The Development of a Location Addressing System for Rural Villages in Botswana: Tlokweng Case Study

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DOI: https://dx.doi.org/10.4314/sajg.v13i1.12

Abstract

Communities rely on location addressing for various purposes in order to optimize their emergency responses, services, and goods delivery. Without a well-designed location addressing system (LAS), governments and other service providers struggle to efficiently and effectively provide goods and services to local communities. Botswana has adopted a Land Administration Procedures, Capacity, and Systems (LAPCAS) project, developed by a Swedish company, to produce a unique system to address the need to pinpoint locations in the country. However, it has not solved the issue of location addressing in villages as the one currently being developed nationally has not as yet been implemented. As a developing country, Botswana needs a LAS to facilitate the identification and location of properties and to plan developments based on the existing infrastructure. Technological advancements such as Geographic Information Systems (GIS), Global Navigation and Satellite Systems (GNSS), and Web 2.0 have made it possible to develop LAS to improve emergency response and service delivery in most Western countries. Thus, a prototype LAS was developed in this study. Using the Python programming language, the GeoPandas Framework, and the Django Web Application, it has already demonstrated its potential benefits in a peri-urban village, namely, Tlokweng, in Botswana. The objective is to show that geoinformation techniques can be used as foundations for identifying locations and navigating the challenges facing rural areas in developing countries such as Botswana.

Keywords: *Location-addressing system; Python programming language; GeoPandas Framework; Service and product delivery; Urban planning and management*

1. Introduction

In the modern world, a locational address presents one of the fundamental means for communities to conceptualize location in that location serves to identify and locate a property. Communities rely on locational addresses for a broad range of services, including population census enumeration, security and emergency response services, product delivery, transportation services, and sanitation services, to mention but a few. Unfortunately, many developing countries do not have well-designed systems for locating properties, particularly in rural settlements (Gakh, 2020; Lehmann et al., 2019). Without a well-established location addressing system (LAS), it is difficult for governments and other service providers to

effectively and efficiently provide goods and services to local communities. For example, emergency service providers usually have challenges in quickly matching a mapped address to a physical location to initiate an urgent and immediate response. Such a shortfall can in some cases be tragic or detrimental as it leads to a longer response time. Technological advancements such as Geographic Information Systems (GIS), Global Navigation and Satellite Systems (GNSS), and Web 2.0 have made it possible to develop LAS to improve service delivery in most countries, particularly those in the Western World.

The current situation in Botswana is that service providers use various means to deliver goods and services to customers which are convenient to them. For example, a pizza delivery company uses hard copy maps to identify and locate the properties to which to deliver their products. Unfortunately, such a traditional system can be time-consuming and ineffective. Inefficiency in this instance would include the possibility of getting lost in trying to identify properties and subsequently making late deliveries which could then impinge on the freshness of the food. Several other makeshift solutions for delivering products and services exist in some institutions within the country. For example, some financial institutions have adopted social media LAS (WhatsApp Location Identifier) to easily locate the properties of their clients and to deliver bank cards within a short period. However, such a means is possible only for customers with smartphones, internet connectivity, and the WhatsApp social media application. Such solutions work only for a population minority. Owing to their lack of the stated resources, particularly internet connectivity, the majority of the population is negatively affected. Well-established international goods delivery and logistics organizations, such as Deutsche Post DHL (DHL), FedEx Corporation, and United Parcel Service (UPS), find it difficult to deliver products to homesteads in countries such as Botswana with a non-existent LAS (Alkhalifah et al., 2022; Chou & Lu, 2009). Rather, they have resorted to goods being collected from their agency offices. Such an arrangement comes at a cost to customers as they are expected to travel to these offices to collect their goods. In contrast, Western countries have efficient home delivery services because of functional LASs.

Even though Botswana does not currently have a well-defined LAS, some efforts by the government have been made to establish such an initiative. In the past, some, such as the Land Administration Procedures, Capacity Building and Systems (LAPCAS) project, were proposed by the government to develop a comprehensive location addressing system to identify and locate properties countrywide. In fact, the government of Botswana, in partnership with the Swedish International Development Agency (SIDA) took on the LAPCAS project with a mandate to improve and build capacity in land administration in the country. The aim was to provide an efficient, effective, and transparent land administration environment to promote the social and economic development of Botswana (Malatsi & Finnstrom, 2011). Unfortunately,

owing to several challenges[1] that it encountered over the last decade, ,and its subsequent failure, the project has not been successfully implemented. Such a failure has motivated this research to conduct a comprehensive study towards the development and implementation of a functional LAS for the country.

Therefore, the objectives of this study are as follows: a) to conduct via a mixed methods approach a comprehensive data collection study to gather relevant data from local communities in order to understand the challenges emanating from a lack of a LAS in the study area, b) to solicit ideas and opinions from the local community that are geared towards the development of a LAS prototype in terms of functionality and applicability, such that it meets their daily requirements, and c) to use the insights obtained from the data collection study to develop a suitable prototype-addressing system for a peri-urban village, namely, Tlokweng, in Botswana.

2. Background

Approximately 75% of the world's population lacks a street address, which means that billion people are 'invisible' (Demir & Raskar, 2018). The commonly used method for recording street addresses is geocoding, which uses latitude and longitude as the locational information reference points (Cetl et al., 2018). However, Demir and Raskar (2018) argue that rural settlements with roads and geocoded address systems are not consistent with the road topology. Therefore, using deep learning methods, they developed an algorithm that extracted roads and junctions from satellite imagery. Unfortunately, there is an insufficiency of geocoding in rural areas in many developing countries. Nonetheless, several alternatives do indeed exist: −they include street networks, parcel boundaries, and address points (Zandbergen, 2008). These address models will be investigated to understand their functionality and possible applicability in rural areas.

