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# Development of an Integrated System to Enhance Spatial Data Processing & Management for Planning Authorities

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## Abstract

In a world where there is constant data generation and processing, the need for an integrated system cannot be overemphasized. The systems that enable storage of large amounts of spatial data and must be made available to multiple users in real time. Studies have shown that standalone desktop spatial systems are often rigid and inflexible to support multiple data processing or demands from multiple users. The integrated spatial management system was designed to address the above highlighted challenges by bringing enhanced possibilities of utilization of spatial data though improving accessibility, visualization, and processing spatial information. The present work employed a mixed approach of qualitative and quantitative techniques to obtain the desired result. Qualitative data collection tools were used to collect field data required to design the prototype. The research sought to establish whether the integrated systems are in use by the targeted institutions, the findings highlighted that 71.4% have no integrated spatial data systems while 28.6% have partial-integrated systems. An overview of the architecture of integrated spatial systems consists of a well distributed database linked to multiple tools and platforms to query both the spatial and non-spatial data. The WEB-GIS and Mobile GIS interfaces were developed to allow multiple users to access information through the web in real time and data collection, respectively.

## Keywords

Integrated Information Management System, Geographical Information System, Planning Authority

## 1. Introduction

The Integrated spatial systems combine multiple spatial tools and data types to

enhance data storage, retrieval, and visualization in real time. In addition, the integrated system architecture integration consists of various spatial data characteristics, software features, and hardware capabilities and automated processes (Wahed, 2017). Integrated GIS spatial data systems provide a very flexible platform for data collection from multiple sources in a variety of formats and the systems also offer the capability of transforming analogy data into digital (Weber et al., 2017). In addition, integrated systems offer the possibility to visualize data in various formats such as graphs, tables and texts which has been proved to be the most efficient way to present geographical information (Wahed, 2017). The process of system integration requires a combination of diverse computational tools and processes into purpose-specific inputs and outputs which also enable the synchronization of data in real time (Longley et al., 2015). In today's fast moving and highly technological landscape, it is not only important, but it is a necessity especially to the institutions working with geographic data on a daily basis (Tao, 2000).

## 2. Related Works

An integrated Geospatial system is a comprehensive system made up of people, hardware, software, data, and methods. In addition, systems combine features and services of Web GIS, Mobile GIS, and Desktop GIS. Integrated systems have been widely applied in urban management through modeling, simulation, and spatial representation. This has also enabled network-wide decentralized communication and improved decision-making in planning authorities (Tao, 2000), as shown in **Figure 1** below.

(Yang et al., 2015) study aimed to provide a practical solution for land price information using web GIS. The findings indicated that GIS-based web integration and web GIS technology allowed for greater understanding of the pattern and distribution of land prices, making it accessible to a wider audience including investors and administrators with limited domain knowledge. The study also demonstrated the potential of web GIS to be applied in various informative web models. The web GIS was designed and implemented to meet the needs of the

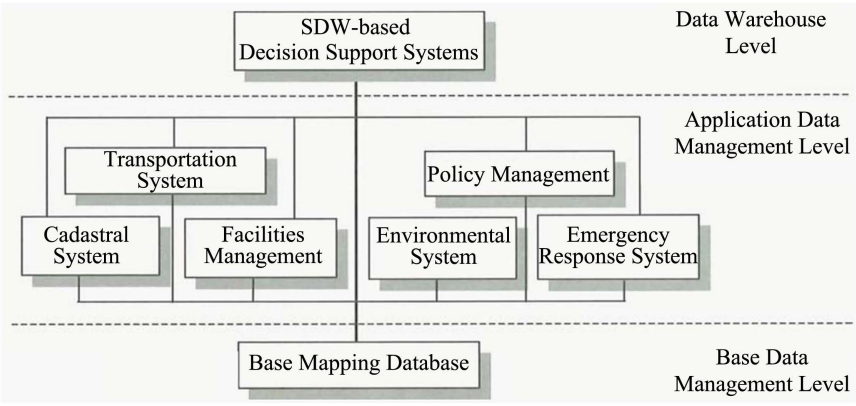


**Figure 1.** Architecture for urban data management.

land market after a review of the background and analysis models of land price (Yang et al., 2015). However, there are limitations with the Web GIS system. One limitation is the lack of real-time data updates. The data on the Web GIS may not reflect the current state of the land prices, making it difficult for users to make informed decisions. Another limitation is the limited spatial analysis capabilities, which may not meet the needs of advanced users who require more sophisticated analysis tools. Additionally, the system may have limited storage capacity, which can limit the amount of data that can be stored and processed. Additionally, the security of the Web GIS system may also be a concern, as it is vulnerable to cyber threats such as hacking and data theft (Yang et al., 2015). (Okello et al., 2017) examined the shortcomings of paper-based utility maps and attempted to address them with a more effective system that was based more on the organization, manipulation, and presentation of spatial data. They concluded that the usage of GIS lowers overall maintenance costs and provides end users with a web-based, central system that contains correct and current information (Okello et al., 2017).

The survey by (Tao, 2000) discussed the importance of Integrated Spatial Data Systems (ISDS) in addressing the challenges of urban data management, such as the fragmentation of data due to numerous operational databases. ISDS offers a solution for integrating and sharing diverse data sets across urban agencies and enables network-wide decentralized communication and decision-making. However, there are limitations to the survey that should be noted. One limitation is the lack of emphasis on the technical challenges and difficulties in implementing ISDS, such as the need for specialized skills and expertise to coordinate the administration and sharing of diverse data sets (Tao, 2000).

