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Real-Time Co-PPGIS-Based Integrated Grievance Redressal Management System Modeling of Public Water Utilities of Lahore

Rashid Mehmood*, Muhammad Atif Butt, Syed Amer Mahmood

Department of Space Science, University of the Punjab, Lahore, Pakistan
Email: *rashidmhmood@yahoo.com

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Abstract

Lahore is the most populous and rapidly growing city in the province of Punjab, Pakistan. The need of the time is to bank on e-governance to meet the demands of the people. To satisfy complaints and grievances linked to the city's emergency services, water supply, and sanitation. Currently, these services are being handled by each department itself, and no proper centralized grievance system exists. There is no integrated approach adopted in response to complaints in the Water and Sanitation Agency (WASA), established by the Lahore Development Authority (LDA). GPS mobile phones have become equally common in urban and rural areas. This paper will introduce an innovative technology-based system named the GIS-based real-time Grievance Redressal Management System, which is initially designed for Lahore. This system employs the Collaborative Public Participatory GIS (Co-PPGIS) environment for visualizing and analyzing real-time geostatistical data in both spatial and non-spatial views through mobile- and web-based applications. Customers will register their complaints through Android and web-based applications equipped with a map and participatory tools provided by the GIS. This paper provides a structure to overcome mismanagement issues in government agencies and devises a check-and-balance flow model primarily for public utilities such as water supply, sanitation, and sewage. Hence, this paper is an effort to resolve public issues and grievances through real-time engagement in a faster, more accurate, and trustworthy way.

Keywords

E-Governance, Co-PPGIS, Grievance Redressal System, Geostatistical

*Corresponding author.

1. Introduction

This template, created in MS Word 2007, provides authors with most of the. A complaint management system is the state-of-the-art tool to enhance the efficiency of all companies and management institutions. It enables customers to register online complaints to eradicate corruption and ensure smooth service delivery. District Lahore has witnessed the huge displacement of people toward the city due to the irregular distribution of resources and opportunities. The increase in population requires more roads, institutions, infrastructure, and dwellings to survive in a small area. To provide quality services has always been a challenge for the government.

To cope with such miserable conditions, the government has to move forward towards state-of-the-art technology and concepts like E-governance. In this regard, GIS is being employed as a best practice in managing water utilities and sanitation. A Geographic Information System (GIS) provides a system that is used for capturing, storing, arranging, managing, and displaying spatial data in software. [1] It facilitates this by providing specific tools such as geo-technics, geophysics, navigation, the Global Positioning System (GPS), surveying, photogrammetry, and remote sensing. [2] Public Participation Geographic Information Systems (PPGIS) has emerged as the most reliable technique for spatial data collection pertaining to all stakeholders of landscape values to produce an integrated approach for policy. [3] [4] It is evident from practices that PPGIS can be employed to map landscapes of various types [5] and is later used in different GIS applications for visualization.

PPGIS techniques are applied in several ways, such as quantitative, qualitative, or hybrid studies. [6] Qualitative techniques permit participants to classify and find issues on the landscape and to gather spatial data relating to specific study area maps drawn with polygons. [7]

An online complaint management system provides department-wise reports showing different statuses, such as pending, closed, or open complaints, along with performance reports. [8] A GIS-based web application is made available on a web browser. This application can easily be opened through an Internet network for gathering data and can be used as a web-based GIS interactive application. [1]

The McDonald's outlet situated in Watu Gong, Malang branch has improved service quality through an adaptable and most reliable form of complaint management, which is the Web-GIS-based Complaint Management System. [9] For complaint registration in colleges, students have to write an application on paper, which is not a user-friendly environment. To cope with this issue, a Grievance redressal system was developed. A web-based interface allows users to register and log in before filing a complaint against the desired issue, which is further sent to and resolved by the competent authority. The proposed model for the Complaint Redressal System will help to lessen people's disappointment with this complaint system and will increase participation through an easy way of filing at everyone's ease. [10]

Water supply is one of the most important services delivered by the Municipal

Corporation. [1] Water utilities include a clean water supply and sewage. To provide these facilities to the denizens of a particular area, there must be a network of pipelines, storage reservoirs, pump stations, hydrants, manholes, meters, and other network accessories. On the basis of structure, it can be classified as horizontal or vertical assets. Vertical assets correspond to the assets that reside above the ground, such as storage reservoirs, pump stations, etc.

