Role of GIS & Analytics in Transforming Municipal Administration

Sandra Maria Abin, Amrutha Elizabeth Shaju, Jishnu Priya K C, Abhijith V, Tony Jose
GIS Analysts
Department of GIS, UL Technology Solutions
Kozhikode, Kerala, India

***Abstract*—Urbanization is well-linked with economic growth. As per the 2011 census report, currently, Indian cities accommodate 377 million people i.e. 31% of India's current population, and contribute 63% of the GDP and are expected to accommodate 800 million in 2050, when one out of every two Indians would be living in urban areas. However, this rapid urbanization is putting pressure on available infrastructure facilities like water, sanitation, housing, schools, hospitals, colleges, mobility, etc. The urban local bodies take up the challenging responsibility for bringing those infrastructure facilities to the general public. An efficient and forecasted approach to planning can only lead the transformation without financial loss. Using specific tools based on new technology is the keyway for large scale transformation at a faster rate, GIS with analytics is an emerging combination of technologies that is capable of producing efficient solutions.**

A complete GIS-based digital data repository can transform the way Local Self Government Departments (LSGDs) function. Data collected through field survey & household questionnaire survey serves as the very soul of the whole system. This solution uses drones to capture images of the ground with micro-level details including terrain and land features which are processed and digitized to develop the base map. The details of all assets including roads, buildings, etc. are collected through the survey along with their photographs. Household surveys collect relevant socio-economic data of citizens. Finally, the data collected are made into geospatial layers and laid upon the base map developed for better analysis and decision making. The whole system is designed in a way that its entire capabilities are available a click away in a user-friendly web portal with analysis & interpretation capabilities. Since the portal is a web page it can be easily accessed from any local device using its credentials, paving the way for transparency and community involvement. It also nullifies the dependency on sophisticated hardware and software requirements to access the benefits of the system.

Integrating data analytics with GIS which facilitates detailed interpretation, takes the whole system to the next level. GIS with analytics finds applications in various fields like Urban and environmental planning, Disaster management, Skill library, Banking, Taxation, Community development, Waste management, etc. This paper reviews how GIS with analytics can play a major role in transforming Municipal administrations through various applications of this system.

Keywords—GIS; municipal transformation; analytics; drone; digital data repository

I. INTRODUCTION

One metric which could measure whether the municipal system is truly world-class is the efficiency of an administrator in the Municipality or LSGD, and how fast he can dispense his responsibilities. This is where the administrative system is stuck. Most of the time the decision-makers are not able to produce problem-specific solutions, not because they are inefficient but because of the unavailability of verified updated data. The best way to make them capable of arriving at comprehensive solutions is by providing them with a detailed digital repository of segregated data. Without a detailed repository of data, it is impossible to carry out a comprehensive plan forward even by an efficient team of officials. It is the basis for evidence-based planning for an urban area. With real good data-driven decision-making tools it is possible to transform the way municipality or panchayat functions. This GIS-based approach focuses on managing the revenue of local self-governing bodies through a series of data collection, analysis and management processes.

This solution uses drones to capture the micro-level details of the ground and develops different layers of data that can be spatially analyzed & interpreted. The prevailing records are collected from the local bodies which are collaborated with the data collected through drone survey, household questionnaire survey and road survey which serves as the very soul of the whole system. Questionnaire survey covers multiple aspects like building and property details, social details, economic details, health details, and utility details as well, hence creating a repository of varied data that can be used for various analysis. The property details which were earlier confined in papers are now spatially refined through geo-tagging and the evidence of their existence is established through respective latitude and longitude and photographs, hence serving to be an effective improvement from the conventional scenario.

The entire data collected is stored directly in the server of State Data Centre with end to end encryption which restricts any third party from gaining access to it and thereby, ensuring confidentiality and safety of the data.

II. CONCEPTUAL FRAMEWORK

This section introduces a conceptual framework for GIS & Analytics in transforming Municipal Administration. The framework is developed step by step starting from Drone Survey, GIS-based Asset Data Survey, Socio-Economic survey and finally the Web Portal.