## 3. Methodology and System Design

The research approach employed in this dissertation was a mixture of qualitative and quantitative techniques to obtain the desired result. Qualitative data collection tools were used to collect field data required to design the prototype.

### Data Collection

Qualitative data was collected through key informant interviews (KII). The questionnaire was pre-tested and adjusted depending on the feedback from the pre-test. Quantitative data was collected through a questionnaire. Further, a quantitative questionnaire was uploaded in KOBO Collect (a digital survey tool) software on the tablet for quick administration and completeness. Furthermore, secondary quantitative data was collected using a quantitative data extraction tool.

### Sample Size

Sample size for quantitative data collection was calculated from planners working in the local authority which is 395 distributed countries wide. The sample size was determined using the formula below.

$$n = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

where

$z$ is the z score

ε is the margin of error

$n$ is the population size

$\hat{p}$ is the population proportion

This means 196 or more measurements/surveys are needed to have a confidence level of 95% that the real value is within ±5% of the measured/surveyed value, as shown in Table 1 below.

**The current model**

The current model shows the need for systems interoperability capabilities as the current workflow is a standalone. Due to lack of interoperability, the planning authority is facing serious problems with data management and integration. Geodata should be as seamless as possible, with coordination across departments where possible. The other gap identified from the current model is that data is collected, processed, and maintained not according to standards and the result is that the organization is faced with difficulties to maintain data integrity across databases and to enable data integration, as shown in Figure 2 below.

**The proposed model**

The proposed model was designed to improve the limitations of the current model by automating planning permission applications and physical inspection. In addition, an integrated database was created with multiple access points from Desktop GIS, Mobile GIS and Web GIS with which improved security, and control of the data-sharing environment. Unlike the current model where the spatial databases are "stand alone systems", the proposed model ensures that data system implementations are not isolated, and the data is shared and managed in real time, as shown in Figure 3 below.

Table 1. Research design.

| Objective | Question | Method |
|---|---|---|
| Establish common spatial data management systems in use by Planning authorities. | What common spatial data management systems are in use by Planning authorities? | • Literature review<br>• Questionnaire administering |
| Develop a data integrated management system based on gaps on (1) | To what extent can an integrated system be designed to enhance spatial data management and processing? | Modeling and system design |
| Develop a data collection application-based on the model on (2). | How can a data collection application enhance data management and processing? | Prototype development and link it to the main prototype |