2.1. Model 1: Street address model

The street address model is the address data model most frequently used by almost all commercial agencies offering geocoding services and GIS companies with geocoding capabilities (El Yacoubi et al., 1995; Lee et al., 2020). The rationale behind the model is such that a street network is represented as line segments that hold street names, house numbers, and block numbers on either side of the street. It is accomplished by initially matching the street names, then the line segments that contain the house numbers, and finally by placing a point along a segment based on linear interpolation within a particular range of house numbers (Zandbergen, 2008). To show on which side of the street line segment an address is located, an

[1] These will be discussed later in the study.

optional offset is usually employed. Its major shortfall is that it relies heavily on spatial interpolation with the addresses being geocoded by approximation against the central lines of the road. It has been reported that some approximated addresses can at times fail to match since their value would not fit into the existing range (Lee et al., 2015; Zandbergen, 2008). Such a challenge requires some 'padding' through linear interpolation (border addition), and even several true address ranges for improved address matching (Zandbergen, 2008).

2.2. Model 2: Parcel boundaries data model

A parcel boundaries data model allows for centroids of land parcels to be used for address information rather than interpolation against the central line of the street (Tapp, 2010). The main difference between parcel and street addressing is that a single land parcel usually has a single house number, whereas a street segment can have an address range. Therefore, an address search of the former can be determined only if there is a match for a particular house number of interest. In contrast, the latter's address search can only be obtained if a house number falls within an address range for the street segment of interest. A shortfall of the parcel address system is that it produces lower match rates compared to the street address model since a single parcel can be associated with many addresses, as in the case of apartment complexes, duplex units, condominiums, etc (Cetl et al., 2018). Despite this challenge, parcel addresses are considered spatially more accurate than street addresses; hence their widespread use in many cities in the United States (Rushton et al., 2006).

2.3. Model 3: Address point data model

An address point data model emerged from the need to overcome the limitations of parcel addressing (Akakba & Lahmar, 2020). Address points are created from land parcel centroids or any point located within a parcel of land. The model does not record separate properties in the parcel data (apartments, duplexes, condominiums, etc.) as different entities. Rather, it records them as sub-addresses to the main address point. Such a model has been widely accepted by Western countries such as the United Kingdom and Australia in their national address databases (Zandbergen, 2008).

2.4. The significance of street addressing in rural villages

An address management system is the single most significant contribution the spatial industry can make to the business community and government institutions (Haanen & Goodchild, 2010). Addresses are commonly used and accepted in everyday life; people assume that everyone has one and that the residents and the property are, therefore, easy to locate. Street addressing is not only concerned with locating properties but constitutes an essential component of city management, the quality of life of the citizens, and other spheres of the economy within the city. In South Africa, personal addresses are often necessary for the following (Gelb & Clark, 2013; James, 2012; Neves et al., 2009): access to social services,

registration of children for schools, opening formal bank accounts, obtaining store credit, purchasing a cell phone or registering such, delivery of mail, delivery of retail services, legal proceedings, registration for voting, obtaining a national identification number, obtaining a driver's licence, etc. A poor person/household would suffer even more should they/it lack a personal address.

Even though street addressing is an essential component of a city's infrastructure, Gakh (2020) argues that the initiative is not sufficiently described for cities in poor countries. According to Gakh (2020), cities embarking on smart addressing initiatives should be smart city oriented. A smart city concept seeks to develop transportation linkages using mixed land uses and high-quality urban services for long-term sustainable solutions. Such a concept can be beneficial to many countries in sub-Saharan Africa which over the last few decades have experienced some dramatic demographic shifts from rural areas to urban centres. The dramatic shifts have subsequently put pressure on local governments, with little experience in urban management to deal with the resultant urban growth. Against this backdrop, Farvacque-Vitkovic et al. (2005) stress that systems for identifying streets, land parcels, and specific buildings have been unable to keep up with the pace of urbanization. This predicament has led to an acute shortage of street addresses and no baseline information in more than half of the urban areas in sub-Saharan Africa (Farvacque-Vitkovic et al., 2005).

In the past, street addressing in most developing countries was an initiative of the colonial authorities who generally introduced a sequential numbering system from the city center (Farvacque-Vitkovic et al., 2005). Nonetheless, the authors argue that such a system was only suited to a slow and controlled urban growth process and could not function efficiently in the context of the post-independence sub-Saharan Africa. Within this era, there has been an increase in the number of unnamed streets and buildings, which further led to additional challenges when officials attempted to update the system with a modern system of alternate numbering (Farvacque-Vitkovic et al., 2005). Haanen and Goodchild (2010) stress that addresses should be short and simple so that they can be readily understood by the public and the available computer systems. Such an adoption would mean that unnecessarily complicated and misleading connotations of legacy and poorly defined systems of the past could then be avoided.

2.5. Street addressing in the context of Botswana

In Botswana, the statutory responsibility for assigning addresses and naming roads lies with local government institutions. The requirement is that all properties should be addressed in a standard manner and digitally mapped. The country recognizes that property addresses, road names, and locality names are an important part of its economic and social infrastructure; hence, the introduction of the LAPCAS project. Initially, it was a five-year (2009-2014)

partner-driven project between the Ministry of Lands and Housing (MLH) and Landmateriet, the Swedish Mapping, Cadastral and Land Registration Authority. To achieve coordinated implementation, the project was divided into seven components, which included: a) national systems for the unique referencing of land parcels and location addresses, b) the improvement of land administration procedures and processes, c) deeds registry computerization, d) systematic adjudication on tribal land, e) the development of Information Technology (IT) procedures and organization, f) the exchange and dissemination of land administration data, and g) training and capacity building. Component (a) is of interest to this study since the objective was to develop and implement a standardized system for numbering land parcels across all land tenures in the country.

