International Journal of Research and Review
Vol. 10; Issue: 2; February 2023
Website: www.ijrrjournal.com
Review Article *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Geographic Information System (GIS) and Healthcare: An Overview

Dr. Shahina Yasmin[1], Dr. Archana Krishna Murthy[2], Dr. Shilpashree KB[3], Dr. Mumin Rashid[4]

[1]Postgraduate, Department of Public Health Dentistry, The Oxford Dental College, Bengaluru
[2]Professor and HOD, Department of Public Health Dentistry, The Oxford Dental College, Bengaluru
[3]Professor, Department of Public Health Dentistry, The Oxford Dental College, Bengaluru
[4]Postgraduate, Department of Public Health Dentistry, The Oxford Dental College, Bengaluru

Corresponding Author: Dr. Shahina Yasmin

DOI: https://doi.org/10.52403/ijrr.20230236

ABSTRACT

GIS (Geographic Information System) are computer-based tools used to visualize, analyze, accumulate and explicate geographic data. The determinants of health status are often correlated and analogous. Establishing GIS-based approaches and programmes can predict and analyze the complexity of web of causation of many health issues. GIS can be used to efficaciously investigate health along with its physical, social and cultural environments. Mapping functions of GIS can be used to plot health attributes for better visualization, exploration, and modeling of health patterns. GIS based healthcare helps in explaining and describing health outcomes, health disparities, healthcare access and how health care delivery can be improved. GIS can also be used to bring all spatial data under one umbrella of "Geo Data Bank" that could provide easy accessibility and help in better utility of healthcare services. In India, the adoption and use of digital spatial methods like GIS in the field of healthcare has lagged. However, the "Computer Aided Utility Mapping Project for six cities" in India is a significant benefit for the GIS users in the country which can be used by healthcare sector in the near future for the upliftment of healthcare facility. The primary focus of the paper is to provide details about benefits of using GIS-based analytical approaches in healthcare planning, the successes, challenges, remedies and future perspective of GIS in healthcare delivery.

Keywords: GIS, healthcare planning, location allocation modeling, public health, spatial analysis, spatial epidemiology.

INTRODUCTION

In order to understand the health/disease process, it is mandatory to explore the relationships between space and community health. Today, geographic space is understood as an active environment, a receptor of social processes and an activator of these processes.[1] Detailed analysis of the pattern of inequality and spatial distribution of different diseases is fundamental in order to address healthcare problems and for appropriate allocation of resources to areas with the greatest social deprivation.[2] Within the many new advancements, geo processing approaches have appeared, and among them Geographic Information Systems (GIS) stand out as remarkable technology in the investigation of these relationship and facilitates in better comprehension between the environment and health.[3] GIS are computer-based tools used to store, visualize, analyze, and interpret geographic data. These data include anything that can be associated with a location on the globe, or more simply anything that can be mapped. [4]

GISs are potentially powerful assessment tools for the investigation of health outcomes, healthcare access, and the

possible resulting health disparities. The mapping function of GIS to integrate health data allows for exploration, visualization, and modeling of health patterns. GIS technology using health data can help in describing and explaining disparities in healthcare access and health outcomes. [5] For example, cases of disease, hospitals, health catchment areas, roads, waterways and country boundaries are all types of spatial data. In a GIS, the data usually include attributes, or descriptive information. The descriptive data also allows one to search and display associated attributes (e.g., number of hospital beds, types of specialized services offered, etc) (Figure 1). [6] In terms of analysis, a GIS offers the opportunity to use spatial data to answer questions. For example: How far is it to the nearest healthcare facility? Where are disease rates higher or lower?