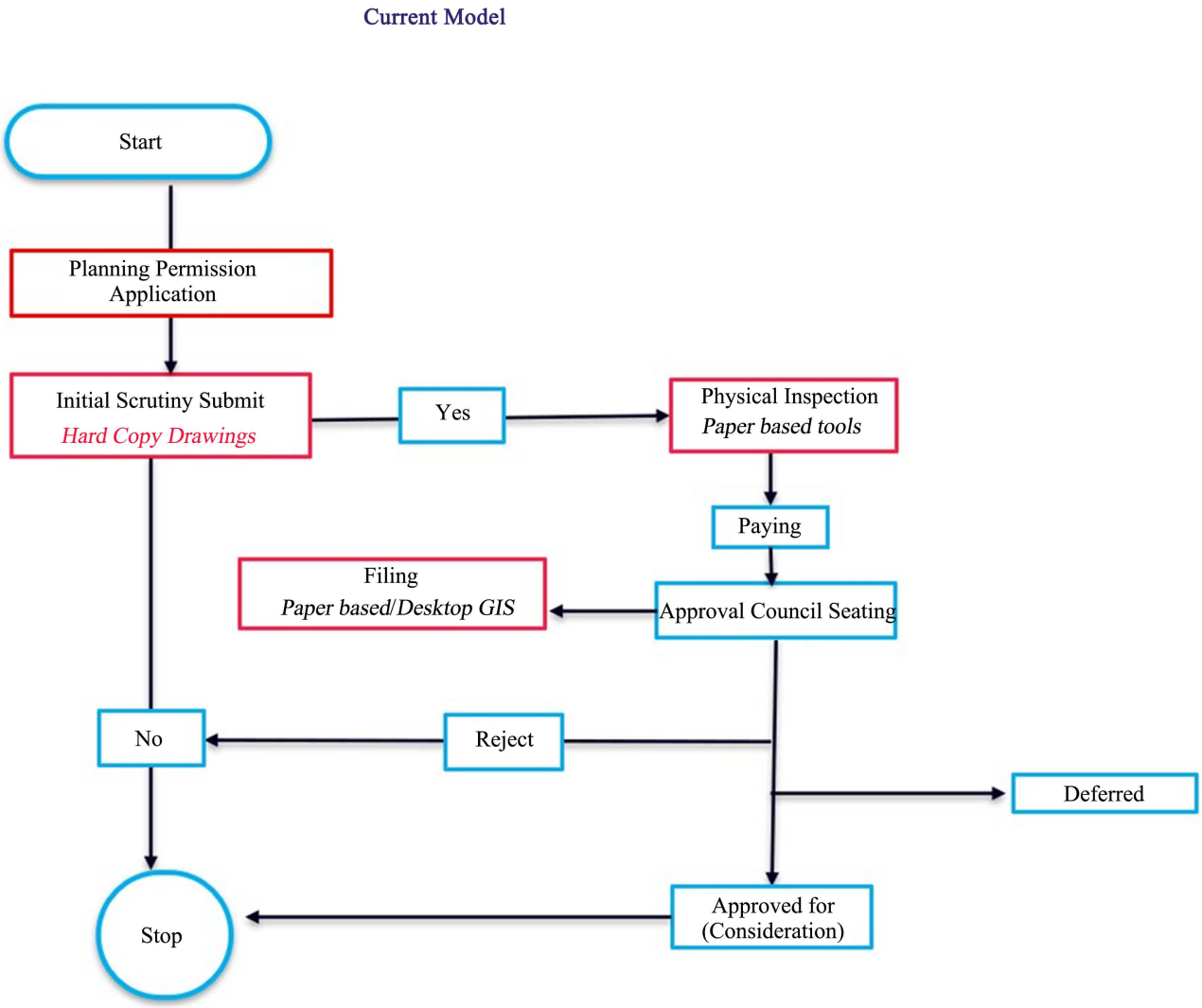


**Figure 2.** Current model.

## 4. Results

This chapter focuses on the results as the output of the research activity. It concludes by showcasing the implemented prototype, the requirements needed for the prototype system to work.

**GIS Systems currently in use**

Regarding the type of GIS Systems currently in use by the sampled institutions, all institutions (100%) presented that they use Desktop GIS. On the other hand, 42% use Mobile GIS while the other 42% use Web GIS, as shown in **Figure 4** below.

**Spatial data institutions specializations**

It was further sought to establish the institutions' specialization's regarding spatial data as highlighted in **Figure 5** below. All institutions (100%) are specialized in data management while 85% in Data collection. It was further established that 57% of institutions are specialized in Data analysis and that 42% are specialized in integrated data management.

