International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(14s) 2026 pp. 477-486
https://doi.org/10.70917/ijcisim-2026-4243
Article

Mapping Health Services: Empowering public health planning through GIS and Spatial Analysis in Karnataka state

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Abstract: Health GIS and Spatial Analysis is a web application and information system that focuses on health services utilizing Geographic Information Systems (GIS) by leverage geospatial technology. This work enables the visualization and analysis of spatial data to facilitate improved public health planning and decision-making. This paper specifically focuses on providing geographical information about healthcare centers across Karnataka, one of the southern states in India. This valuable resource empowers users to access information pertaining to various layers of healthcare centers and medical education institutions within the state of Karnataka. Through the selection of geographic layers, users can effortlessly locate healthcare centers in their desired areas. Additionally, this work employs buffer analysis, a spatial analysis technique, to identify and present nearby health services. The positive outcomes obtained from this work demonstrate that incorporating enhanced spatial analysis and data visualization through Web GIS offers a practical and adaptable solution for developing interactive map applications.

Keywords: GIS, Spatial analysis, Buffer analysis, Measurement tool, Base map gallery.

1. Introduction

The advancement of web technology has given This system provides geographical information about healthcare centers allover Karnataka. This can help users to obtain information about the different layers of healthcare centers and medical education. In this paper, the Web GIS application integrated with Buffer analysis is a type of spatial analysis used to identify areas surrounding geographic features. The process involves generating a buffer around existing geographic features and then identifying or selecting features based on whether they fall inside or outside the boundary of the buffer. This analysis will help the user find healthcare centers within the selected geographic boundary. A thematic map is used to represent the districts with different colors, providing a unique identification that offers the best visualization for the user. provide geospatial information about healthcare centers for users. Allow users to check different layers and display the corresponding details. Render the map and display the location of different healthcare layers, along with the total count of selected health centers. Use a thematic map to facilitate better and unique visualization of each district

of Karnataka. Allow the user to choose different map styles and measurement tools to measure area, distance, latitude, and longitude with different measuring units. Enable user-defined buffer analysis to find health centers within specific geographic boundaries by specifying the distance and display an information table for each health center. Provide a facility for users to search for locations in the search bar, navigate to the specified location, and display its information in a pop-up. rise to Web GIS, which combines GIS capabilities with web applications. This technology empowers users to store, analyze, and visualize both static and dynamic geographic data effectively. By utilizing the HTTP protocol, Web GIS enables interactive visualization of dynamic geospatial data through web applications. Map servers facilitate flexible searching and analysis of geospatial information on web nodes. Web Geographic Information Systems leverage the World Wide Web to store, visualize, analyze, and distribute spatial information over the Internet, providing a comprehensive platform for managing geospatial data. Geospatial technology plays a vital role in supporting improved public health planning and decision-making. By utilizing geographic layers, users can easily access the locations of healthcare centers. Spatial analysis, an integral component of GIS, is extensively utilized to assess the suitability of locations for various systems. It helps determine the feasibility of specific locations and aids in making informed decisions related to public health initiatives.

2. Literature survey

GIS integrates spatial and attribute data into a unified system, facilitating the seamless integration of information from diverse sources and databases. Converting maps and spatial data into a digital format through GIS enables innovative approaches for manipulating and presenting geographic information and knowledge. GIS also plays a vital role in establishing connections between geographically proximate activities, which might otherwise go unnoticed. These connections are essential for a comprehensive understanding and efficient management of activities and resources.

The survey highlights global GIS use in healthcare but focuses on limitations in Malaysia [1], especially in delivering essential healthcare information to government service-seeking patients. It stresses integrating critical data, such as medical expertise availability in government hospitals, into the GIS system [8]. The survey discusses how GIS-based analysis and systems can address these issues, enabling patients to access crucial treatment information based on specialist services and improving healthcare facility accessibility. The introduction emphasizes GIS technology's role in enhancing community healthcare quality in Johor Bahru, Malaysia, by providing accurate location data, expertise details, and travel information to medical centers, creating a more efficient healthcare information delivery system.

The methodology highlights the growing importance of urban planning amidst rapid urbanization and the role of GIS technology in supporting it. It explains GIS spatial analysis functions and their application in urban planning [2]. The paper showcases the versatility of GIS spatial analysis across urban planning domains and envisions its future in the field. It underscores how computer-based GIS [10] enhances urban planning's quality and efficiency by considering multiple factors like social conditions, economics, and management, fostering a more integrated and scientific approach.