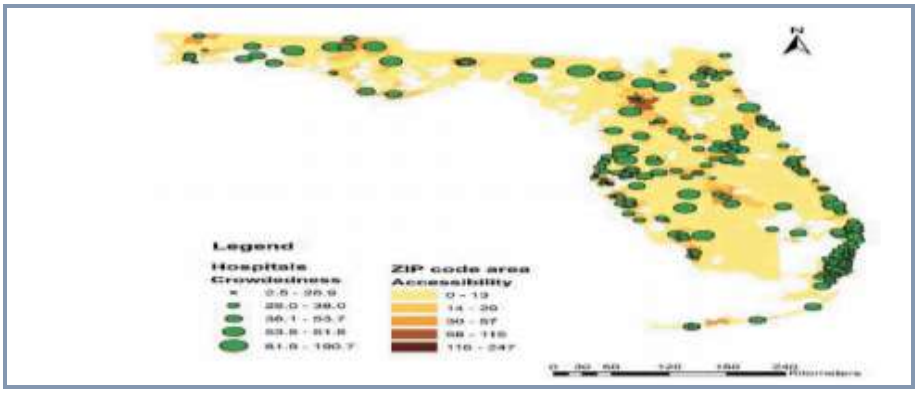

Figure 1: Potential crowdedness in a hospital versus. zip code (Source: 6)

Rationale

Dating back to 1854, the seminal work of John Snow illustrates the power of mapping and geographic systems to respond to the cholera outbreak. GIS mapping helps in identifying, preventing and controlling diseases. Furthermore, GIS helps to analyze spatial distribution and risk factor patterns, and can be used to improve the impact of public health interventions. Using GIS to intersect between public health planning and spatial representation can enable to make prompt and credible decisions that can save many lives.[7] Many studies suggests that Geographic Information Systems (GIS), is a reliable method that can be used in epidemiological studies, to furnish valuable information with regards to geographic distribution of diseases, elucidating the mechanisms of diseases, pathogenic agents, and their associations with social, economic and environmental factors. [8, 9]

Scope of GIS:

Development of GIS-based locational analysis models have stimulated innovative health care applications due to advances in computing power and graphics.[10] Although GIS has been used for several decades to survey health care systems, the scope of GIS-based approaches has grown rapidly in recent years. There is significant scope for every country to leverage the full benefits of GIS. Specific services include:

Analyzing need for health care: GIS is being used to map and analyze the geographical variation in need for health services and to develop innovative health care services. The foundation for health services planning and analysis depends on exploring geographic variation in population and population need for health care. People are spread unevenly across the globe, and there exists a wide range of variation among populations along many dimensions - including age, gender, social, culture, and economic status - that affect their need for health care, their access to health care, and their types of service utilization. A recent

example is the endeavour at creating "community environmental health profiles" that describes a certain population's demographic, economic, and lifestyle characteristics as well as exposure to potent environmental risks. [11]

- *Analyzing access to health care*: The type and quality of services available to a particular population, the distance, time, cost, and ease of traveling to access those services influence health care decisions. GIS research helps to identify the geographic determinants of health and consequently accentuates the geographical dimensions of access to healthcare services. Access describes people's ability to use health services whenever required. [12,13,14] For medical ailments that require regular contact with health care providers, distance to the healthcare facility and travel time and can create hurdles to effective service utilization.[15,16] Differences in geographical access within the population and for population sub groups can be evaluated and calculated using GIS based methods. Using the access measures and tools available in GIS, policy-makers and researchers can investigate health disparities and probe inequalities in health care access .[17]
- *Locating Health Services*: The objective function of a GIS based location-allocation model are: maximizing population coverage or minimizing average distance and these are important decision-making considerations especially in developing countries where use of health services are strongly influenced by distance.[18,19,20] In more recent times, optimization models are being used for vehicle routing problems - to calculate and locate the shortest-path routes for Meals on Wheels programs - and in GIS-based ambulance routing systems.[21] A case study of healthcare planning using GIS in Varanasi was conducted with the aim to calculate the area requirement of a hospital and to investigate the specific sector that needs to develop better health services and facilities. [22] The Geographic Information Systems can be conveniently used in numerous healthcare services, for example, an ambulance deployment system in Greece, recently being used which includes GPS-based ambulances equipped for continuous monitoring of vehicle positions, and helps in calculating shortest path from incident site by incorporating real-time road congestion data from traffic sensors. (Figure 2). [23]