Proper maintenance of these assets is as important as the provision of services to customers. This can enhance the assets' life and help provide quality services. In developing countries like Pakistan, water supply and sanitation have been ignored since they are considered secondary issues on the priority list. To eradicate this problem in the provision of quality services, the prime objective is to identify the possible cause, so that it can be remedied through systematic planning and management. The current structure fails due to the following reasons:

- Poor or no maintenance structure of assets due to a low budget
- Lack of planning by the government
- Feeble institutional structure and intensive interference by politicians
- Nonexistence of clear water policies in relation to service coverage and standards
- Poor monitoring and evaluation
- Lack of imposing service standards
- Plenty of legal obstacles and barriers for local service providers

A few things are necessary to address in the provisioning of public utilities like water supply, etc., which are given below:

- Provision of utilities without a competitive environment
- No incentives for organizations or individuals for the provision of services.
- Nonexistence of community in planning and delivery

In this regard, to provide quality services, grievances and complaints from customers must be responded to within the prescribed time span. The study introduces real-time map sharing along with location among all stakeholders (service provider, rescue service provider 1122, etc.) to come up with an integrated approach to cope with the issue, whether it belongs to maintenance or emergency/accidental. The location of a water utility objection is the key element when addressing grievances from any customer. GIS technology in water service maintenance can be fruitful.

The following are the types of complaints expected from the user:

1) Bill issues
2) Parts/Installment
3) Pipeline leakage issue
4) Quality-of-service issues
5) Field Staff issues

The Android application carries a real-time map-sharing facility and geo-tagging of water service delivery assets. Locations of assets like valves, meters, hydrants, pumps, and manhole covers will be displayed on the map as users log in. By signing in to the application, users' locations will be shared with WASA, Res-

cue 1122, and associated agencies. These agencies already have a database of assets regarding all the relevant networks, like water supply and sewage lines, with complete attribute information and status. This would lead to setting up a collaborative and integrated system to address customers' complaints and emergency services with a rapid response.

2. Study Objectives

The chief objectives behind the current study are featured below:

1) To collect geospatial data on water and sanitation facilities (pumps, supply lines, manholes, etc.).

2) To develop a spatial network of the water supply line and sewage line.

3) To integrate the data into a GIS environment in the form of layers.

4) To design and develop an Android application for users for complaint registration and to locate the issue through a geo-tagging option.

5) To design an integrated conceptual framework model for Co-PPGIS-based infrastructure and complaint-sharing mechanism for the stakeholders.