Spatial analysis [3] is a core facet of geographic information systems (GIS), dedicated to examining geographic patterns, relationships, and processes within spatial data. This field employs various techniques and tools to uncover insights about the spatial distribution of features and phenomena. In urban planning, environmental science, epidemiology, and logistics, spatial analysis plays a crucial role, aiding informed decision-making by dissecting spatial attributes and relationships in data. This versatile approach is applied in detecting disease outbreaks, optimizing transportation routes, assessing land-use patterns, and predicting future trends from spatial data. In essence, spatial analysis is an essential asset for addressing complex spatial challenges and enhancing decision-making in diverse fields.

The WebGIS system for identifying disease-prone regions closely aligns with the goal of improving public health planning using GIS technology. Their approach combines Multi-Attribute Utility Theory (MAUT) [4] with geoprocessing techniques for spatial and attribute data analysis, offering an adaptable framework. Following their structured approach, including system requirements, spatial data modeling, and Conceptual and Physical Data Models, ensures the reliability of our web app. Additionally, their use of Geoprocessing Layers for buffering and other operations serves as a practical reference for advanced spatial analysis like buffer analysis in our project. This publication provides a valuable template for designing a sophisticated Web-GIS system tailored to public health needs, in line with our objectives of enhancing healthcare service planning and accessibility in Karnataka.

The methodology in paper [5] emphasizes optimizing healthcare capital investments, with a focus on the role of proximity in healthcare provider and facility location decisions. It includes a case study using spatial data visualization to assist in locating and sizing a Neonatal Intensive Care Unit (NICU) in a rural hospital network. GIS analysis of public and system-specific data uncovers healthcare system market share and customer travel patterns, vital for decision-making. This study illustrates the use of spatial data mining tools for knowledge discovery, highlighting the significance of spatial data visualization in healthcare, especially for facility location decisions [12] based on market analysis.

The insights from research paper [6] provide valuable methodologies for our healthcare project. Integrating a Health Information System (HIS) with Location-Based Services (LBS) aligns with the mission to improve healthcare accessibility. They emphasize LBS's role in delivering real-time location information to mobile users, particularly in healthcare. The methodology uses ArcGIS for network analysis to determine proximity and optimal paths to healthcare facilities, introducing an innovative Bidirectional algorithm. By incorporating similar LBS and network analysis techniques, the project aims to enhance healthcare service planning for efficiency and user-friendliness. This survey offers insights into implementing an HIS with LBS and network analysis for healthcare facility location [13].

The methodology emphasizes spatial health research's crucial aspect, examining disease patterns alongside environmental factors, particularly climate change's health impact. It introduces a Spatial Data Analysis Infrastructure (SDI) [7] to predict and manage health risks, correlating diseases with climatic air pollution. The SDI comprises modules, including a clinical data collection app, Hadoop-based data mining, and a GIS web app for visualization. This innovative prototype merges big data, data mining, and GIS to uncover connections between environmental factors and health conditions. The paper showcases SDI's versatility through cases on male and female infertility, fire concentration, and points of interest in the Apulia region, highlighting its applicability across diverse domains.

3. Methodology

This section explains the implementation of the work. It covers the process of data collection, data analysis and implementation of the model as presented in Figure 2.1.

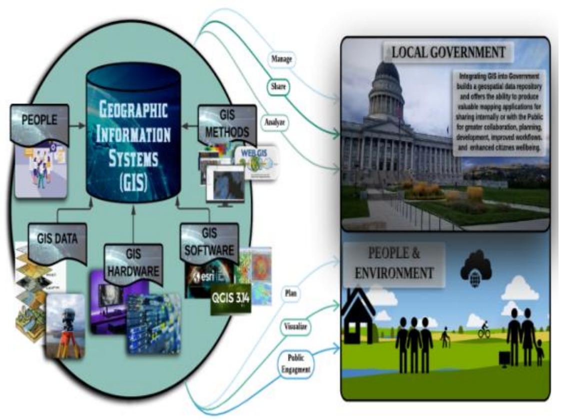

Figure 2.1. Spatial Data Infrastructure

The work aims to explore the utilization of Health GIS and Spatial Analysis in Karnataka State for better public health planning and decision-making. Conduct a comprehensive review of existing literature on Health GIS, Spatial Analysis, and Web GIS [11] applications in the healthcare sector. Identify relevant studies, methodologies, and best practices in the field.