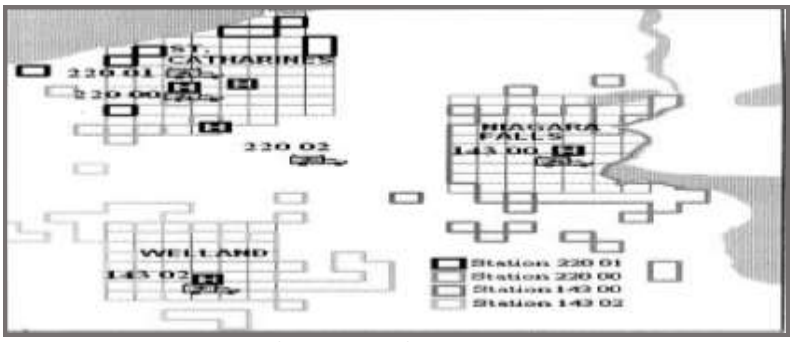

Figure 2: A map of ambulance of catchment areas. (Source: 23)

- *Geographic variation in utilization*: The assumptions about patients, service allocations and service utilization including assumptions health care supply measurement and access variables can be critically examined with the help of GIS. 10]
- Geospatial data-based WHO standard operating procedures for maps and Web GIS applications will help in worldwide

exchange of information on disease prevention and control.
- GIS can help in strengthening country data, regional data, analytics which will help in making the health information system more robust and efficient.
- Trusted geospatial partners through a network of agencies can help in augmenting timely assistance.
- GIS community consisting of trained and technical experts can help in innovative technology-based research.[7]

Successes of GIS

GIS can be linked to real and measurable public health benefits. GIS has many successes as well as challenges (Figure 3). [24] GIS can be successfully applied to monitor and predict many diseases mainly from developing countries. Some of the advantages and successes of using GISs are:

Understanding the socio-cultural determinants of health: Modifiable predictors of health like socioeconomic, cultural, and educational determinants outcomes can be investigated using GIS.[25] GIS helps in analyzing the dissemination of social determinants of health and help identify the disease hotspots and thus help in development of targeted interventions to address them. [26]

Disease surveillance: Epidemiological factors such as land use, surface temperatures, rainfall, oceans and land cover have a major impact on the disease process can be analyzed using spatial observations. GIS are being used globally as mapping tools for disease surveillance and monitoring programmes. Mapping action of GISs provide a visual representation of underlying geographical distribution of diseases, understanding of disease rates over time, and enabling the detection of outbreaks or probable epidemics. Consequently, GIS based surveillance system has opened up newer avenues in creating early-warning systems for emerging and re-emerging diseases. [10]

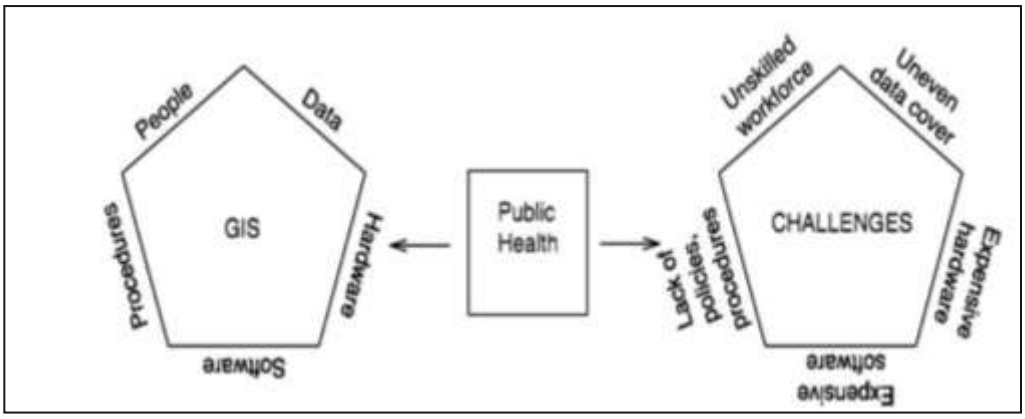

Figure 3: The figure represents GIS. Data, hardware, software, procedures, and people are the five components of GIS which are located at the five edges of a pentagon. In a GIS public health data are perfectly suited to be stored and analysed as information layers, provided location specific information (e.g., addresses, geographic determinants, street names, etc.) is also provided in the database. A GIS-based geodatabase loses its analytical and predictive power where one or more of the components are missing or are inappropriately resourced.
Challenges of GIS is graphically represented by the right-hand pentagon in the figure includes unskilled workforce, expensive hardware, uneven data cover, lack of policies and expensive software. (Source 24)