A. *Drone Image*

Surveying with a drone offers enormous potential to GIS technology. With a drone, it is possible to carry out topographic surveys of the same quality as the highly accurate measurements collected by traditional methods, but in a fraction of the time. This substantially reduces the cost of a site survey and the workload of specialists in the field.

During a drone survey, the drone flies at a height of 170 to 200 meters from sea level with a camera, covering the area of interest & the final image is encoded in GeoTIFF, which is a standard tiff image file format that includes additional spatial information embedded with it. The image distortions are corrected and the images are stitched together during post-processing using photogrammetry software thereby creating a highly accurate orthomosaic map.

The various geometric anomalies in raw Drone imagery are corrected by Geo referencing the imagery using Ground Control Points (GCP) that are collected through the Differential Global Positioning System (DGPS) survey.

B. *Digitization*

The base map is the basic GIS system that allows the user to view the important physical and administrative features in an area. This is the basic and key factor for building a GIS-based database for the area.

Using the heads on digitization technique, the drone image of the area is digitized to prepare a base map by digitizing all the features available in the image like Buildings, Vacant Plots, Roads, Bridges, Railway Tracks, Parks, Gardens, Stadiums, Slums, Water Bodies (River, Lake, Pond, Drainage, and Canal etc.), etc. While doing the digitization, special care of data correctness is taken like no overshoots/undershoots, proper layering, proper symbology etc.

The digital map data should be GIS compatible. Each map object should be defined uniquely by its feature code and symbology (point, line, and polygon).

C. *Field Data Collection*

All the data of the respective local body are directly collected through the field survey. Separate customised survey applications are used for data collections. Questionnaires are prepared in consultation with the LSGD officials. Majorly, two kinds of data collection processes are there, one is a door to door survey of all the buildings in that area, and the other is the asset survey to collect the detailed information of all the other assets. Finally, the data collected are checked for quality & integrated into the GIS platform to generate a database. This is made available to the authorities and citizens through a Web portal.

1. Door to Door Survey

Door to door surveys are conducted using the GIS implemented devices to collect the spatial and non-spatial data of each building within the given administrative boundary of the local body. Photographs for each building are taken along with the household survey. The area measurements are made with the help of laser instruments.

Detailed information of buildings include the building type, subtype, usage, new and old property ID, survey number, roof and floor type, detailed floor wise area, building status, near the road, waste management and disposal, solar panel, electricity consumer number, licence number(if commercial), GST number, bathroom, latrine, AC, etc are also collected.

Socio-economic data are also collected along with this survey. This comprises of the details regarding the factors such as infrastructure facilities, transportation facilities, utility details, electric transformers, street taps, street lights, quality features like drainage, waste dump and other factors like residential association details, bank details, cattle and poultry details, vehicles, ration card, government funds, boundaries, etc. which will become a data set for the developmental planning of a local body.

2. Asset Survey

To carry out any developmental activity or for a better decision-making process in an LSGD, the authorities must be aware of details of other assets also, including culverts, roads, landmarks, bridges, electric posts, High mast light, etc in that LSGD accurately and precisely. Such details are also made available by conducting asset surveys and incorporating them into the prepared base map for a better understanding.

D. *Web Portal*

This whole system with its entire capabilities is available a click away in a user-friendly web portal which acts as a valuable repository of information that will help in times of need as it can create reports which can be tailored to suit the requirements of the user. Since the portal is a web page, it is possible to easily access from any local devices using its credentials, paving the way for transparency and community involvement. It also nullifies the dependency on sophisticated hardware and software requirements to access the benefits of the system. All the available tools and layers help to bring out location intelligence which helps to understand the real-world problems and difficulties and hence improves decision making. High-resolution drone imagery enables better visual interpretation through the extraction of micro-level details. The Latitude and longitude values of any location within the drone image are obtained and it is displayed towards the bottom of the screen. The map scale is also available towards the bottom left corner which signifies the level of detail.

1. Tools

- Basic map tools like zoom, pan, locator, scale..etc are available in the portal
- Measuring tools to measure length, areas and radius within that areal extent are available which helps gather information as per the demand of the situation.
- Buffer widgets are also available to determine the area covered around a particular point.