For example, model can link toxic admin boundary with hospitals locations through geographic proximity.

To commence the work, begin by sourcing data from Karnataka State Remote Sensing Application Centers (KSRSAC) and other pertinent repositories. This data is accessed through APIs. The scope of data collection should encompass healthcare facilities, medical education resources, geographic layers, and other spatial data essential for the research. It's crucial to note that the GIS infrastructure involves an integrated system comprising both hardware and software components. When it comes to collecting and visualizing data from APIs on the client side using JavaScript, the process entails securing the requisite APIs, initiating HTTP requests, extracting and manipulating the acquired data, and dynamically updating the user interface to present the information retrieved. As delineated in Figure 2.1, it is imperative to identify appropriate research methodologies that align with the research objectives. This methodology selection may involve a blend of qualitative and quantitative approaches, such as case studies, survey questionnaires, interviews, and spatial analysis techniques.

Develop a Web GIS application incorporating the selected research methods to visualize and analyze the geographic data in the APIs. Implement buffer analysis and measurement tools to identify healthcare centers within specific geographic boundaries. Analyze the collected data using appropriate statistical and spatial analysis techniques. Perform buffer analysis to assess the proximity of healthcare centers and evaluate their distribution across Karnataka. The development methodology for the Web GIS and Spatial Analysis for Health services website involves several essential components. First, Module Development covers the creation of modules like Home, About, GIS View, and Contact Us. These modules serve to design the homepage, provide comprehensive project information, offer an interactive map interface, and facilitate user communication.

Satellite Base Map Creation is another critical aspect, where the base map's layout and style are meticulously designed to offer an informative visual backdrop. The integration of the satellite base map into the GIS View module ensures proper alignment with other map features and tools.

Layer Identification focuses on identifying various geographic feature layers based on different sectors, including healthcare facilities like hospitals, scanning centers, and paramedical colleges.

The development also includes the creation of a Base Map Gallery within the GIS View module, measurement tools for distance and area calculations, and thematic maps to visually represent specific attributes of the geographic data.

Layer Selection and Information Presentation allow users to choose which layers they want to display on the map and provide popup windows for detailed information when interacting with map icons.

Finally, the implementation of a Search Bar and Buffer Analysis enhances user capabilities. The search bar enables quick location searches related to health features, while buffer analysis creates zone-like areas around health facilities based on user-specified distances. These improvements empower users to navigate and analyze geographic health data more effectively, making the WebGIS system a valuable tool for healthcare planning and analysis.

4. Results and Discussions

The work culminates in a robust and user-friendly GIS Viewer, offering valuable insights into the healthcare sector, visualization tools, measurement capabilities, and analytical features tailored to the designated region. The addition of buffer analysis functionality significantly enhances user convenience and expedites access to specific locations and relevant information.

The work comprises four main functionalities: Home, About, GIS View, and Contact Us. The "Home" module serves as the primary landing page, featuring the project title, main menu navigation bar, and a "More Info" tab. The "About Us" module provides information about all included sectors and their functionalities. The "Contact Us" page displays the geographical location of KSRSAC with a map.

The landing page includes relevant information about the Health GIS project, its objectives, and features as shown in the figure 4.1 and provide navigation links to other modules.

Figure 4.1 The main landing page of Health GIS

The about us page includes background information, project goals, and any relevant research or data sources as shown in the figure 4.2 and present information in a clear and concise manner.

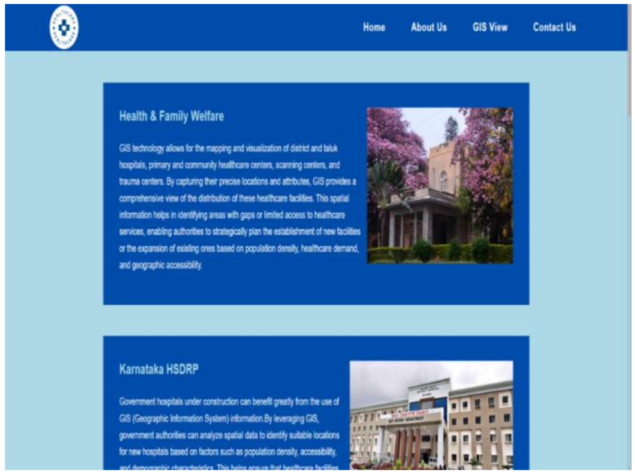

Figure 4.2 This page provides an overview of GIS & Spatial Analysis for Health Services

The "More Info" tab is a descriptive page that provides detailed information about the work as visualized in figure 4.3. It offers a comprehensive overview of the project's purpose, goals, and features. The images, displayed in an engaging slideshow format, visually showcase the different hospitals, capturing its essence and enhancing the user experience.

