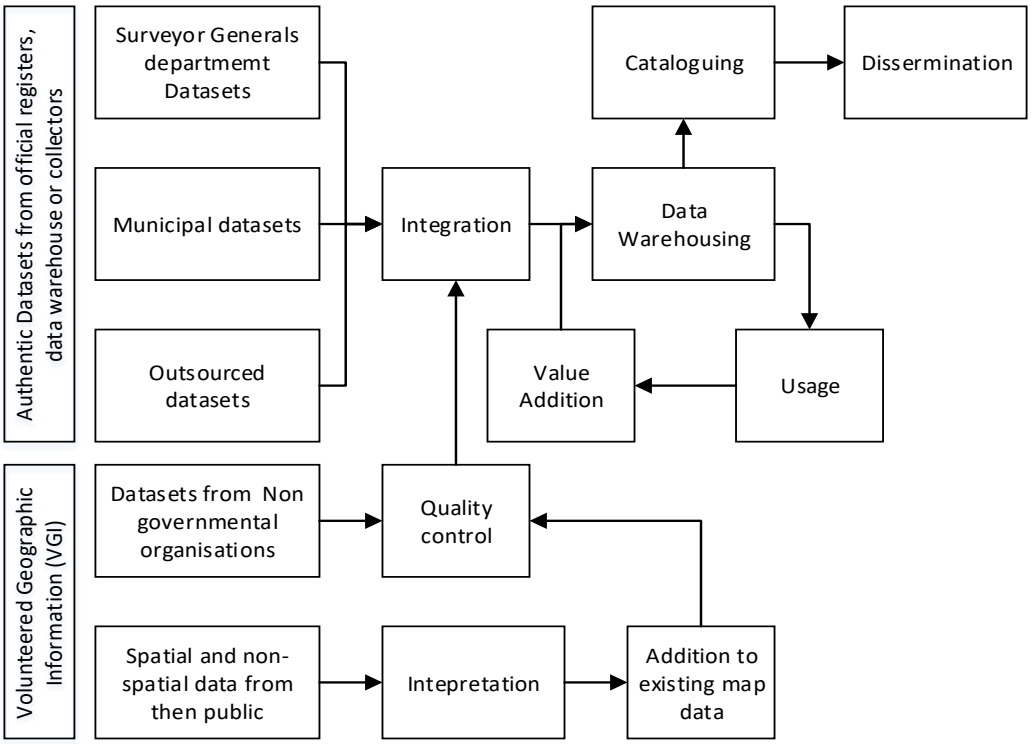


Figure 4: Incorporating VGI in municipal operations

## A NEW GIS MATURITY MODEL

Table 1 provides a GIS maturity model built upon the one presented in (Kurwakumire, 2014) but now represents the present context of advances in information and communication technology such as artificial intelligence and machine learning together with the need to be more responsive to different challenges such as the disasters (Penki et al, 2022) continuously resulting from climate change. While the grassroot, intermediate, advanced and integrated systems have been maintained, their scope has been widely changed when compared to the work in (Kurwakumire, 2014).

The grassroot level focuses on collecting raw data and converting available analogue data to digital format and the development of geodatabases that are utilized by GIS sections. The GIS sections are small units, in most cases, housed in other departments. The intermediate stage shows growth and transformation of the GIS unit into an independent department. The organisation is beginning to understand the value of spatial data for different operations. The

geodatabases are now network based so that different departments can access data sets they require. In the advanced stages, there is a realisation of the need to remove inconsistencies and redundancies in the datasets, so a structure data warehousing approach that incorporates cloud systems is introduced that enables multitasking and multiprocessing by different users from different departments. The GIS is now linked to electronic government so that different services are spatially enabled. In the integrated phases, different departments have operational systems, but all linked to the same centralized data warehouse and there is functional webGIS with which the public can interact with the system.

| | **GIS Level** | **Characteristics** |
|---|---|---|
| 1 | Grassroot | Desktop systems, Focus of data collection and digitizing infrastructure maps, Creating digital map content through scanning and Coordinate geometry (COGO). Small GIS unit. Limited capacity to conduct huge projects. |
| 2 | Intermediate | Networked (Server based) system, Growing GIS unit, GIS Team is working collaboratively, Unit is creating its digital footprint, Unit is designing databases and applications for marketing to other sections of the municipality. Independent GIS units. More capacity in terms of human resources is available. |
| 3 | Advanced | Data-warehousing component, Integration with systems such as billing; Integration with internal service systems, focus on an updated cadaster; There is web presence; Some data sets can be accessed from the web. Other departments are requesting specific applications for use in their routine work. |
| 4 | Integrated | Linkage to geoportals, Connection to spatial data infrastructures, Linkage to electronic government, Creation of public participation platforms, Functional webGIS, Users can download custom made datasets. Different departments have customized applications for use through desktop and mobile systems within the organisation and remotely. Public can interact with municipalities through webGIS. |
| 5 | Autonomous | High level BIG data applications (Disaster management and early warning systems), System is connected to sensory networks, Near-real time data collection, Public online one-stop service points, Public provides volunteered geographic information for city management, Citizen centric GIS, Social change. Some systems based on machine learning algorithms are available which process data as it is collected to provide information for decision making. There is high usage of data science in analysing geographic phenomenon. Public supports municipalities with volunteered geographic information (VGI). |

The autonomous stage is added to the maturity model to demonstrate wider connectivity and linkage to other spatial information systems. This stage reflects a high level of spatial enablement for both local municipalities and the public. At the autonomous stage there is

massive production and consumption of spatial data products support not only planning but the daily operations of the municipalities. Spatial data is viewed as key in all municipal operations that include land management. Multiple public, private, non-governmental organization and even the public cooperate I the creation of official spatial data sets and the supporting unofficial data that is harnessed as volunteered geographical information which in totality improves the richness of available data and increases the capabilities of municipalities to respond to ill-defined problems.

## CONCLUSIONS

GIS adoption in local municipalities is still in its infancy stage in local municipalities in South Africa due to low level benefits that are being realized. Furthermore, the lack of dedicated GIS sections within local municipalities limits its diffusion to other sections within the organisations. The local municipalities operate within grassroot and intermediate systems from the GIS maturity and benefits model presented in (Kurwakumire, 2024). GIS use needs to improve and cater for changing needs of society and to aid in solving global challenges such natural disasters manifesting in form of droughts, wildfires and floods. From this need, a framework is proposed for improving the GIS maturity model to enable the evaluation to be more representative of the current capabilities of spatial information systems. Systems need to be community oriented and to transform into social GIS.

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## BIOGRAPHICAL NOTES

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