2. Layers

- All the collected information is available as different layers in the portal eg: building assets, landmarks and building status etc.
- Most layers are subdivided to get the micro-level details about the area.
- Detailed information including photographs of a particular point in a layer can be accessed by clicking on it. Portrayed legends make the interpretation process easier.

3. Search & Report

- Based on 3 parameters: building name, owner's name and property id.
- Advanced search to obtain tailor-made information for any purpose.
- A detailed report based on the applied search, Specific reports which only include fields according to our requirement helps a lot in the analysis and interpretation of real-world issues.

Here, the data is availed as layers that can be overlayed, correlated and analyzed for applications influencing the quality of life of citizens.

E. Analysis Dashboard

Analytics tools are applied to the collected segregated data to visualize that in a consolidated form. Dashboards are customised to the requirements of the respective LSGD. Statistical finds of revenue analysis, lifestyle disease, count of specially-abled people, education, employment and skill details, sanitation, welfare beneficiary mapping shall all be represented in a well-structured dashboard.

Integrating data analytics with systems that facilitate detailed interpretation takes the whole system to the next level. This can help to bring improvements in fields of economic development, social welfare and sustainable planning.

III. METHODOLOGY

The basic approach of this model is based on data collection. All the information regarding the people and entities that come under a particular local body will be collected through secondary as well as primary data collection. The collected data is represented in layers, which include man-made assets, Natural assets, Sustainability information, Socioeconomic data, Utility details based on the type of data, and are stored in the database as records or as maps. The stages of this model include;

A. DGPS/ GPS Survey

DGPS survey provides positional corrections to GPS signals by using a fixed, known position to adjust real-time GPS signals to eliminate pseudo-range errors. This is carried out to find ground control points(GCP) which are used to improve the accuracy of drone images through georeferencing.

B. The image captured through Drone Survey

With reference to ground control points, high-resolution drone images are captured to create an accurate base map with all relevant details.

C. Drone image post-processing

The drone images are georeferenced using the Ground Control Points (GCPs) which are well-defined sharp points both on the ground and on imagery. The image distortions are corrected and stitched together to produce an accurate single image for the entire area.

D. Creation of large scale base map

This map or map series provides the base for the whole system. Detailed land use land cover information will be made available on the base map.

E. Field survey

Using a survey application field survey will be carried out. The application shall aid the surveyor to record the measurement of land, structures, trees, and other relevant details required. The questionnaire is prepared to define the specific details that have to be collected through the survey and this form is finalized with the government officials.

F. Door to door survey

Socio-economic details of the people living in that particular local body are collected through a household survey

G. Data syncing

The advanced quality check of the data is done to ensure the accuracy of the collected data. Using the information collected through the field as well as door-to-door survey, layers are created and linked with the base map. To easily understand the collected data, it is visualized through a web portal, with different tools.

H. Use of Analytics

Through the use of analytics tools, the visualization of the centralized data is made possible in a well-structured form. This representation makes it easily understandable and helps in quick decision-making.

IV. APPLICATIONS

The main challenge faced by all Local Governments in India is the lack of accurate information on the natural and man-made resources under their jurisdiction. Lack of accurate and authoritative information is a major obstacle not only in formulating various development projects but also in implementing them accurately. With this solution, it is possible to overcome this limitation and develop better alternatives.

A. Tax Collection

- With aerial photogrammetry (drone imagery), the built-up area can be inspected using the building's footprint. Thereby, tax losses can be avoided.
- Accurate information is obtained by measuring the floor area of each building using laser tape as part of the GIS survey.