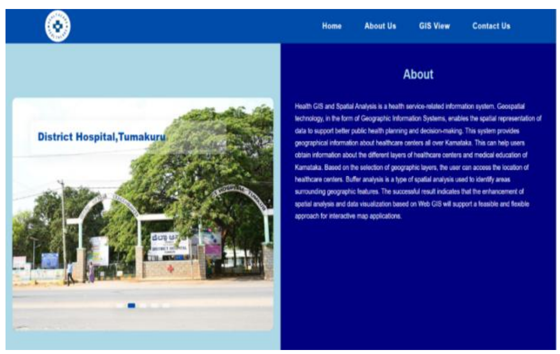

Figure 4.3 Expressive Information about project with health center images

The GIS viewer is a powerful functionality, allows users to view and interact with the geographic data. Implemented the map interface where users can visualize different layers and sectors.

Integrate the buffer analysis functionality to identify specific geographic features within specified boundaries based on distance as shown in the figure 4.4.

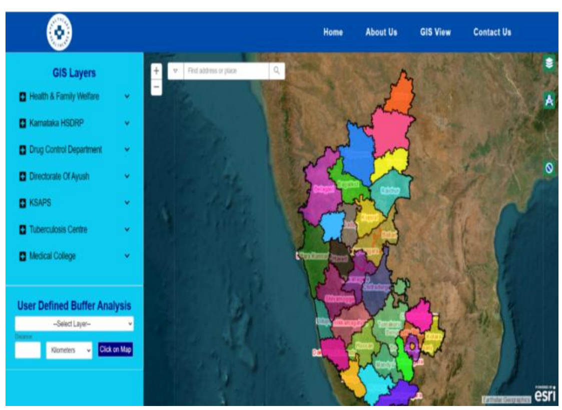

Figure 4.4 The primary view of GIS Viewer with Sectors.

In the GIS view, administrative boundaries are visually distinguished using a spectrum of colors, effectively highlighting state, district, taluk, and hobli boundaries, and providing a comprehensive and intuitive mapping experience. It is demonstrated in the figure 4.5.

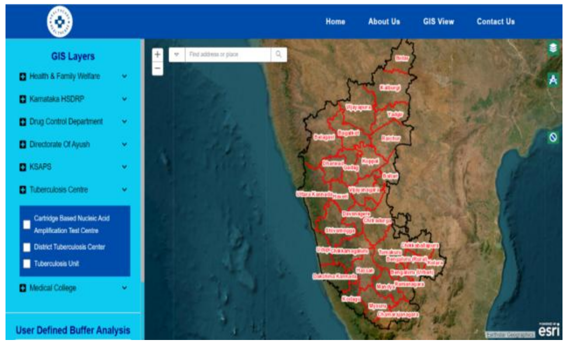

Figure 4.5 GIS Viewer with admin boundary

In this geographic feature view, based on the sectors like Health and Family Welfare, Karnataka HSDRP, Drug Control Department, Medical Colleges, and others, identify different layers of geographic features as exposed in figure 4.6.

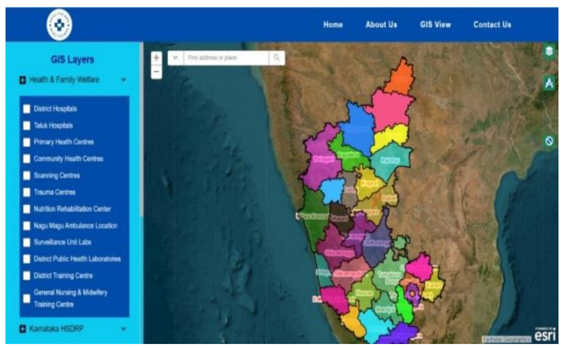

Figure 4.6 Views of Geographic Features.