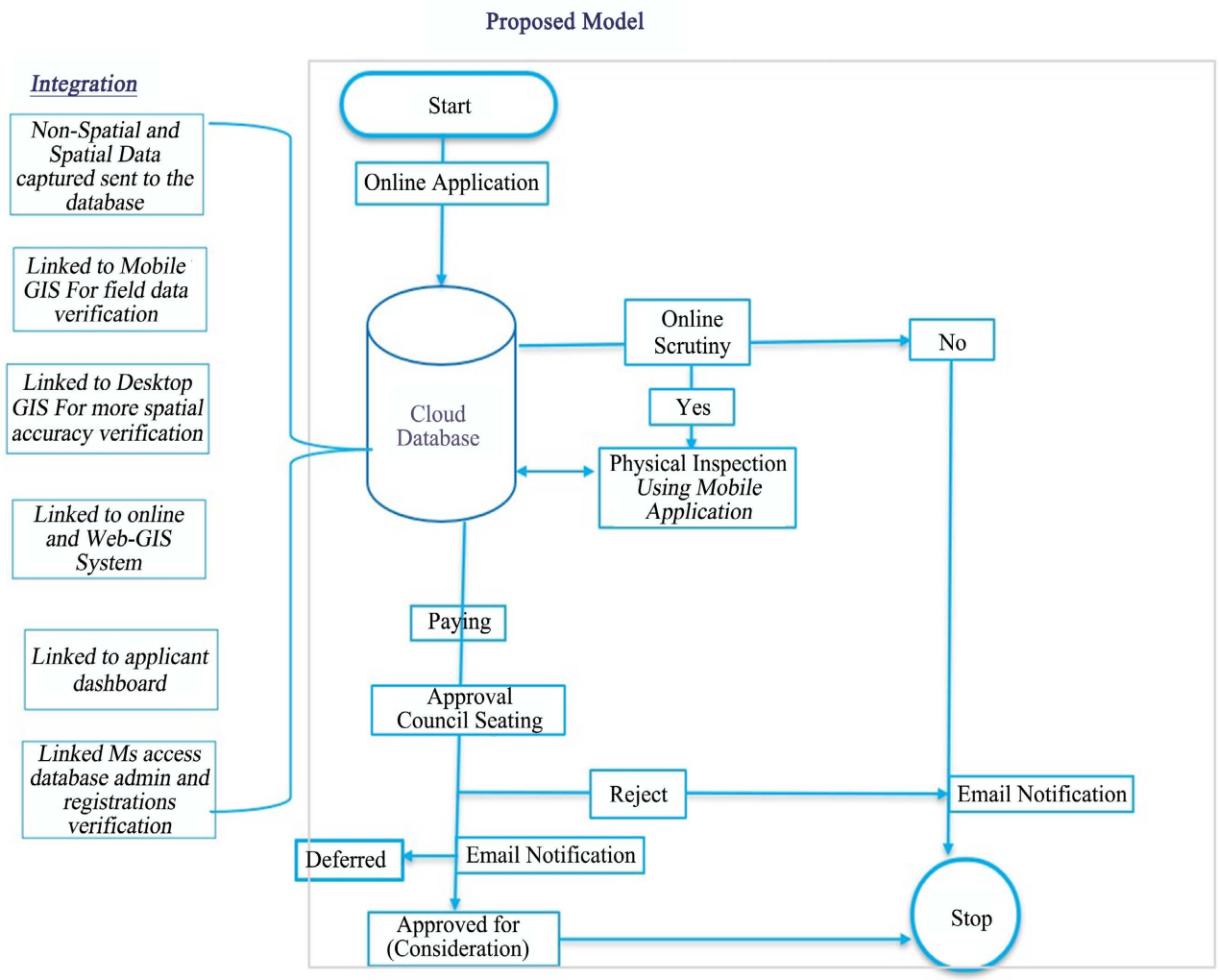


**Figure 3.** Proposed model.

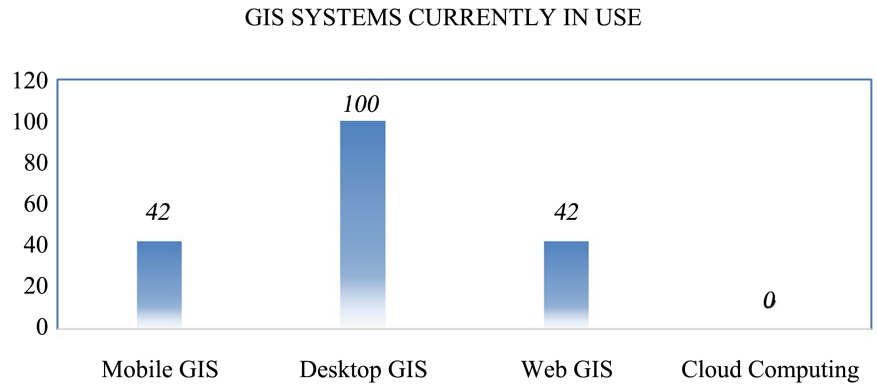


**Figure 4.** Type of GIS Systems currently in use.

Lastly, it was sought to establish whether the data storage systems being used in the target institutions are integrated with other systems. As shown in **Table 2** below, 57.1% have not auto-integrated their data storage with other systems while 28.6% have auto-integrated their data storage systems.

Table 2. Data storage systems auto integrated with other systems.

| | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| **No** | 140 | 71.4 | 71.4 |
| **Yes** | 56 | 28.6 | 100 |
| **Total** | 196 | 100 | |

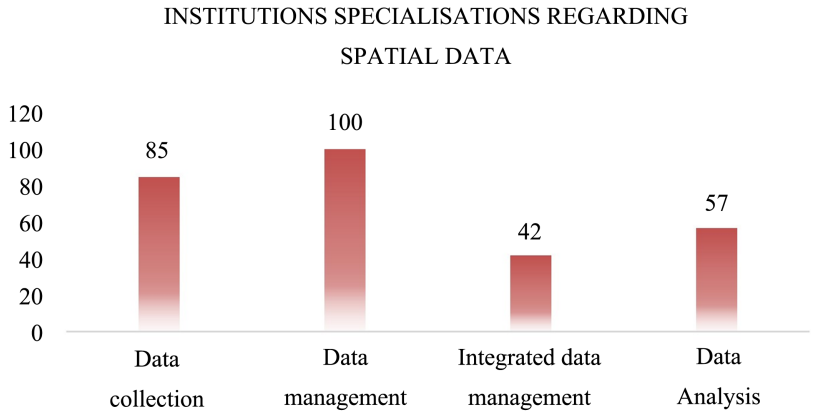


Figure 5. Institutions specialisations regarding spatial data.

### Implemented System

The system prototype was developed with three modules, client application, the data capturing module and the system administrator's module. The client module focused on property management and application for planning services, the field inspection module focused data capturing, the field report was issued based on data collected by the mobile application. The administrator's module had features such as reviewing the applications from clients by rejecting or approving, reviewing the reports, and land use map.

### Client Module

This module shows how the clients, or the user was using the system upon successful login, the user was given the access rights of the dashboard, as shown in Figure 6 below.

The system also allowed the users to apply for the land conversions (customary to state) this was done by uploading the csv file with the latitude and longitudes (coordinates) for the parcel, as shown in Figure 7 below.

### Admin Module

The module had features such as reviewing the applications from clients by reject or approve, review the reports, and land use map, as shown in Figure 8 below.

The system was developed with an application review panel, in order for the admin to monitor and review all the applications from the client, as shown in Figure 9 below.

The system was developed with an approval panel to review all the applications from the client, as shown in Figure 10 below.