- Administrative zone boundaries are determined and buildings that do not fall within the tax range are identified. This also helps to eliminate tax losses.
- The level of revenue leakage in each ward can be analyzed and the causes can be addressed

B. Health Management

- Spatial information is available in conjunction with health data to help identify the causes and prevalence of diseases.
- Complete information on people with physical and mental challenges.
- Details of those in need of special consideration, including the elderly and children.
- It is possible to examine the relation of geographical location to the diseases of individuals in an area.
- Pain and palliative activities become more efficient.
- It is possible to understand the source of infectious diseases and could prevent their spreading.
- Helps to identify and prevent waterborne diseases

C. Disaster Management Support

- Vulnerable areas can be identified and mapped.
- Provides complete information on man-made and natural resources in disaster-prone areas.
- It helps to suggest the necessary scientific precautions in such areas.
- Immediate response to reduce the extent of catastrophe after a disaster.
- Will provide information about those in urgent need.
- Complete information on camps, hospitals, and roads should
- available to help expedite and mitigate disaster response

D. Beneficiary Identification

- Pieces of information regarding people in need of special social protection are available as part of the GIS survey. This will help in targeting the welfare of the deserving.
- Provides local information regarding the population of children, the elderly, and people with disabilities. This will help us in any salient situation like a disaster.
- Identification of beneficiaries under several government schemes can be carried out by GIS-based mapping and analysis.
- A GIS-based skill library can be created, so that unemployment can be addressed.

E. Basic Infrastructure Planning and Development

- Location-based information with photographs on waste disposal facilities, sanitation, and freshwater availability is present a click away.
- Helps to understand the areas lacking infrastructure facilities and to make appropriate decisions.
- Complete topographical information on slums and colonies is available.
- Development plans can be formulated based on such GIS-enabled accurate information

V. CASE STUDY

A major problem faced by the Local Self Government Departments is the lack of tools for managing and maintaining their assets. Previously the asset management was carried out through keeping the hard copies of the details in records like assessment registers, but timely maintenance and periodic updating of the data was a serious issue. The respective LSGDs shown in this case study have adopted a GIS solution to this problem. GIS & Analytics were brought together which led to the digital transformation of these local bodies.

With the help of the latest technologies like Drone, DGPS, laser tape, and specially designed applications, all the demographics and property ownership data, details of all the water bodies, bridges, drainages, buildings, and roads with the photographs and all the relevant socio-economic-cultural details of the members are collected, analysed and stored in a user-friendly mode. The data determining the tax fixation of the property, the property owner, the number of rooms, overall area, and other data within the city limits is obtained by GPS facility.

The project would help in meeting the challenges of the new age, planning for developments based on modern information technology, facilitating bureaucracy and providing better service to the people expeditiously.

Objectives

- To collect a detailed inventory of the assets of the respective LSGD.
- To create a centralized repository of this information, centrally controlled and accessible to relevant stakeholders.
- To integrate the solution with Enterprise GIS.
- To create a decision support system for taking various decisions about the assets by integration with a standard Asset Management Software.

Scope of the work

- Base map Creation for the LSGD using Drone Survey
- GPS and TAB enabled property Survey (Residential and Commercial)
- Development of Web-Based GIS Solution using open source Technology

The digital transformation of two LSGDs using GIS and Analytics as the technology driving the transformation are explained below:

A. Case Study of LSGD-I

1) Study site: LSGD-I location is a coastal area situated in Kerala, India. The municipality consists of a 22 sq. km area with 34,528 properties.

2) Materials & Methods: This municipality aimed for a complete digital transformation that can facilitate urban planning, project management, citizen satisfaction and tax efficiency. The approach was to bring about a holistic data-driven decision support system to improve governance & to escalate the happiness index of the people living in the municipality.

To achieve this aim a GIS system was introduced to municipality LSGD which uses capabilities of modern

technology such as Drone survey, GPS, laser method, and customised application based household questionnaire survey etc to prepare Base Map, Land Use/land cover pattern, layers showing public infrastructure (Roads, Bridges, Utilities) details and a single centralized Web GIS portal to display the data. The whole solution and the questionnaires for the field surveys were customized to achieve this aim of holistic development of the municipality.

A Drone Survey was conducted covering the entire area within the Municipality. Drone Image was rectified using Ground Control Points (GCP) and the Digitisation of that image was done in the GIS lab to extract different features like layers. Asset details along with the citizen details were collected from all the wards under the municipality rough field surveys using customised questionnaires. All the remaining asset information was collected using the DGPS surveying technique. The field surveys were carried out by trained surveyors monitored by survey coordinators. The collected data from the field was sent to the GIS lab daily for rigorous quality check and quality assurance processes. The verified data was then published on the GIS Web Portal. Analysis dashboards were also provided in the web portal with compelling issues and patterns uncovered from the Data.