A thematic map view visually represents specific themes or attributes of the geographic data as shown in figure 4.7. Use different colors, symbols, or patterns to represent different values or categories

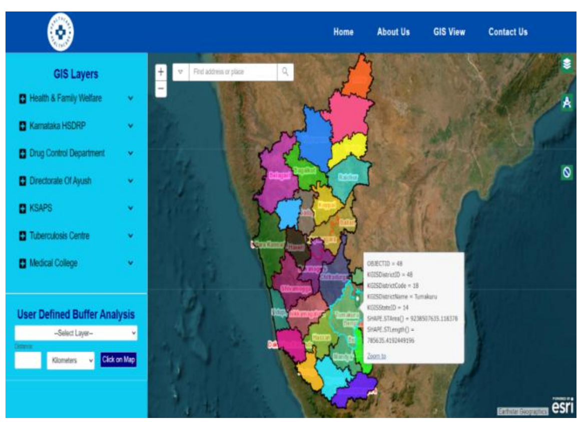

Figure 4.7 Thematic Map view with pop up information of districts

Identify and implement measurement tools within the GIS View module as exposed in figure 4.8. Allow users to measure distances and areas on the map for analysis purposes.

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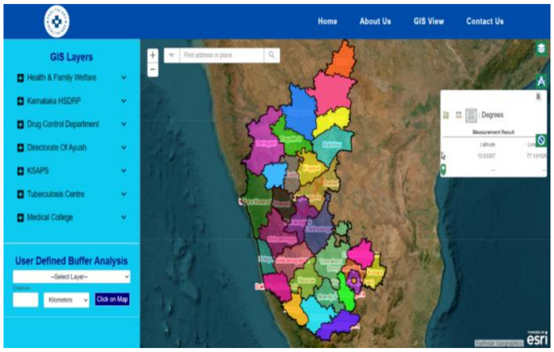

Figure 4.8 Measurement Toolbox

A base map gallery within the GIS View. Provide a selection of base maps for users to choose from. And displaying the chosen layer in the legend as illustrated in figure 4.9.

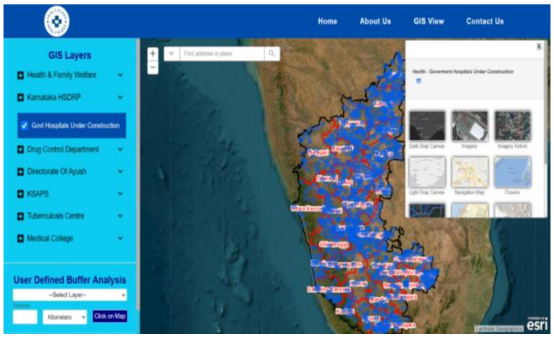

Figure 4.9 Base map galleries with legend

Geographic layers allow users to choose the layers they want to display on the map from the identified layers. And provide checkboxes for layer selection. When a user clicks on an icon, display a popup window with relevant information, such as village ID, the name of the location, and the belonging district with name as portrayed in figure 4.10.

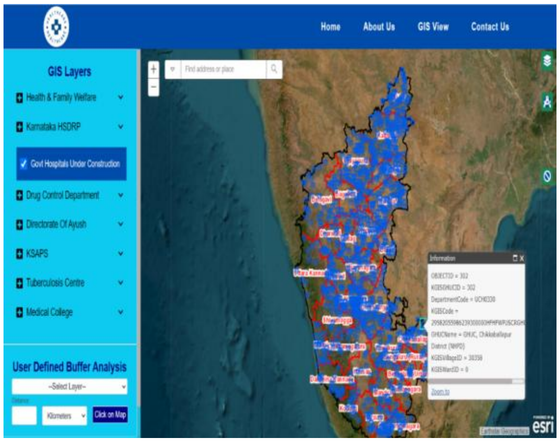

Figure 4.10 Mapping Geographic Feature Layers with Popup Information Display.

Buffer Analysis is a spatial analysis, that enable users to set a distance (in kilometers or miles) to define zones around health facilities, and provide detailed geographic feature data within the specified boundary in a table as demonstrated in figure 4.12.