(i)Mapping: GIS maps helps to analyze and locate doctor or patients or hospitals. Consequently, GIS-based web portal or applications helps to make suitable decisions and facilitates comprehensive listing of hospitals, the number of healthcare providers and provides a complete framework for exploring health care facilities.

(ii)Tracking of Diseases: In healthcare industry the most remarkable feature provided by GIS is tracking. In case of an infectious disease spreading over a wide range of area, GIS can help to identify and

recognize the probable areas of spread. (Figure 4). [27]

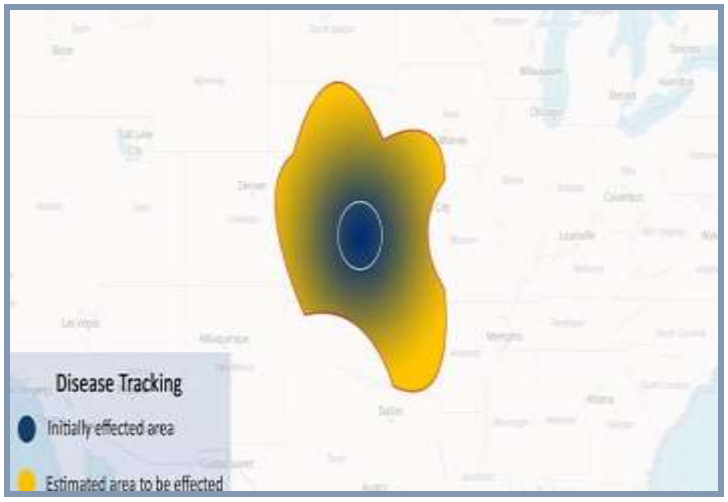

Figure 3: GIS showing diseases tracking (Source 27)

Discovering Health Trends: GIS can predict health related trends, which in turn can provide with public health care target healing endeavor. Consequently, GIS can detect long-term geographic based trends in the health of certain demographics of people.

Improving Healthcare Services: GIS enables in better analyzing, planning, management and delivery of health services after determining healthcare needs of target community. Consequently GIS helps in delivering improved national healthcare services to the community. [26]

Challenges of GIS

Restricted access to GIS infrastructure: One of the major setbacks of GIS technology is the lack of infrastructure. This is attributable to the need for complicated and expensive GIS software, which may be a major set-back for limited resource bound setting. [28]

Technical incompetence and inexperience in GIS technology: Of the numerous challenges, one of the major barriers in GIS, is the requirement of basic to more advanced skills.[29] Many organizations are still deficient in basic technical experts, adequately trained or devoted staff, required to focus on GIS-related programming and planning.[30]

Data unavailability and incompetent analysis: Although geographical information systems in health care has been acknowledged extensively, some experts have lamented the fact that health and population datasets are imported on an ad-hoc basis and as such are not routinely stored or available for analysis. [31, 32]

Miscellaneous: Few other challenges in GIS such as confidentiality and privacy issues, restrictions to data access , data ownership, data outcomes and data inconsistencies could pose a problem in data collection parameters in GI systems.[33] Other factors such as the lack of availability , weak management of health data and the lack of maps of spatial behaviors observed between supply and demand could be the notable hindrances of GIS based healthcare planning process .[34]

Recommendations/Solutions for GIS based healthcare planning

Certain Approaches and suggested solutions that could eliminate the challenges could be:

- Use of GIS software which are open sourced and are user-friendly, and using structured query language (SQL) algorithm packages analogous to the available commercial alternative. [29]
- Sustained use and maintenance of GIS resources by local capacity building, training, motivating and adroit planning.[35]