According to Khama and Seleka (2017), the LAPCAS project developed a process for the systematic surveying, registration, and adjudication of tribal land within the legal constraints of the current laws. Nevertheless, this process met a few challenges, including the following: a) lack of interest of claimants to provide documentation to claim their land rights (Isaacs & Manatsha, 2016), b) no concern shown by occupants for the lack of certification for the plots they occupy (Malope & Phirinyane, 2016), c) the lack of a legal framework to compel community members to register their land rights, d) insufficient publicity, resulting in a lack of participation and buy-in from local communities (Isaacs & Manatsha, 2016), e) a shortage of skilled personnel, such as surveyors, land use and adjudication officers, and f) delays in producing and issuing new certificates for already adjudicated plots (Ministry of Finance, 2016). These challenges resulted in a very slow registration process: out of a targeted 464,634 plots for the first quarter of 2015/2016, only 25,255 (8%) had been adjudicated, while 209,449 (45 %) had been surveyed (Khama & Seleka, 2017).

Since its proposition, the LAPCAS addressing component has never been implemented. Despite its well-documented scope of work, Ditsela (2017) argues that the project suffered implementation challenges because of organizational politics and power struggles from the MLH and the Department of Surveys and Mapping (DSM) leadership toward other core stakeholders. According to Ditsela (2017), the project further experienced some adverse political interference, which created social divisions, fuelled tensions, and led to increased unrest between key stakeholders. Thus, the project lacked a conducive environment in which to thrive and to meet its initial objectives; hence, its subsequent failure. This study intends to investigate and use geoinformation techniques as foundational motivations for solving the locational challenges in the rural areas of developing countries such as Botswana.

The widespread availability of geocoding tools in GIS software and their functionalities, such as spatial analysis and geocoding, have made street addressing possible in many Western countries. The methodology section that now follows outlines in detail how the geoinformation techniques have been effectively applied in the study area.

3. Methodology

Street addressing is intended to provide authorities with an effective and efficient system of baseline locational information for a city so that high-performance management systems, using only a few resources, can be applied. In this instance, baseline locational information includes establishing reference points for locating devices and networks to improve communication. This requires extensive knowledge pertaining to the management of locational information through city mapping, codifying streets, conducting census surveys, setting up easy-to-use computerized systems, and developing applied management tools (Farvacque-Vitkovic et al., 2005).

To understand people's perceptions of and the current ways of locating properties to deliver products and services, a preliminary data collection activity was conducted in the study area (Tlokweng, Botswana) for four weeks, extending from September to October, 2022. The selected location of the study area proved to be representative of the broader population, offering variability and diversity within the country and providing for a richer understanding of the factors influencing location addressing in Botswana. The objective of the study was to gain insights from the public about the challenges arising from the lack of a proper LAS and to investigate how a new system could be developed to add value to the local community. Thus, the concept of a new LAS was introduced to determine, via a mixed methods approach, the participants' perceptions, and attitudes towards it. Questionnaires were presented to the respondents and structured interviews were conducted in a quest to understand the current processes used by organizations to locate home addresses in Botswanan villages. The approach facilitated the collection of information through different angles of questioning and as such, provided additional evidence, ensuring greater validity and a better understanding of the research problem (Freshwater, 2013; Johnson & Onwuegbuzie, 2007). In addition, this approach provided strengths that offset the weaknesses of both the questionnaires and the structured interviews, respectively. For example, the questionnaires were used to address the research problem and to record participants' views about existing challenges in location addressing, and suggestions on potential remedial factors. The structured interviews were then used to further explore the information collected from the first data collection phase: the key findings, outliers, and extreme cases arising from the responses to the questionnaires, which were noted and considered at a later stage in an in-depth analysis. Furthermore, the preliminary data collection approach included a comprehensive review and an assessment of problematic makeshift addressing systems in the study area and, as such, provided insights and justification for developing a prototype system for villages in Botswana.

A total of 42 participants were engaged in this activity. According to Baker and Edwards (2012), this number provides an opportunity for a researcher to penetrate beyond a very small

number of people without imposing hardships of data collection and in consideration also of the time constraints that researchers have. For this activity, 24 participants were from selected organizations from the land and government sectors (**professionals**) and 18 were from business ventures (the **business community**) in the study region. The anticipation was that the two distinct groups could provide valuable insights and findings from different perspectives, thus eliminating the likelihood of bias should a single group be selected. The residents were not engaged at this point in time since it was believed that the groups selected were better positioned to offer a broader and deeper understanding of the context and trends and to use their expertise to make informed predictions of location addressing in the study area. To broaden the range of perspectives, the participants were selected not only from one organisation. Rather, they were deliberately selected from different establishments and sectors within the study area to bring greater variability (Table 1). A purposive sampling technique was used in selecting the organisations since they complied with the characteristic requirements of this study. As such, the anticipation was that their engagement would provide for an in-depth understanding of the subject matter, the opportunities associated with location addressing, the challenges emanating from the lack of a proper addressing system, competition dynamics and the pertinent regulatory influences in the sector.

Table 1: The number of participants engaged in the study area.

Number	Organisation Name	Sector	Number of participants
1	Water Utilities Corporation	Utility services	4
2	Botswana Power Corporation	Utility services	2
3	Tlokweng Land Board	Government	5
4	South-East District Council	Government	6
5	Statistics Botswana	Government	4
6	Botswana Post	Goods and mail delivery services	3
7	DHL	Goods and mail delivery services	2
8	FedEx	Goods and mail delivery services	1
9	Sprint Couriers	Goods and mail delivery services	3
10	Debonairs Pizza	Food delivery services	2
11	Romans Pizza	Food delivery services	1
12	Choppies Supermarket	Grocery delivery services	3
13	Shoppers Supermarket	Grocery delivery services	3
14	Spar Supermarket	Grocery delivery services	3

All participants were consulted during working hours and at their respective organizations. They were each given a questionnaire to answer within three days; and on the fourth day, follow-up interviews were conducted individually. The questionnaires acted as an initial basis for discussion, while the interviews probed for greater understanding of the researched issue. To exploit the greatest potential from the respondents, the interviews and the style of the questions posed in the questionnaires were varied, starting with more general conversational

questions, and gradually introducing more specific probing questions. Starting with non-directive questions early in an interview can establish rapport with the respondent and provide insights into what is important to them before introducing sensitive issues (Salmons, 2014).

