

# A Conceptual Framework of Public Health SDI



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**Abstract** From several years, public health is one of the major problems faced by several countries including India. This requires proper Public Health Information System (PHIS) that is safe, reliable, and efficient. At present, most of the public-health-based information and management system are lacking the support of real-time data uploading, data visualization, data analysis, and decision-making. To overcome these issues, Spatial Data Infrastructure (SDI) became the promising approach through which the improvements can be made. SDI provides an environment in which users can share and access the geospatial data with the common set of policies, standards, and network protocols. The main objective of the present work is to conceptualize an SDI framework for public health using open-source resources so that users can access the health information easily from the developed system. Moreover, the concept presented in the paper can be applied onto the larger scale.

**Keywords** GIS · Public health · SDI · Framework

## 1 Introduction

The rising level of population, climate change, urbanization, deforestation, and several other factors are adversely affecting the human health and increasing the risk of different kinds of diseases all over the world including India. These factors are affecting our society and public health. From several years, Geographic Information

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System (GIS) technology is playing an important role by providing several spatial tools that are very helpful for public health [1]. Research papers related to the use of GIS in public health, and causes of diseases and its outcomes have been studied to understand the need and importance of Public Health Information System (PHIS). These papers are related to the effects of air pollution [2], malaria disease distribution [3], socioeconomic factors in PHIS [4], etc. The classical approach to manage and access public health data is very tedious and time-consuming process. Therefore, it is necessary to combine the collection, visualization, management, and access of public health data with new technology. To develop the PHIS, information about spatial key entities like geospatial location, administrative boundary, etc. and nonspatial entities like sociotemporal information, environment study, disease information, etc. are necessary.

Many desktop-based public health solutions are provided by different organizations. Desktop-based solution requires professional who has in-depth knowledge of GIS tools and software. But, with the development of the Internet, the health services became easily available and accessible. Standards and policies were defined for easy access of web-based geospatial application through the Internet [5]. PHIS is very useful for the public. Most of the public health organizations collect health data locally when they required and make decision on them. However, this process is very unorganized with limited scope to access the public health information [6]. Due to such drawbacks, concept of Spatial Data Infrastructure (SDI) became the promising approach to enhance the overall capability of the system.

SDI provides the capability to discover, access, process, visualize, and manage the geospatial data [7]. The goal of SDI is not limited to the sharing of the spatial data, it also facilitates the documentation of the information and development of different data standards [8]. SDI is mainly a distributed network of computing nodes which exists in the different scales (e.g., local, state, national, and global) [9]. The geospatial datasets are deployed on these distributed nodes for geospatial analysis, processing, and decision-making. From several years, various developed and developing countries have started to develop the National Spatial Data Infrastructure (NSDI).

Interactive web-based PHIS can be developed by the collaboration of the public health with SDI. Several challenges faced by public health can be overcome through the public health SDI by providing different disease dispersion maps where user or decision-makers can make assessment. Furthermore, public health SDI also provides different services and sharing mechanisms that make improvement in the conventional approach to share the public health information [10].

The main objective of the present work is to develop a conceptual framework of SDI for public health using open-source resources. The proposed public health SDI framework is based on the three-tier client-server architecture.

## 2 SDI and Its Components

To understand the necessity of geospatial information within the different sectors, several countries all over the world have started to think to develop a geospatial infrastructure. Therefore, the concept of SDI comes into the real world that facilitates the discovery, publish, access, and sharing of geospatial information. The primary goal of SDI is to share and exchange the standardized geospatial data to the end user. Different standards and policies have been provided by different organizations through which sharing of data became easy. Several authors have defined SDI differently. Rajabifard et al. [11] stated that “SDI is fundamentally about facilitation and coordination of the exchange and sharing of spatial data between stakeholders from different jurisdictional levels in the spatial data community.” The hierarchical relationship of different levels of organization is presented by Rajabifard et al. [11]. It includes the development of SDI from local, regional, and national to global level that requires the support of top to bottom level SDI participants. Figure 1 presents the components of SDI and their dynamic relationship.