3) Results & Discussion: According to the assessment register of Municipality, the total number of building assets was 29,137. But after the GIS Survey, it was found that 4631 buildings were not in the records.

Also, this survey updated the status of all existing buildings, by considering the changes in building zone, roof type, building usage, road width, floor type. This record helps in updating the tax collected thereby accounting for a 31.9% increase in revenue to the Municipality as shown in Table I.

B. Case Study of LSGD-2

1) Study site: The grama panjayath is located in the south-western suburbs of Kerala. The three sides of the panjayath are surrounded by water. About 2.5kms of the area is covered by the sea. The total area is about 17.57 square kilometres. There are 23 wards in this panchayat.

2) Materials & Methods: Previously the grama panchayat was following a conventional tax management system which lacks in quality and causes issues to the civic authorities by wrong assessment of properties, increases in the number of unassessed properties and tampering of records which is buried in paper works.

This GIS mapping project was done to geotag all the assets of the panchayat, codifies the collected micro-level land use information, and makes it accessible at the web portal. So that the tax collection process became proper and efficient thereby an increase in the revenue generated in the Panchayat. The tax collection process was developed to make the process proper and accurate thereby increasing the revenue generated in the Panchayat.

TABLE I. Results from LSGD-I data

Total Revenue Increased: 31.9%		
Sl No	***Factors Responsible***	***Compelling Issues Identified***
1	Change in Building Area	• 9.7% Building found with changes in the area
2	Rise in lifestyle diseases	• 5541 people suffering from lifestyle diseases out of which 56% are senior citizens & 41% in the age category of 35-60. • Also noticed that people suffering from these ailments are majorly coolies, NRIs and business people.
3	Improving the life of specially-abled people	• Major disabilities noted are Blindness, Dumbness, Deafness, Down syndrome, Mental disabilityand orthopaedic impairment. • Among them, 55.25% are men and 44.75% are women. • Among them with age above 18, only 15.63% are employed. • Of the total disabled population, 81.06% are literate out of which 7.14% are graduates, and 48.97% have blue or white cards which leaves them without any pensions.
4	Right to Education	• There are about 49 children in the age group of 10 to 18 years who are unable to pursue education • Among them 59.18% are girls and 40.82% are boys. • Most of them come from underprivileged segments of society with parents who are unable to support their government support education due to various reasons (currently unknown).
5	Employment and Skill Enhancement	• There are 9,546 unemployed people in the Municipality in the age group between 25-55. • There are 1,038 unemployed men and 8,508 unemployed women out of which 2,237 (23.43%) are highly skilled, 169 (1.77%) skilled and 7,140 (74.8%) unskilled.
6	Lack of bathrooms and latrines	• Residential buildings without bathrooms & latrines were identified and reported

The method and methodology of the project are almost similar to the Municipality project but the major outcomes achieved through the project were different. A Drone Survey was done covering the entire area within the panchayat boundary. Drone Image was rectified using Ground Control Points (GCP) and the Digitisation of that image was done in the GIS lab to extract different features like layers. Asset details along with the citizen details were collected from all the 23 wards of Grama Panchayat through field surveys using customised questionnaires. All the remaining asset information was collected using the DGPS surveying technique. The field surveys were carried out by trained surveyors monitored by survey coordinators. The collected data from the field was sent to the GIS lab daily government support for rigorous quality check and quality assurance processes. The verified data was then published on the GIS Web Portal developed for the Grama panchayat. Analysis dashboards were also provided in the web portal to the requirements of the Panchayat authorities.

3) Results & Discussion: According to the records of Panchayat, the total number of building assets was 17526. But after the GIS Survey, it was found that there were 3000 extra buildings in the Panchayat that were not in the records.