- Make data available and accessible at a global level by developing global repositories of data collection tools and by establishing standardized format for data collection and storage which in turn will facilitate data sharing through existing international collaborative approaches.
- Engaging local experts (scientists, engineers, academics) in framing long term sustainable solutions for development and knowledge transfer and up-skilling of local staff.[24]
- Effectiveness and appropriateness of geospatial methods should be identified with the help of rigorous research. In addition, the effect of spatial decision support systems on disease control and disease elimination should be analysed and assessed by setting-up a formal framework . [36]
- At present many countries currently lack GIS- based health information systems. Expanding its collaboration with partners like the WHO GIS Centre will help in making an immediate and lasting public health impact.
- Geospatial solutions for health include advancing the use of GIS in earth observation and remote sensing data for health-related SDGs. It also provides core capacity building for governments, WHO country offices, and technical departments.[7]
- Health-related behaviour differs across geographic settings and thereby public health policy should be tailored to suit such variations. A repeated model based on stratified subsets of data can help policy makers and researchers to identify the variability of results across those areas ,or use of analytical models such as SGWR can help detect spatial non-stationarity.[37]

Indian scenario

Geospatial technologies and GIS based approaches are being extensively implemented worldwide for improving health, but India's adoption of these approaches has been dilatory. The adoption and use of digital spatial methods for health in India has lagged somewhat compared to developments in technology and science. [38] In India, the major hurdles associated to the use of GIS could be attributed to expensive software and their unavailability at numerous locations; unavailability of micro level data and lack of trained manpower. In India, public health professionals and medical community along with the universities and technology-oriented institutes have adopted geospatial technologies and strategies to address health-related problems. This group, however, is not well equipped and doesn't have access to open spatial data, such as roads, stream networks, and socioeconomic data, and may lack academic training.[39] The provision of these data and a heightened awareness of spatial analysis tools are mandatory for planning, budget allocation and resource management for a better response to India's health challenges. In India, the "Computer Aided Utility Mapping Project for six cities" is a significant advancement for the GIS users [40] where in 3D Spatial Data Infrastructure with a city wide unified large scale [1:1000] has been developed. At present, the use of Open Source GIS software is gaining popularity in India and is expected to overcome the hindrance of highly priced commercial software. In addition, experts believe that expanding the six city mapping to rural areas will enhance and improve rural healthcare. In addition, fully functional GIS centres well equipped with hard ware, software and spatial data should be established at each state level, all GIS related studies from macro to micro level should be stored and recorded in a national level registry of India.[39]

Future directions

In public health GISs has attained a remarkable place among healthcare professional due to the technological and visualistic information it can offer with regards to analyzing, surveying, monitoring,

planning and allocation of health resources. The spatial behaviors of health care consumers and providers described by conventional models are not suitable for the new "digital" health care landscape. These new spatial behaviors, and their interaction with health which can be studied and modelled in GIS, have high priority for future research and development. [10]

DISCUSSION

In healthcare planning, GIS technologies has contributed efficiently in supporting health professionals in studying and analyzing issues such as health accessibility, health outcomes and health disparities. Prior to the inception of GIS, the spatial relationship between health and place was a major issue in the field of healthcare. The recent trends in healthcare shows that the most salient hindrances are disease surveillance, disease mapping, the evaluation of the accessibility and utilization of healthcare, epidemiological modeling and health information management, as well as location allocation modeling for healthcare services. Geographic researchers and spatial planners should focus on development of GIS-based applications and analytical approaches to analyze and prevent their spread, and to assess disparities in access to healthcare. GIS by means of its analytical approach and statistical method has contributed in the field of healthcare planning. However, GIS-based healthcare approaches, faces a number of major barriers such as restricted GIS-infrastructure and technical capacity, limited data availability and analysis incompetence. With ongoing public health challenges, and developing innovative technologies, the adoption of geographic information based health policies has a great potential for both success and favorable public health outcome in the near future.