As illustrated in Fig. 1, the core components of SDIs are people, data, policy, standard, and access networks. Rajabifard et al. [12] categorize these components in two parts, first part considers the fundamental role of people and data, while second part considering the standard, policy, and access networks as a technical component. People are here representing stakeholders, decision-makers, different agencies, and users. Data is the core component of SDI which includes different categories of datasets that share between producers and users. To recover technical barriers, technical components like access network works as a distributed network mechanism to exchange the spatial information. To define the policy, several factors are considered apart from exchanging of data like data security, data privacy, data recovery, authentication, and good governance. Moreover, standards can also perform the key role in SDI, which are defined for data, metadata, and services [13]. SDI provides service-oriented model for data discovery, data processing, and application for broad range of users [14]. SDI functionality involved service-oriented architecture to construct the dynamic, flexible, and configurable environment.

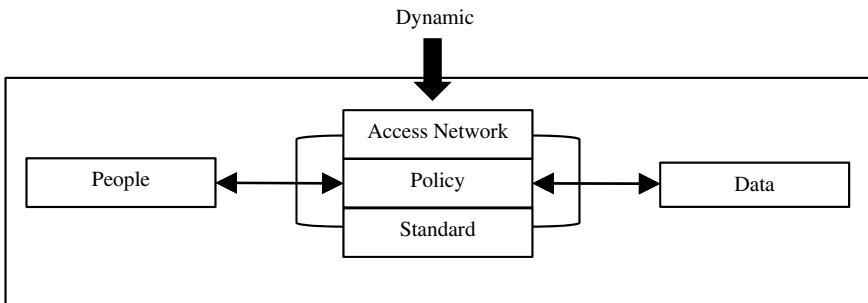


Fig. 1 Nature and relationship between SDI components. Adapted from Rajabifard et al. [12]

### 3 Collaboration of SDI with Public Health

The sharing of public-health-based information is crucial for preventing harmful disease, responding to emergency services and makes it understandable to the public and producers. Many health organizations do not have professional tools to map health-based information which is necessary to take immediate actions at emergency [6]. Over the last decade, GIS plays an important role within public health sector. With the availability of several desktop-based tools, it became easy to develop the desktop-based emergency system. But it requires GIS professionals having in-depth knowledge of GIS. Desktop-based solution requires lot of time, money, and skills to analyze the spatial data and render the results for interpretation.

With the growth of information technology and enhancement of the Internet, several web-based solutions become available to access the public health information. It is estimated that 80–90% of government data are related to the geographical data [15]. These datasets associated with a particular location like latitude and longitude, address, area code, census information, and administrative boundaries. The same is true for health data. These location-specific data translated into the information and integrated with the different datasets [16]. In year 2003, the term “Geographic Information Systems” is added into the controlled vocabulary thesaurus of US National Library of Medicine [17]. Such step spreads the use and importance of GIS in the field of health researches.

Several developing and developed countries all over the world are facing the problem of irregular spatial distribution of health information [18]. Health facilities in the rural areas or the remote locations are dealing with many difficulties to access the health-based information [19]. Most of the research till now considers the adoption of GIS tools for the analysis and management of public health information, while limited research has been found that includes integration of public health with the information infrastructure. Thompson et al. [20] advised that implementation of healthcare system demands geospatial data, but most importantly data harmonization and data sharing are the keys to improve decision-making process. Boulos [21] has illustrated the potential of different geospatial tools in several public health problems. It also includes the comprehensive analysis of national-level spatiotemporal health information infrastructure. Croner [5] identified that several key elements are necessary to develop a national public health information infrastructure such as involvement of highest level authority, current status of health resources, technical introduction, and geospatial readiness.

Several other factors are also necessary to develop the sustainable PHIS to discovery access and manage public health information. As the public health database involved heterogeneous data gathered from different sources such as different health agencies, census data, epidemiological data, etc, it requires geospatial and statistical analysis to identify the final outcomes. There are several barriers in effective communication between different participating agencies because different health agencies have different sets of communication protocols, policies, standards, and service interface [20]. Moreover, for the effective PHIS, local and national agencies

work collectively to gather the public health data from distinct geographical locations, and it is necessary to adopt such system which eliminates the duplication of data [22]. It is identified that local-level agencies have better information about their geographical area and other factors than national-level agencies. So, the participation of local-level agencies is much more required for the sustainable public health SDI.