In terms of ethics approval, the project was considered low risk by the University of Botswana since it satisfied the University's ethical expectations and was subjected to the appropriate level of ethical review. The ethical approval process helped shape the approaches to the key issues, such as data protection, guarantees of confidentiality, and anonymity.

The geospatial datasets used in this research were collected from DSM as the national custodian of data and these included shapefiles (road network data, land parcel data, land use, and land cover data) and a 30 cm high-resolution orthophotograph. One of the most common challenges in dealing with the geospatial data was in converting the address data into coordinate values that could be mapped, analysed, and superimposed on other datasets in order to locate properties in an area of interest (Le Texier et al., 2018; Li et al., 2016). Nonetheless, the explanations and clarification gained through the literature sources, and the insights garnered through the data collection study, were put to good use in developing a comprehensive location addressing system for rural villages in Botswana.

3.1. The concept of geocoding using an address locator

The concept of geocoding is simply a process of finding an association between the attributes of the address and its specific physical location, as defined by its latitude and longitude, and which can be displayed on a map (Burns et al., 2014). Thus, the geocoding tool facilitates the conversion of a physical address into its geocoded coordinates. The first process involved in geocoding is to create an address locator concentrating on the two components of the address in terms of its style and reference data. The style refers to the format of the data being geocoded. Each style determines the level of geocoding detail that can be performed and the resultant output information. In this study, the commonly used geocoding style of the ESRI software suite, called the US address dual ranges (Dao, 2015; Kinnee et al., 2020; Zandbergen, 2008), was used to convert the address data of the sample dataset (Mmaratanang Ward) into geocoded coordinates that entailed apartment number, plot number, street name, and village ward (suburb).

The US address dual ranges style uses the street network data model concept to geocode geographic data. Furthermore, it is in line with the Land Survey Act of Botswana (Republic of Botswana, 2016), a legal document that guides the development and management of geospatial activities in the country. The Land Survey Act (Republic of Botswana, 2016) states that the numbering of lots shall proceed consecutively in each block and progressively along the streets or roads adjoining a block. Reference data for the dual range style are in the form of a line geometry dataset (Mmaratanang Road Network), which contains street segments. Each street

segment in turn consists of several address elements, such as house number, street name, village, and district. The advantage of using the dual range style is that it allows the geocoding tool to identify a specific house number from a range of house numbers along a street line. In addition, it identifies the side of the street where the house is located for easier navigation and identification of addresses.

To demonstrate the applicability of the location addressing system, a prototype application was developed using the Python programming language (Dumedah, 2021), the GeoPandas DataFrame (Zhou et al., 2021), and a Django Web Framework (Puneet et al., 2022). These programming languages and framework are interoperable with the GIS package used in this study which is, in fact, ArcGIS Desktop 10.8. Python is a high-level, general-purpose programming language, with its design philosophy emphasizing task automation, website and software development, and comprehensive data analysis. GeoPandas is an open-source package for manipulating DataFrames in Python to facilitate spatial operations on geospatial data. It is a package designed to work with vector data, which in this instance involve shapefiles. GeoPandas allows one to process shapefiles representing tabular data where each row is associated with a geometry. Furthermore, it provides access to various geospatial functions for applying geometries, geocoding, and plotting maps. The geopy functionality of GeoPandas was used to geocode a list of addresses in the study area which returned a GeoDataFrame containing the resultant point objects in a geometry column.

A user-friendly web interface was then created with Django, a free and open-source web framework, to enable participants to interact with the application to search for locations using different criteria, such as ID, street name, land parcel address, or plot number. Once the whole system development had been completed, it was deployed on a Microsoft Windows operating system and thoroughly tested in the study area to ensure that it would function accordingly, as required.

4. Case Study: Implementation of the LAS in Botswana

The study area for this research was a peri-urban village, namely, Tlokweng, located in the South-East District of Botswana. The village shares a border with the capital city of the country, Gaborone to the east. According to Statistics Botswana (2022), the population of Tlokweng in 2022 was 55,508 people. An increase in the city population owing to rural-urban migration has led to an influx of the population into the nearby villages of Tlokweng and Mogoditshane. Furthermore, the high cost of living in the urban areas has led to people settling in these villages where the housing and amenities are affordable. Therefore, it is necessary to investigate initiatives that could improve the standard of living for the people in such peri-urban areas, and, as such, could ease the pressure of overcrowding in the cities, such as Gaborone. The

anticipation is that the design and implementation of a location addressing system would address the challenges of service provision and product delivery to improve livelihoods in the peri-urban areas of Botswana.

To adequately implement the LAS in the study area, all participants (42) who participated in the initial data collection phase and feasibility study were engaged at that stage in testing and evaluating its usability according to their initial aggregated requirements. This activity took two months to complete because of the varying and demanding work commitments of the participants. The process involved the interactions of the participants with the developed prototype and responses to the simple queries and functionalities that arose that included: a) navigating through the application to appreciate its composition in terms of the available datasets, functionalities, and different tabs and icons, b) using the search function to locate land parcels within the study area, and c) applying the geocoding module to identify locations and navigate to places in Tlokweng. The objective of the interaction process was for participants to interact with the application and later, upon completion of their tasks, to rate and evaluate its usability. An online questionnaire, with 10 questions, was designed in the SurveyMonkey website, to provide a platform where participants could share their experiences of interacting with the application and suggest improvements to it.