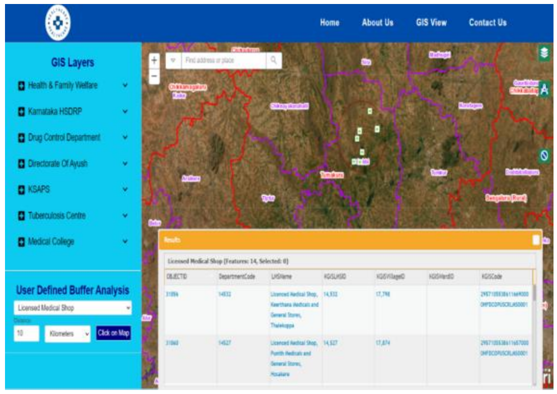

Figure 4.12 Buffer Analysis with Table Display of Information

A search bar is a beneficial functionality to search for geographic locations associated with different health features as shown in figure 4.13.

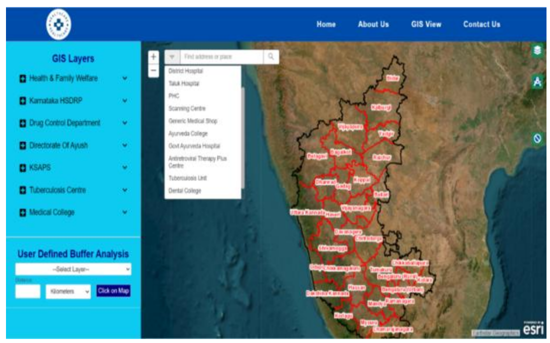

Figure 4.13 Search Bar with Dropdown Menu of Geographic Features.

Search bar functionality allows users to effortlessly input the name of a health facility or a specific location as shown in figure 4.14. This feature enables quick navigation to the desired area on the map, simplifying the user experience and enhancing efficiency. Users can easily locate and access the information they need by simply typing in the relevant keywords, ensuring a seamless and intuitive interaction with the system.

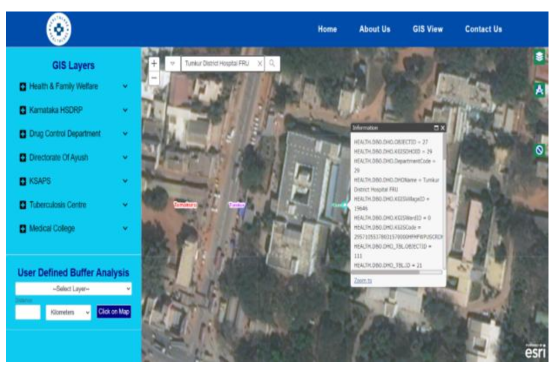

Figure 4.14 Precise Mapping of the Searched Tumkur District Hospital's Location.

A contact page is a useful page, where users can find contact information for project coordinators or administrators as exposed in figure 4.15. Include a contact form or email address to facilitate communication with users.

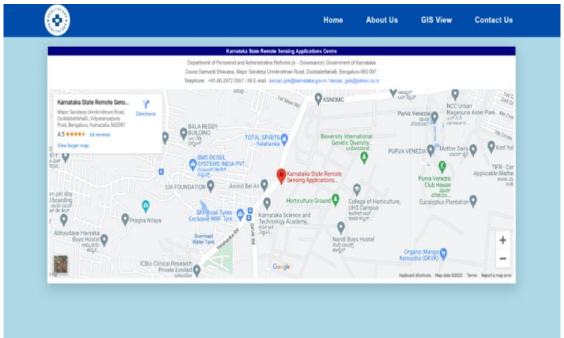

Figure 4.15 Contact information.

5. Conclusions

Health GIS and Spatial Analysis are invaluable tools in the healthcare sector, harnessing the capabilities of Geographic Information Systems and geospatial technology to enhance public health planning and decision-making. This work provides comprehensive geographical data on healthcare centers in Karnataka, allowing users to explore various layers of healthcare facilities and medical education institutions efficiently. Advanced spatial analysis techniques, such as Buffer analysis, aid in identifying nearby health services. The successful outcomes showcased here highlight the potential for advancing spatial analysis and data visualization in Web GIS, offering a promising framework for interactive map applications. These innovations have the potential to transform healthcare accessibility and resource allocation, ultimately improving health service delivery in Karnataka and beyond.

Author Contribution Statement

The author confirms that he is solely responsible for writing this manuscript

Funding

The author declare that no funds, grants or any other support were received during the preparation of this manuscript.

Competing Interests

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Has this article screened for similarity?

Yes

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