Collaboration of public health and SDI provides the effective environment for the public health organizations, decision-makers, stakeholders, and users. SDI represents information infrastructure by including institutional arrangements as well as people, standards, and protocols for the effective sharing of geospatial information. The same is considered in the case of public health SDI.

## 4 Generic Framework of Public Health SDI

The generic framework of public health SDI is presented in Fig. 2. The basic goal of this framework is to provide the interoperability of data and services by including standards and policies provided by SDI. Open Geospatial Consortium (OGC) and several other standard bodies like International Organization for Standardization (ISO) provide such standards and services for the interoperability. Interoperability ensures that the geospatial data can be searched, located, and retrieved from anywhere either from individual desktop or service provider.

OGC has introduced open web service that is based on the SOA and also provided different geospatial specifications such as Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), Catalog Service for Web (CSW), and Web Processing Service (WPS) [6]. WMS has the capability to produce maps dynamically rather than to access specific georeferenced data. WFS defines the interfaces to access geospatial features on the web. WCS provides the interface to find geographical coverage area from the whole geospatial datasets, i.e., it returns actual raster details as per the user request. WPS offers standardized interfaces through which spatial processing functionalities like publish, discovery, and bind operations can be performed over the network. CSW defines interfaces for discovery and access of catalog data. In general, these service specifications integrated with the specific geospatial application develops the interactive web GIS application to perform common set of actions like search, discovery, and access.

The developed public health SDI framework includes three modules which are user-specific application, service interface, and distributed health datasets. Accessing public health information through standard service interface is important for data accessibility and interoperability. Through the standard service interface, improvement can be made in conventional PHIS. The creation and management of health database are present in distributed manner within public health SDI because different health organizations cooperate with each other. This framework provides several advantages to PHIS, for example, better accessibility of health data, easy interaction of public because of visualization of health information in maps, and most importantly cost reduction of healthcare application.

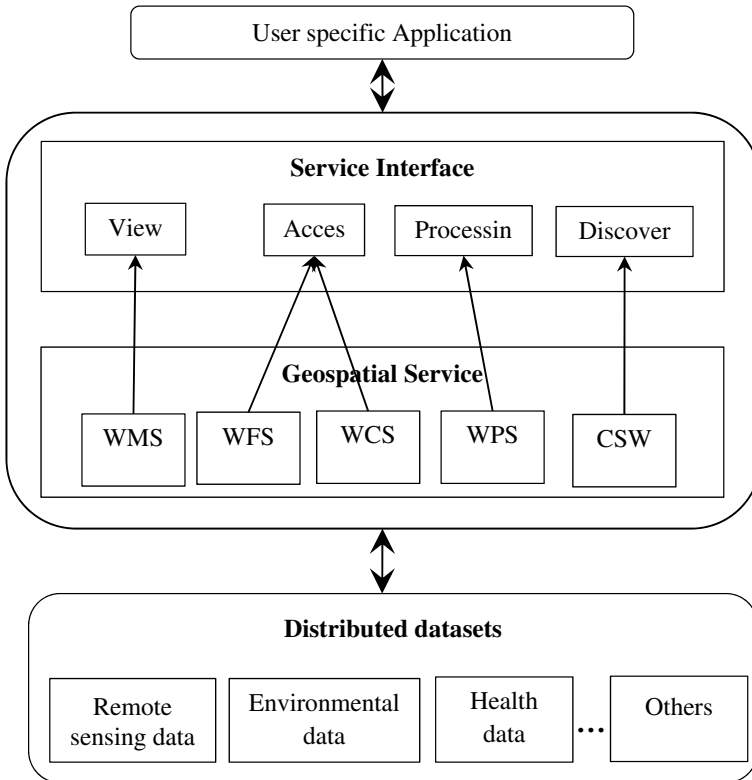


Fig. 2 Framework of public health SDI

## 5 Methodology Adopted

The proposed public health SDI framework is based on the three-tier client–server architecture. It requires free and open-source software and resources to manage the public health database, to publish the geospatial data on to the server and to authorize the users. All these responsibilities are managed by the administrator. Figure 3 presents the layered architecture view of public health SDI framework. It includes three layers which are data layer, application layer, and client layer.