Also, this survey updated the status of all existing buildings, by considering the changes in building zone, roof type, building usage, road width, floor type. This record helps in updating the tax collected thereby making an increment in revenue (Table II).

TABLE 2. Revenue Analysis

Total Revenue Increased: 45.60%		
SL No	***Factors Responsible***	***Percentage Contribution to Revenue Increase***
1	Change in Building Area	55.7%
2	Change in Building zone	6.2%
3	Change in Road width	11.4%
4	Change in Building Floor Type	6.2%
5	Change in Building Roof Type	4.75%
6	Change in Building Usage	15.7%
7	Social Welfare Schemes	224 people are illegally receiving more than one pension. Rigorous monitoring can avoid this revenue loss

VI. KEY CHALLENGES AND FUTURE DIRECTIONS

The major challenge is the adaptation of government organisations to new technology. Organizations with GIS resources can use the fullest advantage of this system. Some changes in the organization structure and at the operational level are needed to make the best use of GIS. But such changes are not that easy to accomplish with government organizations. This also makes some of the government officials reluctant to implement GIS technology in their department.

Another major challenge is the legal issues with the data, which is the base component of any GIS system. Data collection might become difficult as the transformation of an LSGD using GIS Technology requires the collection, storage, manipulation and analyses of the personal details of citizens of that area. So a proper system is necessary to ensure the safety and security of this data.

Beneficiary identification is one of the major applications of this transformation system. The major challenge in implementing this is the lack of awareness among the general public about the future advantages of this. It might lead to the collection of wrong or inaccurate information which can reduce the quality and authenticity of the system.

VII. CONCLUSION

The importance of using GIS at the local administrative level is increasing because it has the potential to implement an integrated multipurpose system that can serve the needs of the general public. The objectives of using GIS include the centralization of information of the general public to eliminate unnecessary effort involved in maintaining multiple copies of the same information and discrepancies, to improve the daily operation efficiency, reduction in duplication through management control, providing information for decision support and policy formation. Local government systems are successful in some of these areas, while other goals are more difficult to attain. Thus GIS Technology becomes a modern solution for age-old problems.

REFERENCES

[1] Greene, R.W., “GIS in Public Policy: Using Geographic Information for More Effective Government”, ESRI Press, 2000, California, p.100

[2] Huxhold, Bil, “Building Decision-Making Capacity by using GIS and Urban Indicator Analysis, Dakar, Senegal”, Dakar, Senegal, 2002.

[3] Longley, P.., Goodchild, M.F, Maguire, D.J, Rhind, D.W. (), “Geographic Information Systems and Science”, Wiley, West Sussex, 2001, p.454

[4] Lemer AC, “Progress toward integrated infrastructure-assets-management systems: GIS and beyond”, Proceedings of the APWA International Public Works Congress. NRCC/CPWA Seminar Series in Innovations in Urban Infrastructure, 1998, pp.7- 24

[5] Chrisman N, “Design of Geographic Information Systems Based on Social and Cultural Goals”, Photogrammetric Engineering and Remote Sensing, 1987.

[6] Crane E, “A Multi-purpose Land Data System for Wyandotte County, Kansas, State and Local Government Systems “- The State of the Art, 1986, URISA, p. 10-18.

[7] Dueker K, ”Multipurpose Land Information Systems: Technical, Economic, and Institutional Issues”, Photogrammetric Engineering and Remote Sensing, 1986, Vol. 53, No. 10, pp. 1361-1365.

[8] McLaughlin J, ” The Multipurpose Cadastre Concept: Current Status, Future Prospects, Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North America”, University of Wisconsin-Madison, 1986, p. 82-93

[9] McLaughlin J, S. Nichols, “Parcel-based Land Information Systems”, Lecture Notes in Digital Mapping and Land Information. Canadian Institute of Surveyors, 1987, p. 199-225.

[10] Bounabat, B, “From e-government to digital governmentsupport their.”Electronic Journal of Information Technology 2017, 8-21.

[11] McLaughlin, ” The Multipurpose Cadastre Concept: Current Status, Future Prospects, Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North America”, University of Wisconsin-Madison, 1984, p. 82-93.