Questionnaires in systems development allow developers to pose fixed questions that directly discuss aspects of the system under investigation. Unlike traditional approaches that produce questionnaires on a sheet of paper, online systems store the responses directly in relational databases, for easier manipulation, analysis, and interpretation. Moreover, the Web environment allows for a wider reach of respondents and flexibility as the participants can answer questions at their convenience. To obtain a varied array of responses, the questionnaire consisted of a variety of questions (Dix et al., 2004) that included : a) open-ended questions – which ask the users for their opinions, without restricting their responses, b) scalar questions – where users specify the degree to which a statement relating to the system is correct, and c) multi-choice questions – which offer users an opportunity to provide a set of explicit and independent responses. The questionnaire consisted of usability questions that included:

a) Rating scales that measured how easy or challenging it was to:
    a. navigate through the application,
    b. use the search button to identify land parcels of interest,
    c. use the geocoding function to identify and navigate to land parcels of interest.
b) Rating scales that measured how poor or good the usability of the application was in terms of:
    a. the visibility of the satellite image when zoomed in for navigation purposes,

b. searching for map features,

c. accessing help functions and guidance documents.

c) General questions about the application and its contents and whether participants:

a. would use such an application to navigate to areas of interest within their community,

b. could trust information from the application,

c. thought the application could improve efficiency in goods and service delivery to consumers.

d) A commentary box that requested participants to:

a. list the functions they liked in the application,

b. outline the tasks that were more difficult to complete and why they were difficult,

c. state the functions they would change in the application and provide reasons for the change,

d. suggest other functions for improving the application.

This study acknowledges that familiarity with Web mapping products and the internet may introduce a significant bias where participants have background knowledge that distinguishes them from other contributors. However, this potential bias was not necessarily a problem here as participants who adequately interacted with the application could provide valuable insights into the overall objective of usability testing and suggest crucial improvements where necessary.

5. Results and Analysis

The results of the **preliminary data collection** phase provided an understanding of participants' perceptions regarding the status of LAS in the country. The consensus is that the current systems are ineffective, outdated (mostly paper-based), prone to abuse, and lack proper route navigation functionalities, which are prominent in well-functioning LASs. From the study, it can be deduced that participants are aware of the technological developments of modern LASs. A large proportion (92%) of **professionals** highlighted their unhappiness about the current state of LAS in the study area (Figure 1). Their concerns were that the current systems and procedures were outdated and did not meet their requirements. Furthermore, they suggested practices that could improve product and service delivery at their respective organizations, including a) emergency services, b) route navigation, c) home deliveries and e-

commerce, d) urban planning and development, e) property ownership and legal issues, f) utility services, g) census data collection, h) business identification, and i) public services.

Regarding peoples' perceptions and current ways of locating properties, a large proportion (83%) of the **business community** indicated that it would be a challenge for emergency service providers to accurately and rapidly identify households in crises. A lack of proper addresses could lead to delays in response times and the potential loss of life and damage to property. A five-point Likert scale of importance (1 – unimportant, 2 – low importance, 3 – neutral, 4 – moderately important, 5 – very important) was used to measure the **professionals'** opinions regarding the need to effectively deliver products or services within a short time. Most of them (79%) responded in the positive by providing answers of four (34%) and five (45%). They asserted that the provision of essential services, such as water, electricity, and sanitation, becomes a challenge without a proper address system. Their reasons were that such service providers could struggle to easily identify and connect with their customers which could ultimately lead to inefficiencies and underserved communities. Surprisingly, respondents from the **business community** took great interest in this question and reflected a higher level of agreement than the professionals (94%). When probed further through interviews, their reasons were that it was central to their core business of adequately delivering products and services.

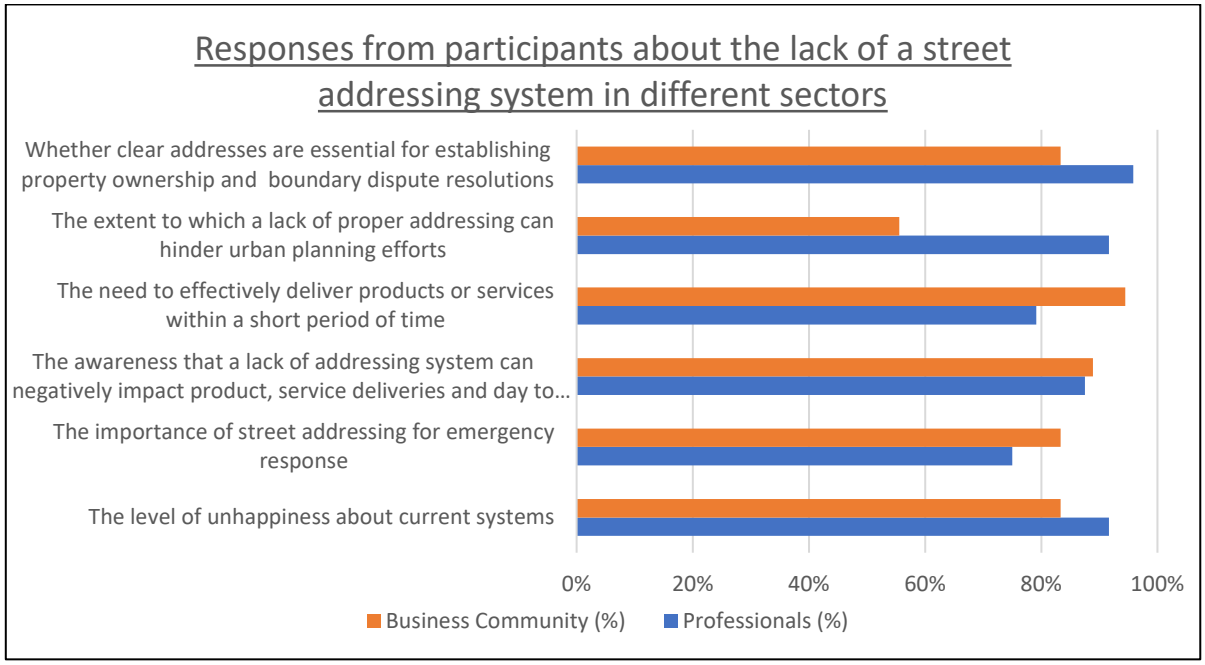

Figure 1: Participants' perceptions about the lack of street addressing systems in different sectors within the community.