The client layer consists of web browser, desktop application, or mobile client through which user can make request and get response from the application layer. This layer provides different geospatial functionalities like discovery, visualization, processing, and accessing of geospatial data. Further, client can also perform actions like zooming and querying on the interactive web maps that display on the client layer.

The application layer is used to develop web-based application through which user can request for different services like data, catalog, or processing services. The web-based application has been developed by using HTML, CSS, JavaScript, JSP,

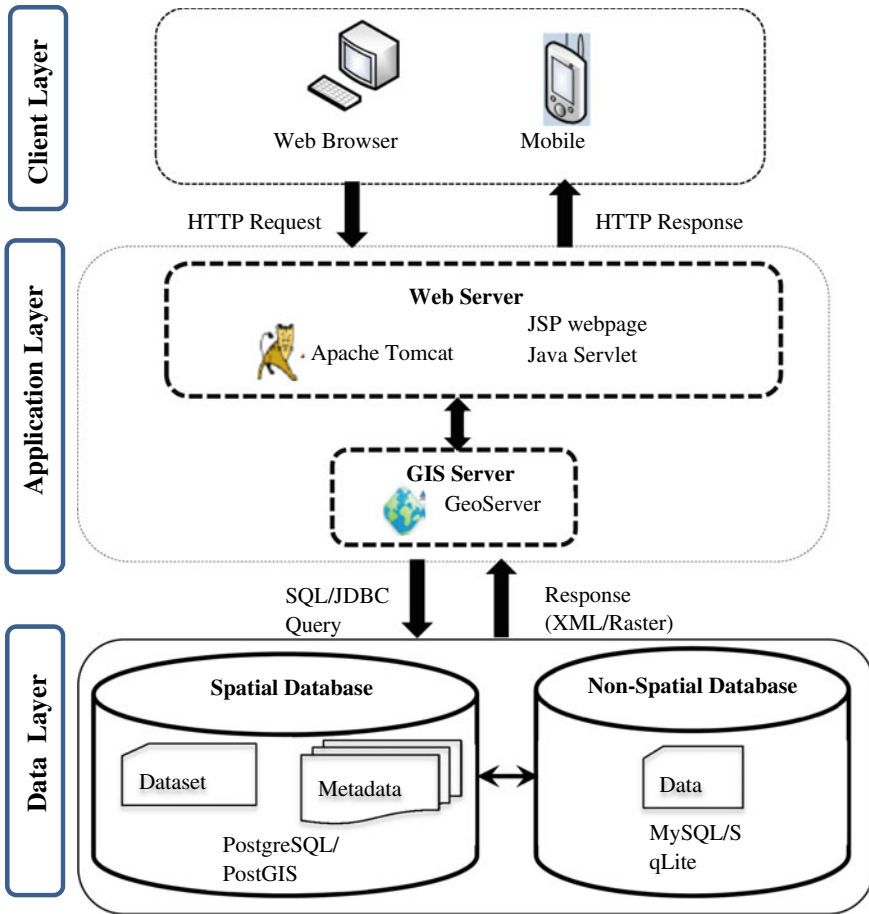


Fig. 3 An open system architecture for public health SDI

and Servlet. Apache Tomcat is used as a web server and GeoServer is used as GIS Server to publish the public health datasets onto the server. GeoServer is an open-source software which provides OGC compliant services such as WMS, WFS, WCS, and WPS for sharing geospatial data on to GIS server.

The data layer contains the public health datasets, for example, geospatial locational data in latitude and longitude values, census data, disease information, emergency information, etc. These public health datasets are uploaded onto the PostgreSQL/PostGIS database. PostgreSQL/PostGIS databases are used to store spatial and nonspatial data. The proposed public health database helps users to analyze, manipulate, and decide. The integration of public health data across the web provides users the facility to access detailed health information.

## 6 Conclusions

The paper presents the public health SDI framework which is interoperable and facilitates accessibility of data in a secure manner. This framework is used to overcome the issues of public health information and management with the support of SDI. The main advantage of public health SDI is that it provides efficient mechanism for discovery, access, and processing of public health data to the end user. The paper presents the three-tier client–server architecture on which public health SDI framework works.