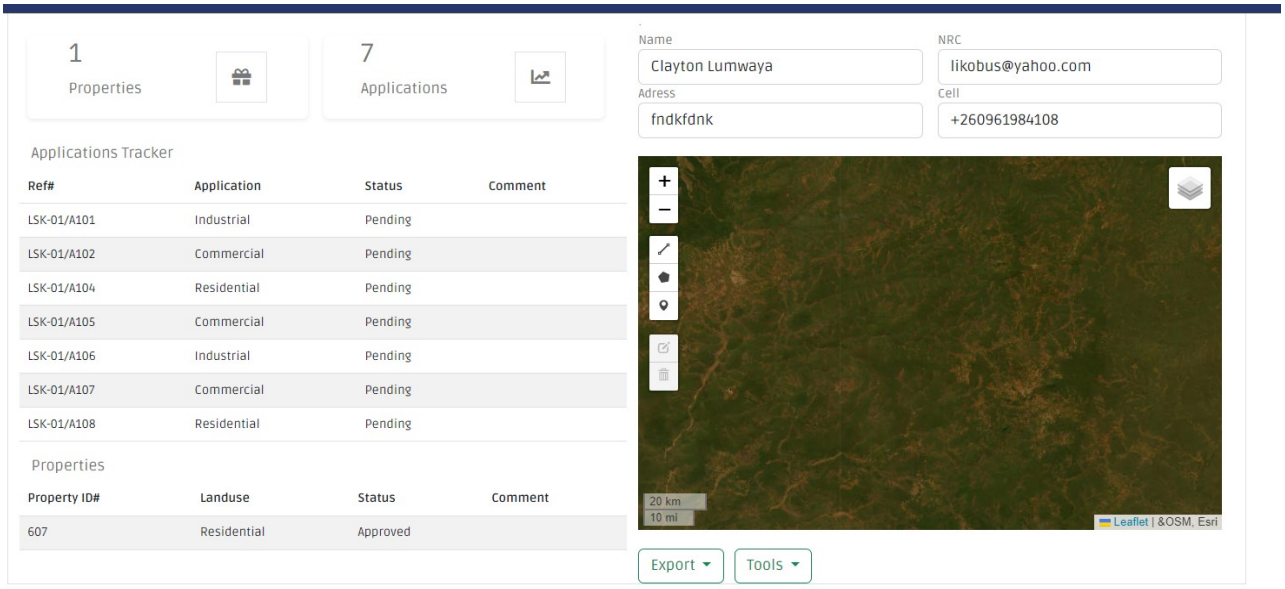


**Figure 6.** User dashboard.

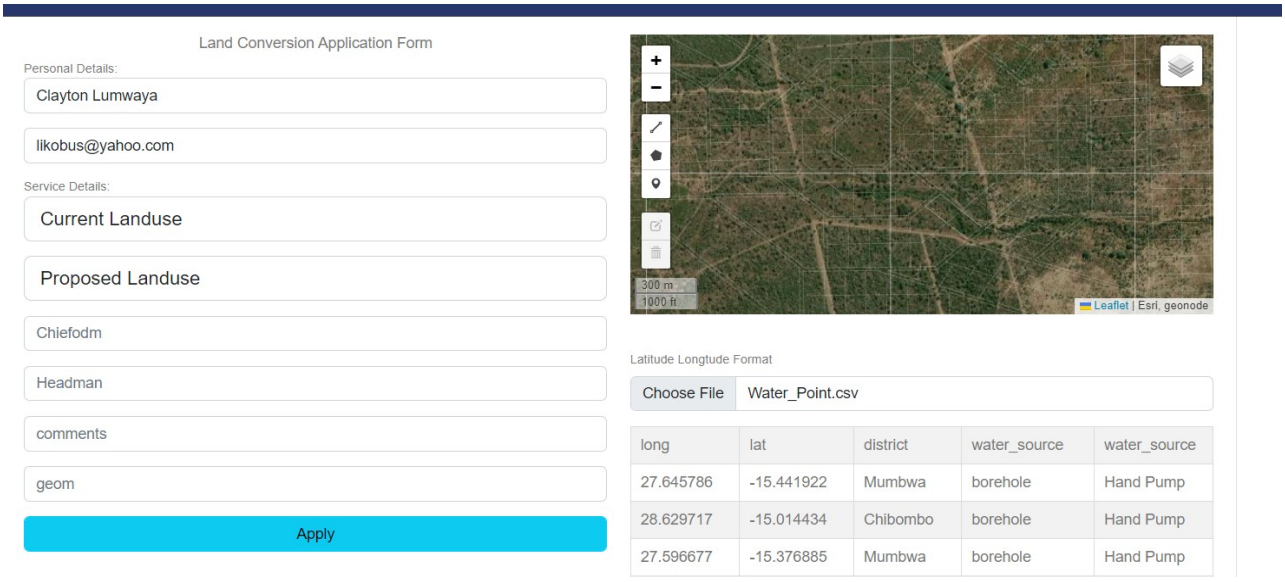


**Figure 7.** Land conversions form.

**Field Inspection Module (Mobile App)**

The system was configured to the app that allowed development control and field inspection, as shown in Figure 11 below.

The system was linked to the Desktop QGIS to allow more advanced geoprocessing functionalities to be performed by admin, as shown in Figure 12 below.

## 5. Discussion

*Common spatial data management systems in use by local authorities.*

This research project focused on understanding geospatial data management and web technologies to improve data processing and management. In trying to