3. Study Area

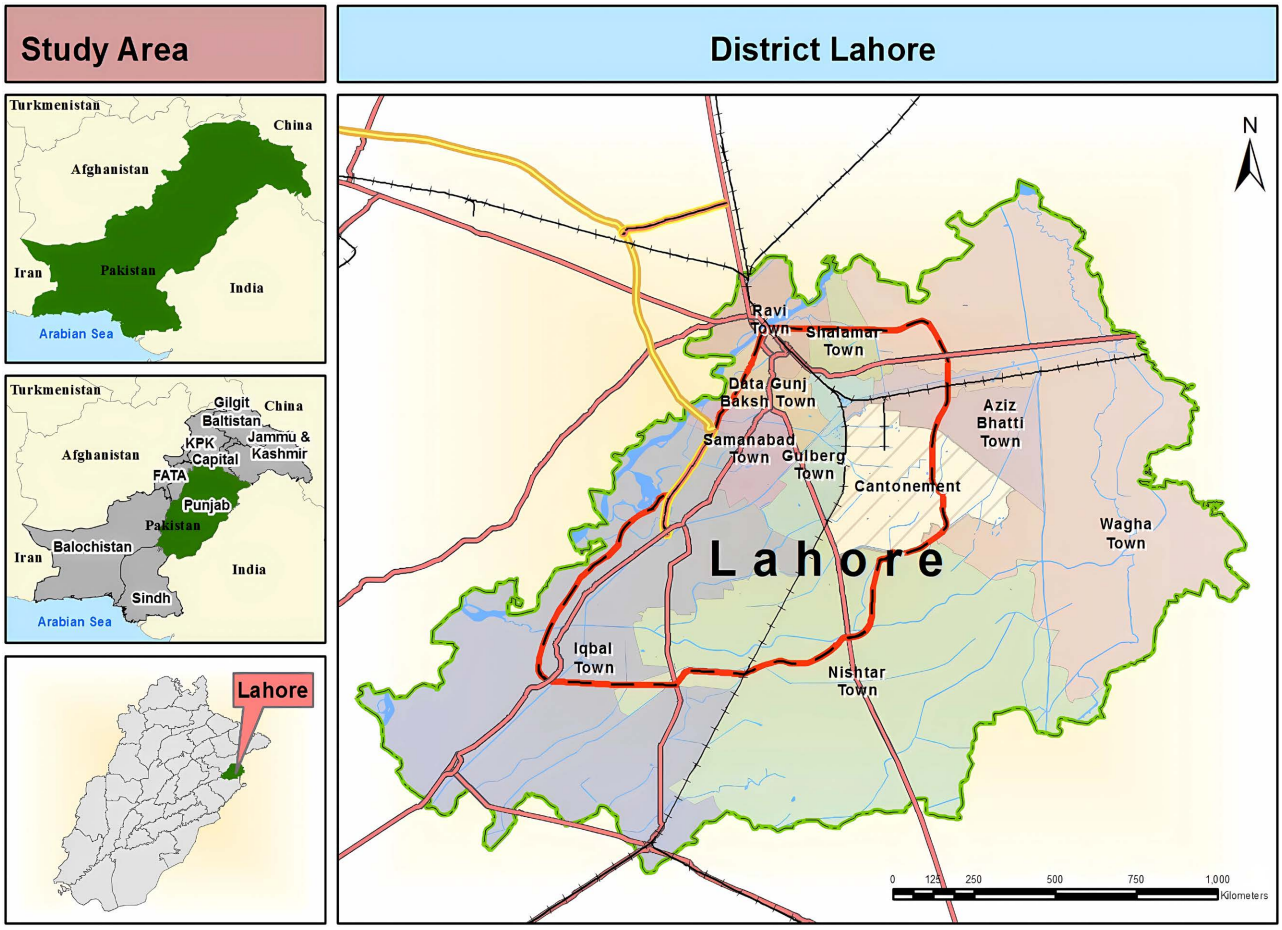

Figure 1. Location map of the study area.

Lahore is situated in the eastern part of the Punjab province, with a spatial position of 31˚32'59"N and 74˚20'37"E, as shown in Figure 1. Land in the Lahore District comprises plain areas and bounded fertile alluvial plains. Lahore had a population of 2.17 million in 1971, which increased to 9.75 million in 2014, with a monstrous jump of 350 per cent. This considerable increment has hindered meeting the demands of the denizens. The built-up area covered 103.42 km^2 in 1972, which expanded to 1772.53 km^2 in 2012, with an addition of 1613 per cent in this span. Such rapid growth in land cover has adverse impacts on the climate accordingly. So, the demands for residential buildings and administrative purposes have also been enhanced in outer areas, especially in the southeast of Lahore. [11]

4. Methodology

The current research study involves the following phases to achieve the above-stated objectives.

4.1. Data Collection

Data collection involves the collection of current maps and the location of water supply lines, sewage, and drainage stations. In Lahore, the Water and Sanitation Agency (WASA) is responsible for running and maintaining these utilities. Currently, there are 316 tube wells that are employed for water supply. The length of pipelines of 3" - 20" diameter is 3200 km in the entire city. Tube wells are producing 329 MGD (million gallons per day) in well-defined hours of the clock. About 4.11 million people benefit from this water. Cantonment, Defense Housing Authority, Model, Railway Colonies, and GORs are excluded from the WASA service area. [1]

As far as sewerage assets are concerned, 11 major pumping stations are present at a key point in the city. The pumping capacity of these stations is about 2456 Cusec. Lift stations are 61 at different locations in each town. Sewers' length is 3610 km, which is being used at present, serving about 80% of the total population. Total drain's length in Lahore is 180 Km, constituting 8 major drains in which 76 tributary drains feed the main drain. The total capacity of these drains is about 6474 Cusec. Pumping stations used for drainage are 4 for the steady flow draining process. [12]

Data were collected from both primary and secondary sources. Primary data involved the drawing of geospatial data from existing maps (water supply, sewer assets, etc.). Secondary data were acquired from the field survey, which included validation of boundaries of the service area and spatial locations of above-surface assets like tube wells, pumping stations, water filtration plants, manhole locations, etc. Along with the spatial data collection, non-spatial data (Attribute data) of each asset was collected from the WASA, like the length of pipeline in a specific road or street, diameter of pipeline, installation date, expiry date, capacity, etc. Data of maintenance staff of the specific area were also collected and

incorporated in the database, which was joined with spatial data. This data contained information about specific people, like name, father's name, Computerized National Identity Card (CNIC), designation, duty time, employee type, contact number, etc.

Survey was conducted on a specially designed Android application in this connection. To validate the information, the survey was carried out in Model Town, a main town of Lahore, as a sample. Teams were devised to conduct the survey door-to-door to get updated information.

4.2. Geo-Database Development

After collecting data from a survey and extracting spatial data from existing maps, database development was initiated. For this purpose, all spatial data were fed into an ArcGIS environment in the form of layers. According to the nature of the assets, the data were further categorized into point, line, and polygon classes; e.g., tube wells were assigned as point features, pipelines were digitized and saved as line features, and the service area boundary was displayed as a polygon feature, etc. In this way, the rest of the assets were classified into these three broad categories based on the nature of the feature or asset. Each category was displayed as a single layer, such as the pipeline layer, the tube wells layer, the pumping station layer, the manhole layer, the drains layer, the overhead reservoir layer, etc.

Along with the visualization of spatial data in software, non-spatial data has equal importance, on the basis of which different queries may be applied in the database to fetch the desired result in no time. So all the attribute information gathered during the survey and existing record information from registers or files pertaining to assets was now integrated with spatial information by the joining attribute tool in ARC GIS. This data was comprised of length, diameter, splice size, date of expiry of pipeline in a particular street, etc.