The main focus is to use the free and open-source software like Apache Tomcat, GeoServer, PostgreSQL/PostGIS, and Quantum GIS to develop the web-based PHIS. The use of such open-source software in the specific geospatial application benefits many users to deliver information efficiently on global platform. This framework can be extended at national level with ease at affordable cost.

## References

1. Mathys T, Boulos MNK (2011) Geospatial resources for supporting data standards, guidance and best practice in health informatics. *BMC Res Notes* 4:19
2. Buzzelli M, Jerrett M, Burnett R, Finklestein N (2003) Spatiotemporal perspectives on air pollution and environmental justice in Hamilton, Canada, 1985–1996. *Ann Assoc Am Geogr* 93:557–573
3. Martin C, Curtis B, Fraser C, Sharp B (2002) The use of a GIS-based malaria information system for malaria research and control in South Africa. *Health Place* 8:227–236
4. Mitchell R, Dorling D, Shaw M (2002) Population production and modelling mortality—an application of geographic information systems in health inequalities research. *Health Place* 8:15–24
5. Croner CM (2004) Public health GIS and the internet. *J Map Geogr Libr* 1:105–135. *Adv Geosp Inf Collect Arch*
6. Gao S, Mioc D, Yi X, Anton F, Oldfield E, Coleman DJ (2009) Towards web-based representation and processing of health information. *Int J Health Geogr* 8:3
7. Nebert DD (2004) Developing spatial data infrastructures: the SDI cookbook
8. Warnest M, Feeney MEF, Rajabifard A, Williamson IP (2002) Fundamental partnerships driving spatial data infrastructure development within Australia. *Cartography* 31:11–20
9. Rajabifard A, Williamson IP (2001) Spatial data infrastructures: concept, SDI hierarchies and future directions. In: *Proceedings of GEOMATICS'80 conference*, p 10
10. Granell C, Fernández ÓB, Díaz L (2014) Geospatial information infrastructures to address spatial needs in health: collaboration, challenges and opportunities. *Futur Gener Comput Syst* 31:213–222
11. Rajabifard A, Williamson IP, Holland P, Johnstone G (2000) From local to global SDI initiatives: a pyramid of building blocks. In: *4th global spatial data infrastructure conference*, Cape Town, South Africa, pp 13–15
12. Rajabifard A, Feeney M-E, Williamson IP (2002) Directions for the future of SDI development. *Int J Appl Earth Obs Geoinf* 4:11–22
13. Crompvoets J, Bregt A, Rajabifard A, Williamson I (2004) Assessing the worldwide developments of national spatial data clearinghouses. *Int J Geogr Inf Sci* 18:665–689
14. Yang CP, Cao Y, Evans J, Kafatos M, Bambacus M (2006) Spatial web portal for building spatial data infrastructure. *Geogr Inf Sci* 12:38–43



15. FGDC. Homeland security and geographic information systems-how GIS and mapping technology can save lives and protect property in post-September 11th America. <https://www.fgdc.gov/resources/whitepapers-reports/white-papers/homeland-security-gis>
16. Foster RW, Ryttersgaard J (2001) The Nairobi statement on spatial information for sustainable development. In: FIG working week 2001, Nairobi
17. Richards T, Croner C, Rushton G, Brown C, Fowler L (1999) Geographic information systems and public health mapping the future. *Public Health Rep* 114:359–373
18. Yang DH, Goerge R, Mullner R (2006) Comparing GIS-based methods of measuring spatial accessibility to health services. *J Med Syst* 30:23–32
19. Hu R, Dong S, Zhao Y, Hu H, Li Z (2013) Assessing potential spatial accessibility of health services in rural China: a case study of Donghai county. *Int J Equity Health* 12:35
20. Thompson J, Eagleson S, Ghadirian P, Rajabifard A (2009) SDI for collaborative health services planning. In: Global spatial data infrastructures world conference, Rotterdam, The Netherlands
21. Boulos MNK (2004) Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom. *Int J Health Geogr* 3:1
22. Goodchild MF, Fu P, Rich P (2007) Sharing geographic information: an assessment of the geospatial one-stop. *Ann Assoc Am Geogr* 97:250–266