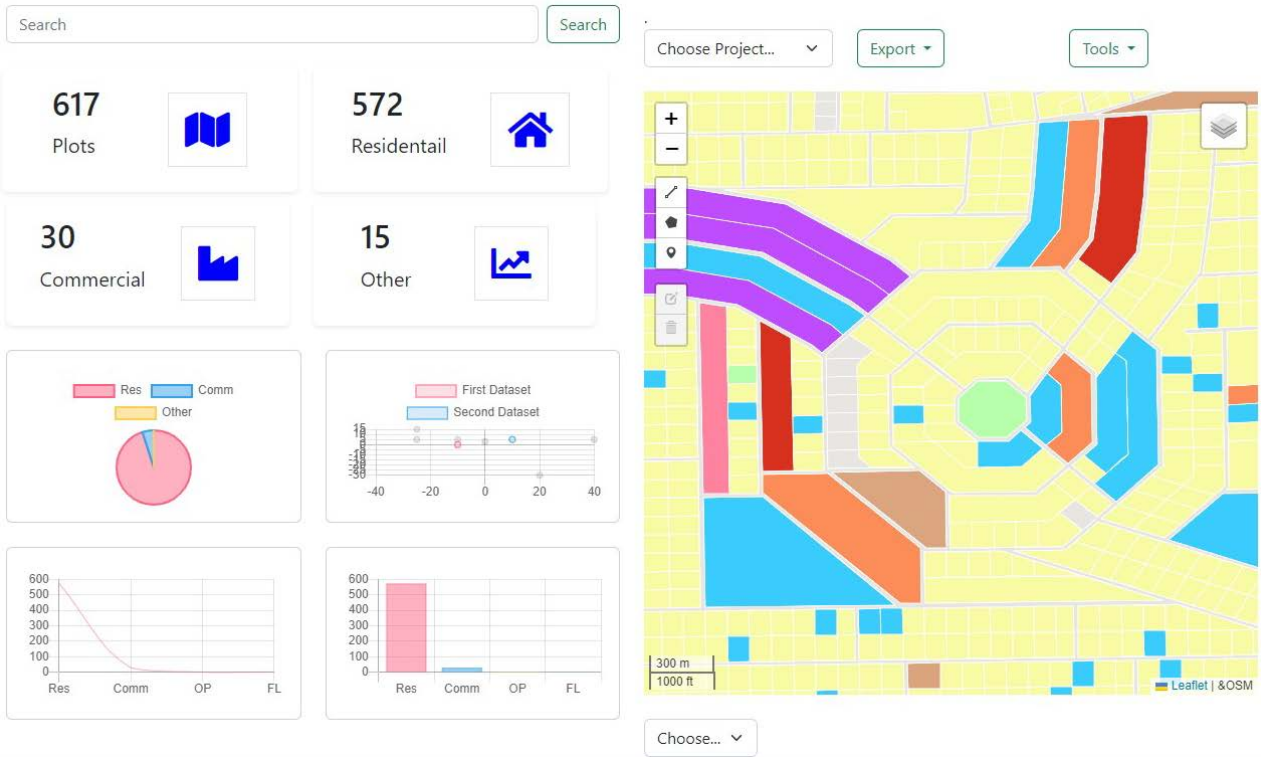


Figure 8. Admin dashboard.

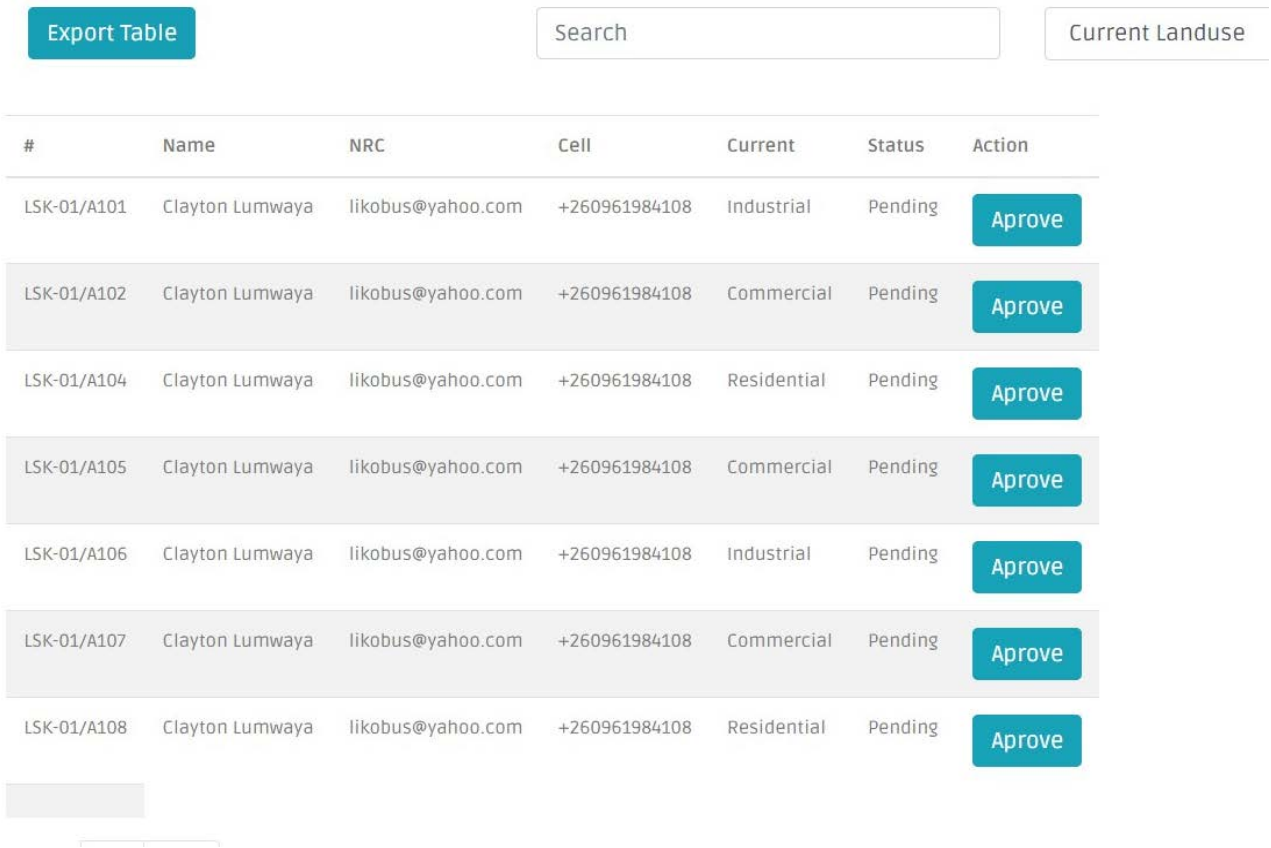


Figure 9. Application review.