5.1. Consequences of a lack of an addressing system

From the professionals' (urban planners, land managers, and land surveyors) perspectives, a lack of an adequate addressing system can hinder urban planning efforts. The consensus is that a lack of accurate locational data can delay the allocation of resources, and the planning of infrastructural developments and hinder planners from effectively managing and delivering services to the communities they serve. A large proportion of **professionals** (96%), particularly property managers and real estate officials, lamented that clear addresses were essential in establishing property ownership and resolving legal disputes associated with land ownership and boundaries. Such resolutions can be achieved through geocoding and georeferencing which use location addressing to link data to precise points on the surface of the Earth. In areas where LASs are non-existent or dysfunctional, conflicts can arise over land ownership and boundary delineations. Respondents (63%) from the statistics office highlighted the need for accurate census data collection emanating from the ability to locate and identify households accurately. One respondent (a senior official at the statistics office) stressed that a lack of a proper addressing system could lead to inaccurate demographic and socio-economic data, which would subsequently affect policy making and resource allocation.

Household delivery services and e-commerce businesses depend on accurate addresses for successful deliveries. The majority of respondents from the **business community** (83%) stressed that a lack of a proper addressing system limits the effectiveness of modern technologies such as GPS navigation to ride-sharing apps, as they rely heavily on locational data. In a nutshell, the preliminary data collection activity has revealed several issues that can result from a lack of a proper addressing system, and which involve the assigning of unique addresses to every location. The consensus is that the implementation of geolocation technologies and the development of an effective LAS can help improve navigation, emergency responses, product and service delivery, and the overall quality of local communities.

5.2 Usability testing results

The results of the **usability testing** activity revealed the importance of the technical and usability aspects of the LAS. According to 85% of the **professional** reviewers, some of the key strengths of the applications are its flexibility, clarity, and offline capability. They observed that its offline capability could be beneficial in remote areas without internet coverage since work could be done in the offline mode and later reconciled and updated when internet connectivity is obtained. Nonetheless, 58% of the **business community** reviewers had concerns about the technical complexities of the application such as its basic navigational functionalities. For example, the panning function, which on several occasions had a delayed effect when loading the orthophoto (during zoom-in and out activities). Such challenges, as highlighted by the reviewers, could frustrate users and result in a loss of interest in using the application. Other concerns were noted and summarized as follows:

a) Some **professionals** (67%) stressed the need to have a system with a faster download speed for maps. According to Dragicevic and Balram (2004), this can be achieved by providing asynchronous services that do not halt other services while waiting for the request to return. Therefore, a user can continue interacting with the application, while waiting for the request to be completed,

b) From the **business community**, 91% of the respondents requested a help tool that focused on 'user perspectives and needs' rather than on a developer's perspectives and instructions. For example, user-centered designs focus on multiple sources of knowledge to support the creation of systems based on the user's abilities and capabilities, and the tasks involved, rather than on the technology of the devices used (Ritter et al., 2014).

The significance of the usability questionnaires is that they exposed important issues to be taken into consideration regarding the development of the LAS, for example, that it can be strategically positioned to be functional to both spatial and non-spatial experts.

5.2. A prototype LAS for Tlokweng village

The constructive nature of the reviews and comments received from the participants strengthened the conceptual, technical, and usability aspects of the location addressing system. Moreover, the usability evaluation activity pinpointed the key areas that could improve the robustness, acceptance, usefulness, and effective implementation of the system, such that it would be relevant to the community it served. The comments have further highlighted important aspects of systems development to consider in terms of conformance to the established standard procedures, institutional frameworks, and official database schemas of the study area. Such considerations have the potential to increase the recognition of the application and the eventual use of its products in many organizations. The developed LAS for Tlokweng village is presented in Figure 2 below. It has basic plot location functionalities that allow users even with limited geographic knowledge to navigate through it with ease by using English language descriptions rather than map icons.

Concerns raised by the professionals regarding the technical complexities of the application were taken into consideration and sufficiently addressed. For example, the snapping tolerance distance between land parcel vertexes was increased to enable the pointer to automatically snap to the existing vertex once the set radius is met. Such activity can improve the quality of the digitized datasets as overlapping land parcels would be eliminated or greatly reduced. Therefore, before implementing the application, all concerns raised by participants were sufficiently addressed. Figure 3 below shows a successful land parcel selection in the application together with its associated attribute data for easier comprehension and navigation.