4.3. Purposed Applications

This phase was divided into two different domains:

1) Mobile Application
2) Web Application

4.3.1. Android Mobile Application

This application was developed for water and sanitation services users. It enables the users to locate the place of issue, type of issue, the placemark facility in place, write a complaint against each mark, attach a picture of that issue, attach voice complaints as well, address, etc., in Google Street Map view. The mobile application also informs users about the status of complaints made against any issue. [13] All this information will be shown in real time in the web-based monitoring interface of the Complaint Redressal Cell at WASA, which will respond within the prescribed time span and keep in touch with the complainant. After redressal of the complaint, a short message service will be delivered to the complainant via the

cell number provided at the time of complaint data entry. In the next section, it is explained how this mobile application was integrated and worked with the web application interface to produce the desired results. The proposed interface, with pipeline, manhole, complaint location as marker, etc., data, is shown in Figure 2. The user can also monitor the whole process, how the command from the center is initiated, and how the complaint is resolved in no time. Hence, this application enables the user to register a complaint conveniently.

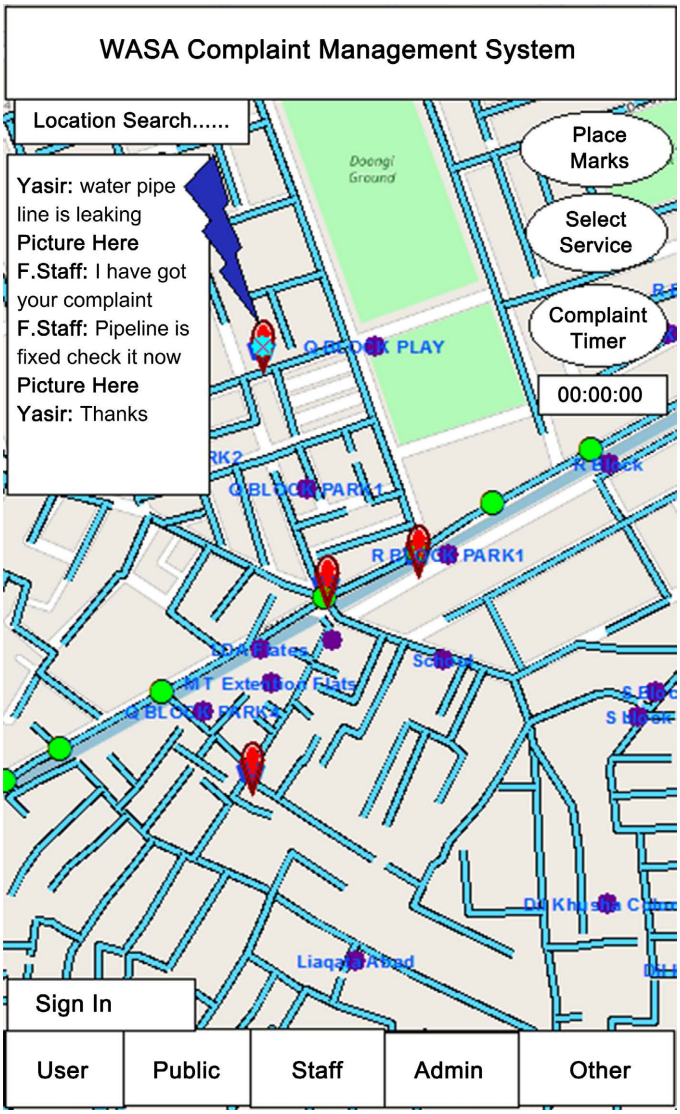

Figure 2. Android app interface.

4.3.2. Web-Based Complaint Redressal Application

It is also pertinent to mention that a user has another way to lodge a complaint, like telephone calls to the contact center or through a web portal for registering complaints. [5] Along with the mobile complaint registration application, there is a need for a complementary system to view and redress complaints by the concerned personnel. So, to fulfil the need, a Web-Based Complaint Redressal Appli-

cation was developed in a multi-layered account system. It depends on the hierarchy of authority or department. After lodging every complaint, it is made time-bound for the complaint attendant. If he fails to respond within the stipulated time span, it will be forwarded to the upper-layer account for taking immediate action against him. This application enables the user to monitor the status and progress made by the authority on the issue once the complaint is registered. [6] It helps eradicate corruption and gives every user the ability to monitor, track, and resolve the issue as soon as possible. [7] Hence, the system reacts to any complaint left for any reason. Moreover, the attendant will generate an optimum route map and share it with field staff in real-time on the Android Application which he carries on his mobile device to locate the issue. Again, this activity would be time-bound, and the system would generate the same response. All activities that are performed at the service provider's end are intimated to the complainant through the Android Application. As a result, a comprehensive, self-driven, and integrated complaint redressal web application has been established to enhance the trust level of denizens.