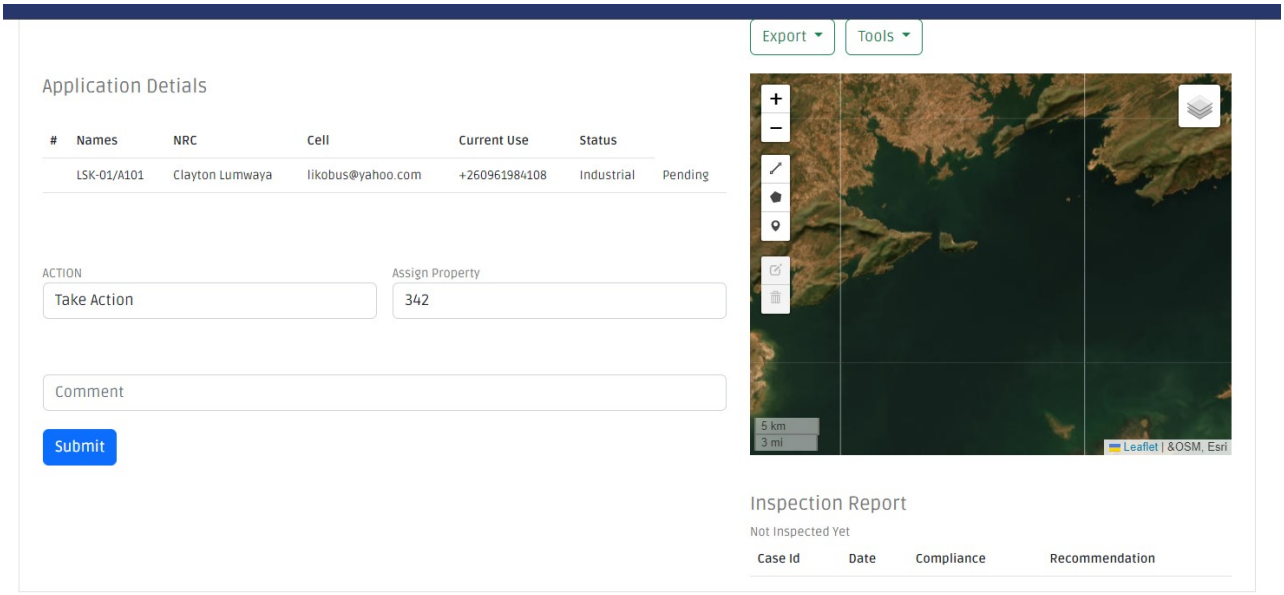


**Figure 10.** Approval panel.

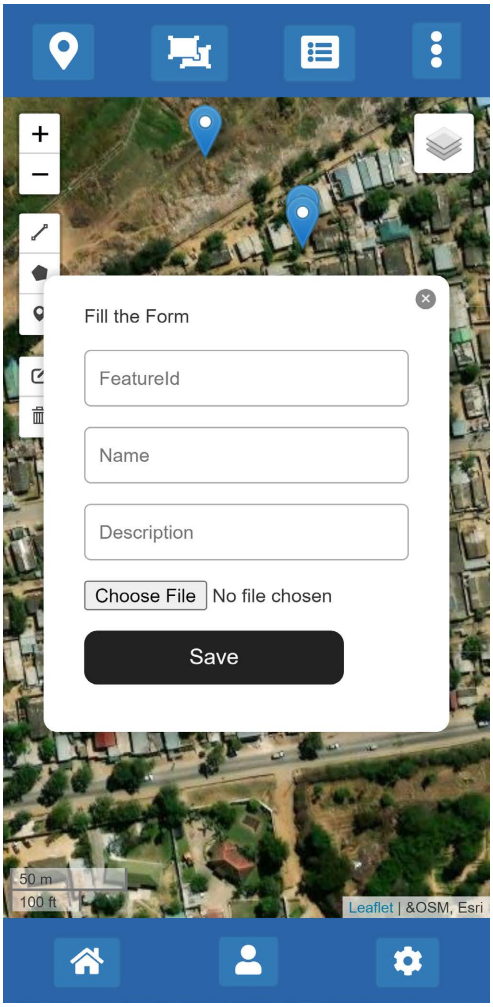


**Figure 11.** Mobile App.

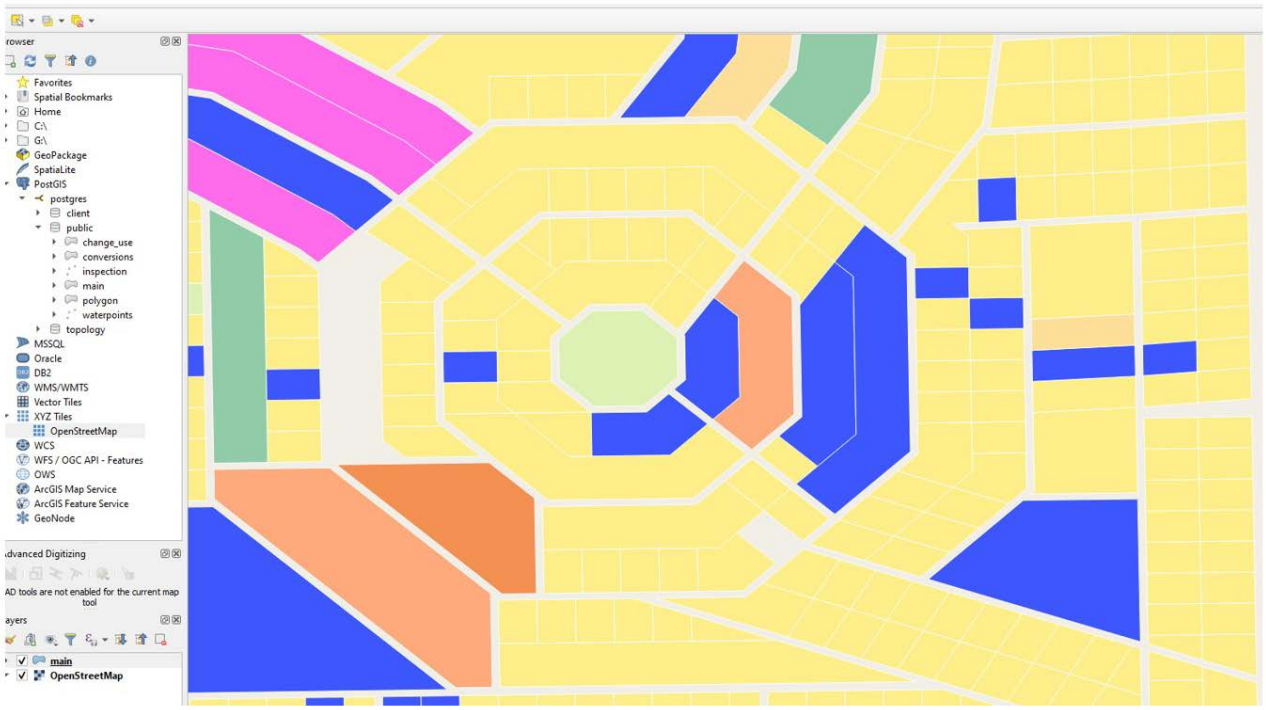


**Figure 12.** QGIS integration.

meet the first research objective, it endeavored to establish the common spatial data management tools used by local authorities. The finding from the research showed that of all sampled institutions, all the respondents used Desktop GIS. On the other hand, 42.9% use Mobile GIS while the other 42.9% use Web GIS. This finding aligns with (Yang et al., 2015). GIS tools are frequently used in conjunction with sophisticated scientific models and are commonly used by the local authority to enhance data management. These findings (Yang et al., 2015) highlighted that integrated Geospatial Information Systems have greater powerful benefits through applying the concept of cloud computing to overcome shortcomings related to desktop GIS which include the huge start-up cost, storage capacity and inability to provide the feature of location independence accessibility where the GIS can be accessed from anywhere and anytime.

Premised on the findings that all the sampled institutions are specialized in spatial data management, the Web Map intentionally incorporated tools based on the tools employed by local authorities in their day-to-day spatial data management. For instance, the institutions sampled are well vested in the use of mobile GIS as well as Web GIS which the system has integrated. This is meant to provide seamless visualization, analysis, and navigation at once compared to traditional methods of spatial analysis.

*Development of a data integrated management system based on gaps identified in* [*research question* 1]

A model particularly aimed at providing an integrated data management system based on the gaps identified through both desktop review and questionnaire administration, was designed. The GIS-based web integrated spatial analysis

models and web GIS technology, which allowed more investors and administrators with limited domain knowledge to obtain further understanding on the change pattern and spatial distribution of land price by an online means (Yang et al., 2015). WEB GIS showed great potential to be applied in diverse informative web models. Most institutions have not integrated their data-storage tools with their data management systems and therefore risk losing data which they have built over time. The system tackles this by leveraging PostGIS as a geospatial information storage. Essentially, the integration process of the system begins by incorporating processes such as preparation, updating and processing data which would be accessed via a server (in this context, PostGIS).