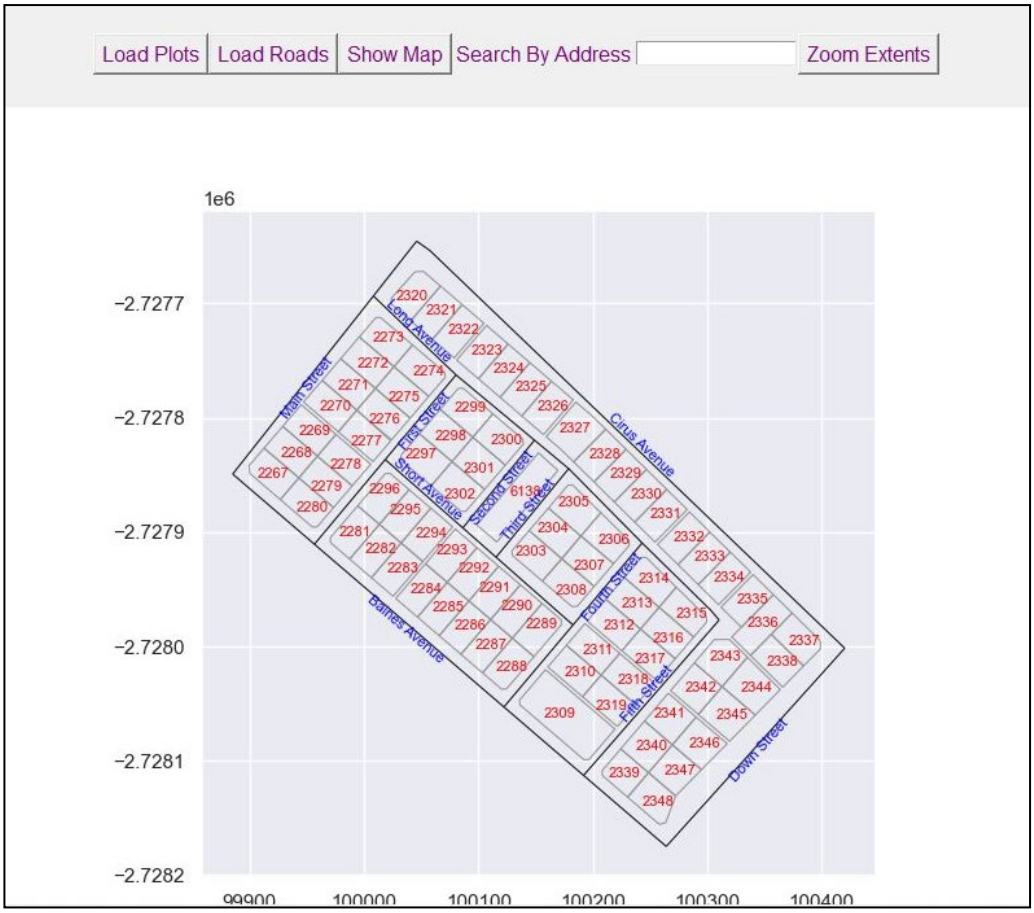

Figure 2: The developed LAS for Tlokweng village.

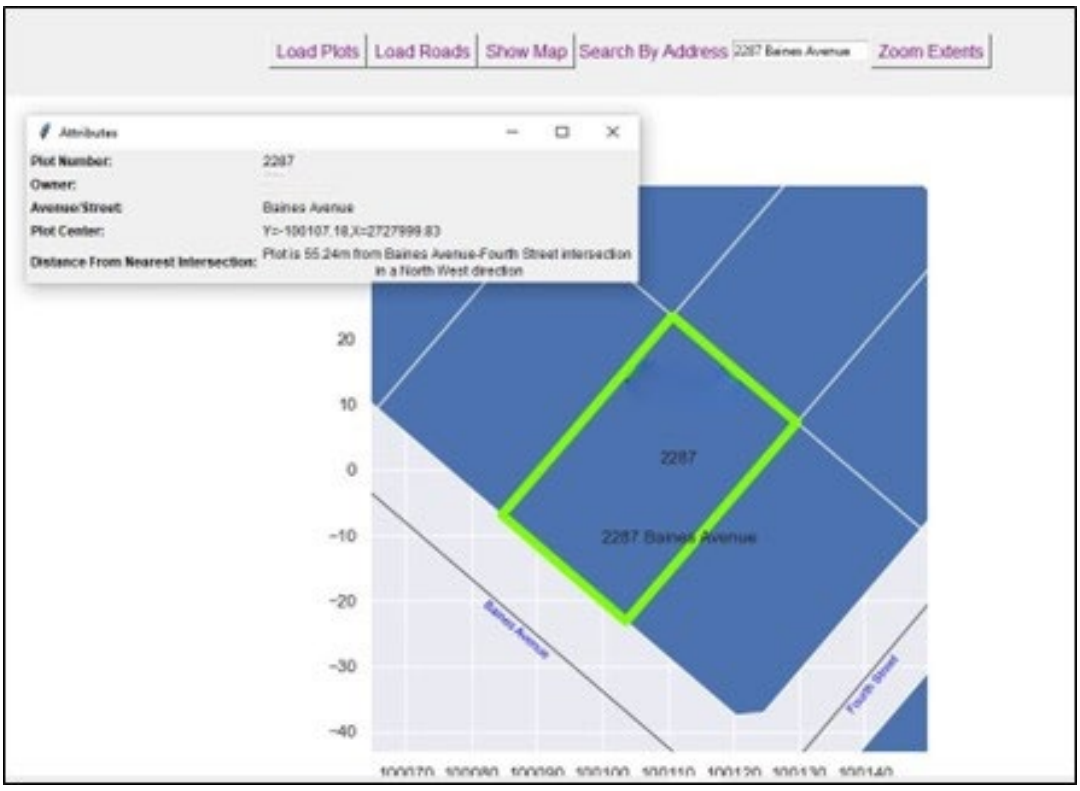

Figure 3: Land parcel selection functionality in the application.

The development of the LAS has further taken into consideration that errors that may be made when users input plot numbers outside those obtained in the application. Therefore, error handlers have been included in it, such that whenever there is an entry of an invalid plot number, an error message pops up, as in Figure 4 below.