4.4. Field Staff Mobilization

Another phase in complaint redressal is to mobilize field staff. As the field staff supervisor receives the map of the location that appears on his mobile screen, he examines the nature of the complaint, whether it is an emergency case or not. After that, he deputes a group of skilled workers to redress the complaint within a specified time. He is also liable for deciding the mode of mobilization, depending on the nature of the area and whether the road is wide enough or not. He shares the location and the shortest route with the field staff for further necessary action. Field staff mobilization is also observed through the tracking application. Hence, effective monitoring of all activities is ensured for redressing the complaint. Mobile application interface which makes the authority officials and denizens ultimately reduce cost and time for both. [8] Hence, the map sharing facility helps to mobilize field staff to locate the fault in real-time. Later sections will cover the results and discussion of the study.

4.5. Database Architecture

The web and mobile application involve the following database architecture.

Figure 3 represents the whole activity from data collection to web and Android-based application development. Data comprises the following possible dataset feature classes in the form of layers:

1) Water Supply Pipelines-Line Data
2) Sewerage Pipelines-Line Data
3) Tube Wells-Point Data
4) Manhole-Point Data
5) Water Filtration Plant-Point Data
6) Disposal Station-Point Data

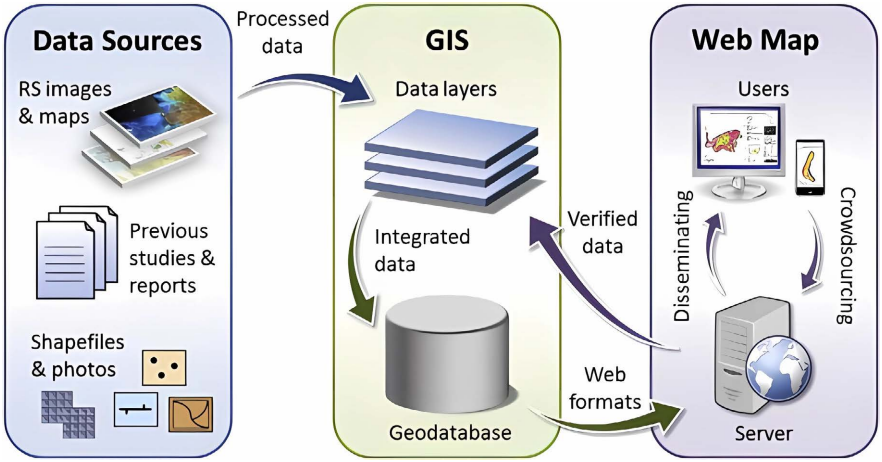

Figure 3. Geo-database design and web development phases.

4.6. System Design and Architecture

The overall system design and architecture are shown in Figure 4. It exhibits an integrated way to redress any complaints registered in the system.

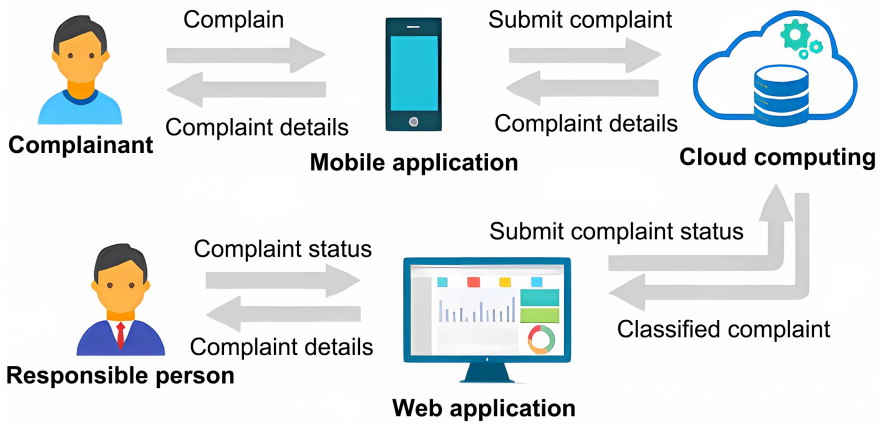

Figure 4. System architecture (Source: Siripen Pongpaichet *et al.*, 2018).

Complainants use mobile applications to report problems. Complaints in cloud computing were then processed and collected in a database. On the employee side, the web application retrieves all categorized complaints from the database, allowing agents to visualize data and review existing complaints. Also, the responsible person can make a note of the correction and update the status of the complaint before sending it back to the person who filed the complaint, as explained in Figure 4. Hence, this elaborates on how the applications and complaints are integrated to register any issue.

4.6.1. Data Structure for Asset Management System

Designing a GIS-based asset management system involves designing its subcomponents: database servers, web services, and user-level taxonomies. Database server design is based on the requirements of the asset management system and the data

attributes used to generate the desired queries. A possible relational data model is shown in Figure 5 to explain the relationship among the different attributes of assets.