*Development a data collection application-based model on* [*research question* 2]

Data collection is a critical and important part of the operation of local authorities, therefore the research ensured that the data collection and monitoring is done by integrating a mobile application at to the web GIS and to the other system to ensure that applications that are due for field inspection were inspected and the collected data is sent through the mobile application. the findings from the research showed that at the moment there isn't any standard template currently being used by the local authorities or planning authorities to ensure development control or ground inspection is done in systematic manner, therefore the research was design form and embedded it the mobile application which is critical to ensure that there is a standard template for field inspection or development control. The findings show that field inspection enabled the local authorities to easily check and ensure that the application sent and what's on the ground is the same. The integration between the mobile application and the web GIS and the system itself enabled local authorities to have standard tools for verification and update in the system and sent back to the server.

## 6. Conclusion

The research project has shown how spatial data management in local authorities, among other spatial data management institutions, can be enhanced using evolving technologies. As per the aim of this study, a data management system has been designed as a prototype for fostering collaboration in the use of spatial data across diverse domains. As asserted by (Singh, 2009), an effective Integrated Spatial Data Management System must be underpinned by an intuitive organizational structure, robust interoperability, and ease of sharing, discovery, access, and use. In this regard, the system provides information which fosters an ability for functional spatial analysis through updated formats and value-added data attributes. The geospatial standards associated with the system are consistent, easily accessible with high interoperability across platforms.

## 7. Recommendations

There is a need for local authorities to transition to integrated data management

systems, this will help to bring efficiency in service delivery and improve data quality.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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