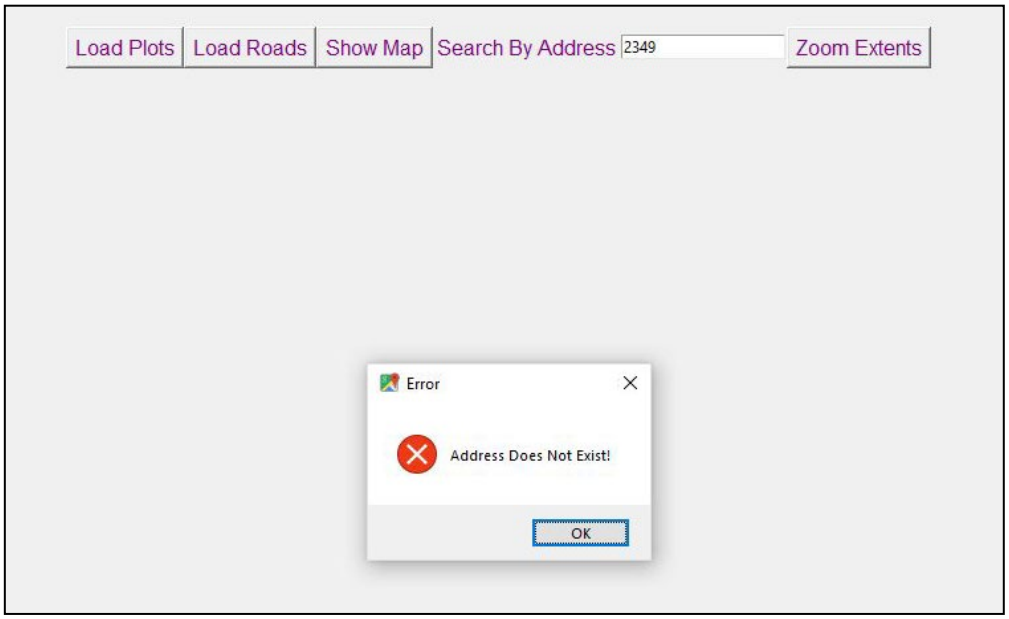

Figure 4: Error notification of an invalid plot number in the application.

The results obtained from the two data collection activities (preliminary data collection and usability testing) revealed valuable insights that helped develop the LAS proposed in this study. Results from the preliminary study highlighted major challenges from both the professionals and the business community regarding the lack of a LAS in the study area and its negative effects. Such concerns by the participants were later used to develop a functional prototype LAS to meet user requirements and to address most issues raised during the preliminary stage. Lastly, a usability evaluation of the prototype was carried out with the same participants who took part in the preliminary data collection study. The usability evaluation measure conducted strengthened the technical, usability, and overall interactivity of the application. The anticipation is that the developed LAS could adequately identify and locate land parcels in the study area for improved service and product delivery.

6. Discussions and Conclusions

This study suggests that a properly designed LAS can help address the many challenges identified through the data collection activity involving key stakeholders in the community; hence, the motivation to investigate and develop a functional prototype LAS for the village of Tlokweng in Botswana. Nonetheless, it should be noted that the sustainability of this LAS depends on the buy-in of professionals, the business community, and local people at large. As

mentioned earlier, many communities rely on location services for various purposes, amongst others, to optimize responses during emergencies, plan infrastructural development, and provide goods and services promptly. However, the lack of proper addressing systems can deter such initiatives, thus leading to poor service and product delivery, as well as hindrances to urban planning. In addition to facilitating address locations, LAS should be viewed as a mechanism for stakeholders to improve urban management in three key areas: a) the production of complete maps of the area to be used by various municipal services, b) the implementation of a systematic tool to collect important socio-demographic data, and c) the development of a tool with a complete address database which can be used to process, update and query census data.

Through an extensive review of the literature, this study has identified that the suitable model for a LAS for a country such as Botswana is the US address dual range, which has more flexibility in verifying addresses than the other address locators that were investigated. Its capability to designate a side of the street segment where a land parcel is located makes it more feasible in that it results in less ambiguity, particularly in the case of first responders. The notion that about three-quarters of the world population lacks a proper street address is of great concern to this study. A preliminary data collection activity conducted in the study area has revealed that the lack of a proper street addressing system poses various challenges to local communities in rural areas. Addressing these challenges requires the application of geoinformation technologies to assign unique addresses to every location in the area of interest. These efforts can subsequently improve navigation, service and product delivery, emergency response, and the overall quality of life for residents.

The methodology section of this study has elaborated on how the data collection activity was conducted successfully by engaging key stakeholders to expose the current successes and challenges of identifying and locating land parcels in the area. A large proportion of the respondents acknowledge the negative impacts caused by the lack of a proper location addressing system. The information gathered was extensively analysed and later used to inform the development of a prototype application that enabled participants to interact with it such that improvements could be made.

Overall, stakeholder involvement in testing and gathering inputs about the usability of the application have brought clarification and an understanding of the issue, as well as suggestions that include the following: a) the identification of bugs and other undesirable aspects that were missed or overlooked by the researchers, and b) ideas on how the application could better be positioned, and functionalities and possible information that should be on hand such that they could benefit all stakeholders. Concerns raised by participants such as the technical complexities of the application were considered and sufficiently addressed. Moreover, the

usability questionnaires revealed important issues regarding the improvement of the LAS such that it can be strategically positioned to be functional to all relevant stakeholders.

In conclusion, this study has successfully proven that geospatial technologies can be used to solve the challenges of the lack of street addressing systems in the rural areas of a developing country such as Botswana. An ever-expanding peri-urban village such as Tlokweng needs a LAS, which is not just a signaling operation, but an indispensable foundation for urban planning and management. Future work will investigate and develop address geocoding systems that use machine learning techniques to improve address matching for various geographic activities.

7. References

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