The proposed complaint asset management will have the following entities, which integrate to resolve a particular issue:

- End Users: Municipal staff, clients/customers
- Authorized GIS Users: A few authorized staff members have been appointed to modify the system.
- Web GIS/Mobile Portal Administrator: Web Designer

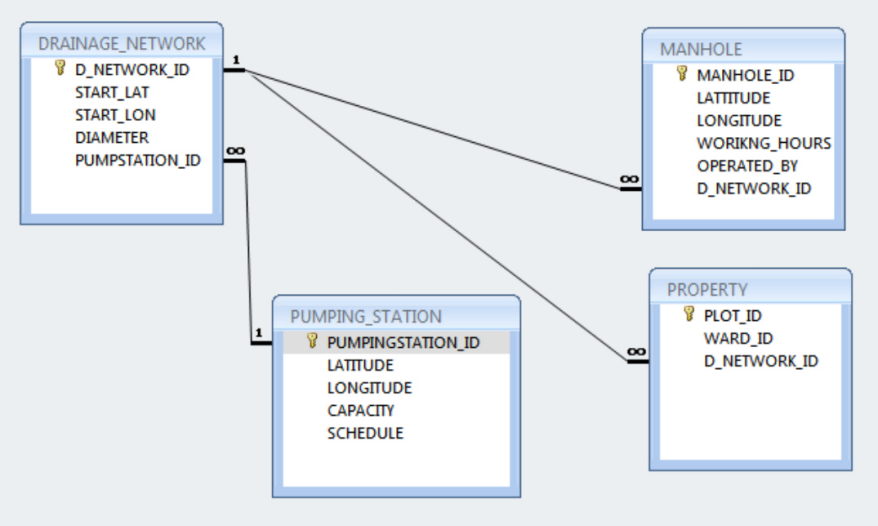

Figure 5. Data structure for asset management system (Source: Saloni R. *et al.*, 2015).

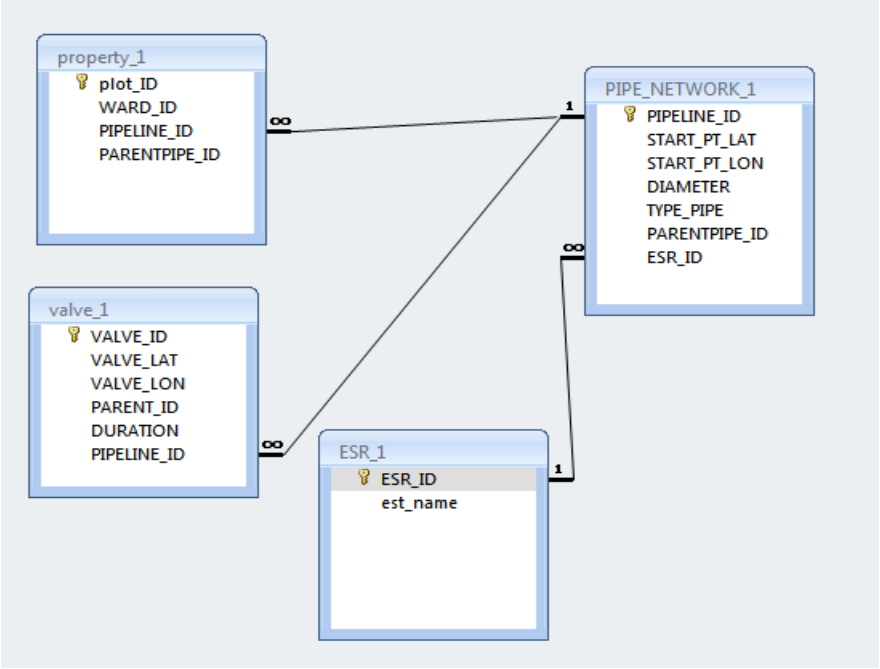

Figure 6. Structure of the data complaint management system (Source: Saloni R. *et al.*, 2015).

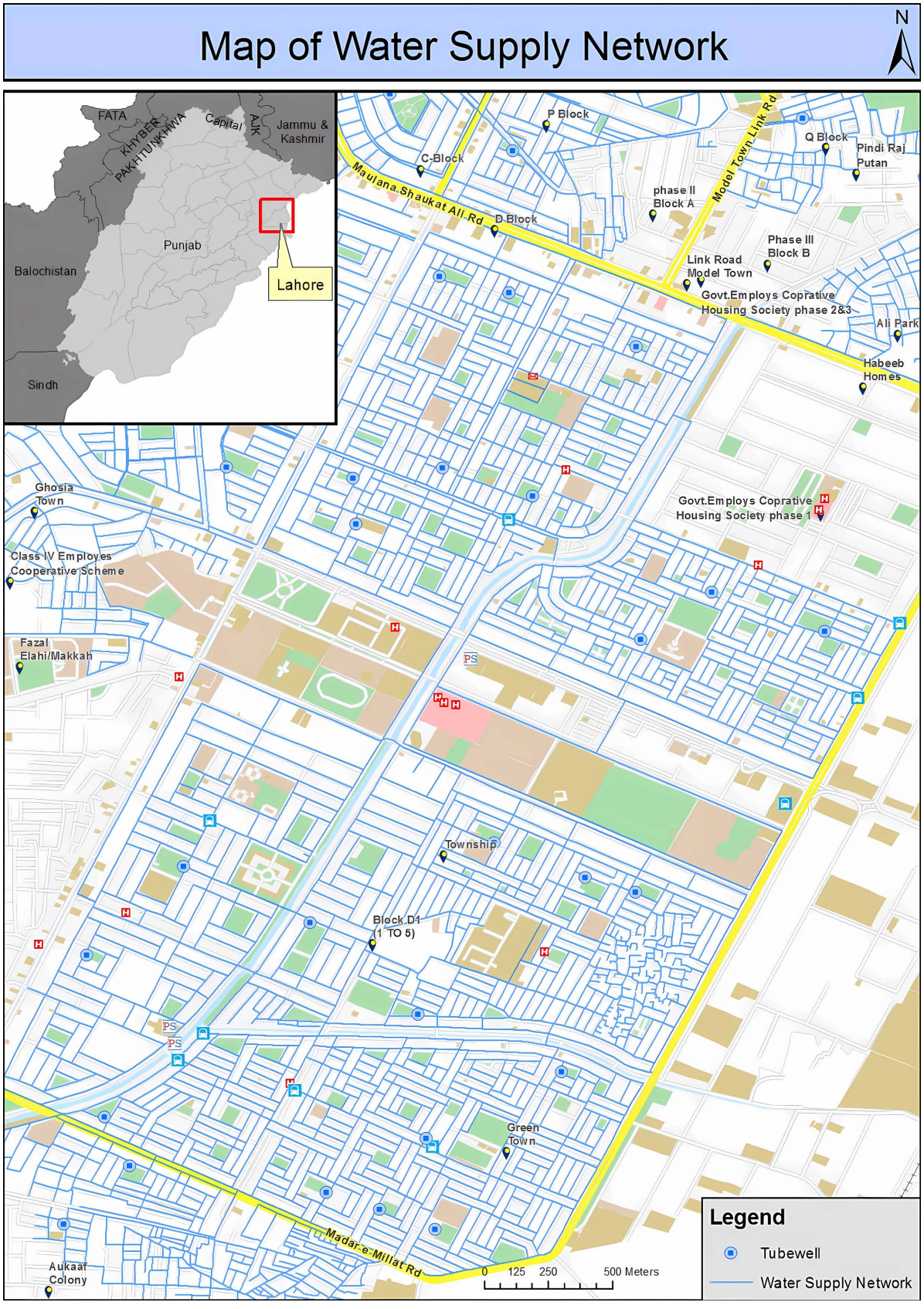

Figure 7. Geospatial data of tubewells and water supply network in Lahore.

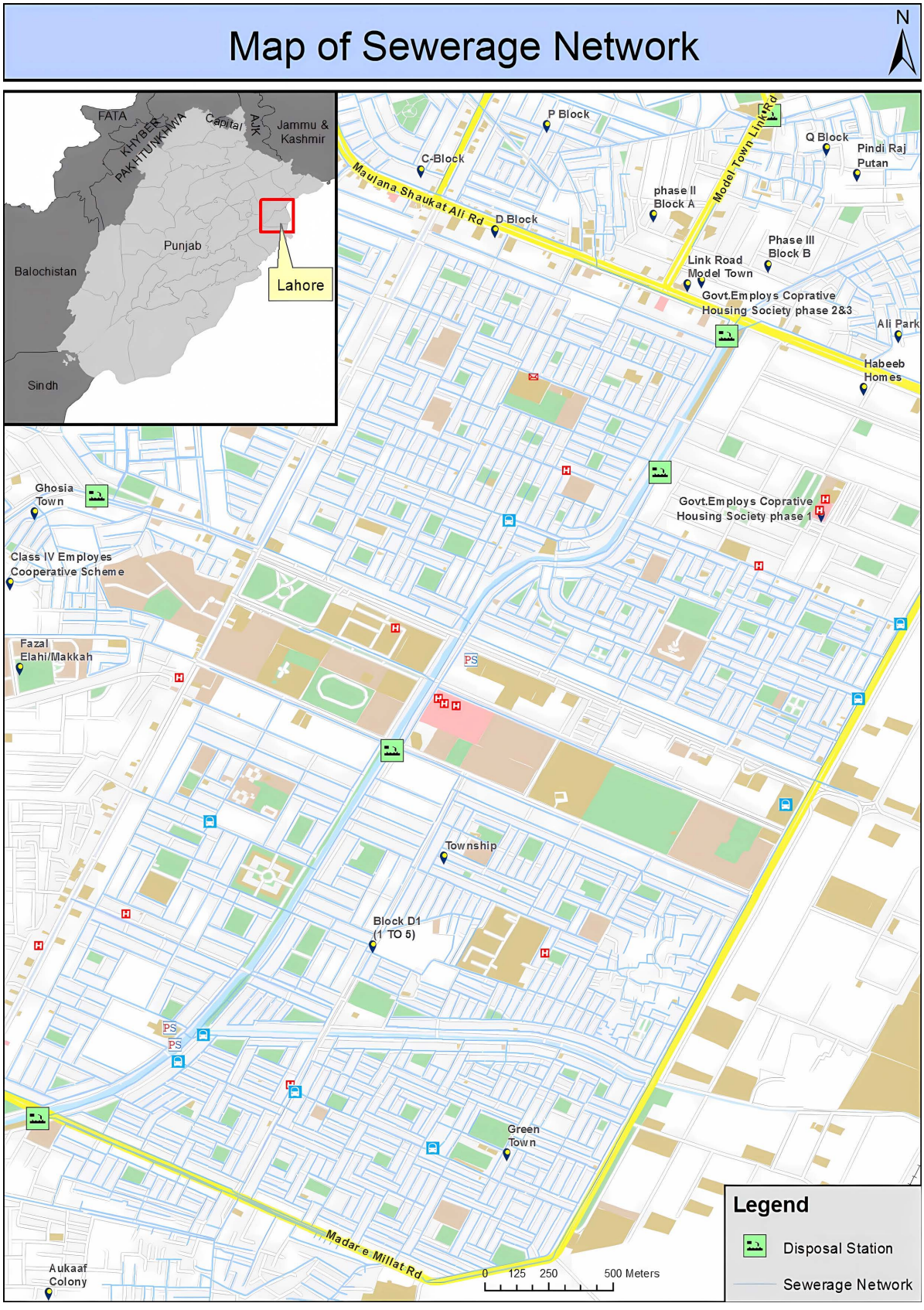

Figure 8. Geospatial data of the disposal station and sewerage network in Lahore.

4.6.2. Data Structure for Complaint Management System

Customer complaints are a key piece of information that reflects customer satisfaction and are the primary measure of customer dissatisfaction. Effective and efficient response to these complaints is a key indicator of an organization's performance. The overall data structure is shown in Figure 6, which provides a relationship among the different entities.

The Complaint Management System structure may be explained through different stages. In the first stage, a database for storing complaints has been created. In the next stage, a relationship between the geo-database and the complaint database has been established. Spatial visualization of complaints in the third stage has been created to have a clear picture of the issue with respect to a particular area. At the fourth stage, complaints are made traceable using a network diagram. The final stage involves the solution of the complaint, which has been accomplished by troubleshooting. [14]

5. Results and Discussion

This section will give the outcomes of the study that relate to designing a model for a complaint redressal system based on public participatory GIS and Network Modelling employed in the ArcGIS environment.

In Figure 7, the geospatial data of tube wells and the water supply network are shown. It is evident from the figure how the spatial distribution of tube wells and pipelines exists geographically in Lahore. On the basis of this network, multiple network analyses will be done to find the optimum path to locate the issues surfaced on tube wells or supply lines.

In Figure 8, the geospatial data of disposal stations and the sewerage network are shown. It provides insight into how the spatial distribution of disposal stations and the sewerage network exists in Lahore. On the basis of this network, multiple network analyses will be performed to find the optimum path for field staff to locate faults in the sewerage line.

6. Concluding Remarks

The current study has proposed a model based on a collaborative approach called PPGIS. It has subjected the data of the water supply line and its associated infrastructure to a GIS environment to have better visualization based on evidence. Spatial data is then embedded in an application developed to handle this data efficiently and embark on a cutting-edge way to deal with complaints launched by the consumer. Both the mobile and web applications provide interfaces for users and network managers. Complaints lodged by consumers will appear on both applications for field staff on mobile and for managers on the web. Managers can create prompt orders for field staff to resolve complaints as soon as possible and can oversee the process as well. It will go on until it is resolved and the user is satisfied with it. Hence, it engages the public with the service delivery provider without having to physically appear before the complaint center to register a com-

plaint. It provides a convenient and cost-effective way to raise the standard of service delivery. Eventually, it amplifies the trust level of consumers in the service delivery department. Despite these benefits, there are certain challenges to be addressed when employing it as a key public delivery tool. People lack interest in such a service. There needs to be an awareness campaign run first for customers, along with training to use it as a tool for the best service.

Declarations

The corresponding author wrote the main manuscript and originated the whole idea of the study. The rest of the authors supervised the entire study, added to the design of databases, and streamlined the analysis.

Data Availability Declaration

Data is available on demand at either stage, which is associated with this study.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors did not use any tool or service based on AI and AI-assisted technologies.

Conflicts of Interest

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

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