CONCLUSION

The determinants of health status are often correlated and analogous. Establishing GIS-based approaches and programmes can predict and analyze the complexity of web of causation of many health issues. GIS can be used to efficaciously investigate health along with its physical, social and cultural environments. Mapping functions of GIS can be used to plot health attributes for better visualization and understanding of disease trends and for improved modeling of health patterns. At a community level, GIS based healthcare helps in explaining and describing health outcomes, health disparities, healthcare access and how health care service utilization can be improved. GIS can also be used to bring all spatial data under one umbrella of "Geo Data Bank" that could provide effortless accessibility and help in better utility of healthcare services. In addition, GIS holds the future possibility of creating virtual communities whose populations and health can be modelled which has a great prospective in the coming years.

Declaration by Authors

Ethical Approval: Not Applicable
Acknowledgement: None
Source of Funding: None
Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Moreira RF, Nico LS, Tomita NE. The relation between space and collective oral health: for a georeferenced epidemiology. Cien. Saude Colet. 2007;12(1): 275-84.
2. Antunes JLF, Frazão P, Narvai PC, Bispo CM, Pegoretti T. Spatial analysis to identify differentials in dental needs by area-based measures. Community Dent. Oral Epidemiol. 2002; 30: 133-142.
3. Stela M. Pereira, Ambrosano GMB, Cortellazzi KL, Tagliaferro EPS, Vettorazzi CA, Ferraz SFB et al. Geographic Information Systems (GIS) in Assessing Dental Health. Int. J. Environ. Res. Public Health 2010; 7: 2423-36.
4. GIS and Public Health at CDC | cdc.gov GIS and Public Health at CDC | cdc.gov (accessed on 1 January 2023).
5. Barbara AG. Integrative literature review: A review of literature related to geographical information systems, healthcare access, and

health outcomes. Perspectives in Health Info. Management 2008; 5(11): 1-13.
6. Wang F. "Inverted Two-Step Floating Catchment Area Method for Measuring Facility Crowdedness."Professional Geographer 2018; 70: 251–60.
7. GIS, geospatial solutions for health, Geographic Information System, Storymap, GIS Center (who.int) (accessed on 1 January 2023).
8. Graham AJ, Atkinson PM, Danson FM. Spatial analysis for epidemiology. Acta Trop. 2004; 91: 219-25.
9. Ruankaew N. GIS and epidemiology. J. Med. Assoc. Thai 2005; 88:1735-38.
10. McLafferty SL. GIS and health care. Annu. Rev. Public Health 2003; 24:25–42.
11. Peters G, Hall GB. Assessment of ambulance response performance using a geographic information system. Soc. Sci. Med. 1999; 49:1551–66.
12. Goodman D, Fisher E, Stukel T, Chang C. The distance to community medical care and the likelihood of hospitalization: Is closer always better? Am. J. Public Health 1997;87: 144–50.
13. Haynes R, Bentham G, Lovett A, Gale S. Effects of distances to hospital and GP surgery on hospital inpatient episodes controlling for needs and provision. Soc. Sci. Med. 1999;49: 425–33.
14. Joseph A, Phillips D. Accessibility and Utilization: Geographical Perspectives on Health Care Delivery. New York: Harper & Row. 1984.
15. Fortney J, Rost K, Zhang M, Warren J. The impact of geographic accessibility on the intensity and quality of depression treatment. Med. Care 1999; 37:884– 93.
16. Haynes R, Gale S, Mugford M, Davies P.Cataract surgery in a community hospital outreach clinic: patient costs and satisfaction. Soc. Sci. Med. 2001; 53:1631–40.
17. Ricketts T, Randolph R, Howard H, Pathman D, Carey T.Hospitalization rates as indicators of access to primary care. Health Place 2001; 7:27–38.
18. Khan M, Ali D, Ferdousy Z, Al-Mamun A. A cost-minimization approach to planning the geographical distribution of health facilities. Health Policy Plan 2001;16: 264–72.
19. Moller-Jensen L, Kofie R..Exploiting available data sources: location/allocation modeling for health service planning in rural Ghana. Geogr. Tidskr 2001; 101:145– 53.
20. Tanser F, Hosegood V, Benzler J, Solarsh G. New approaches to spatially analyze primary health care usage patterns in rural South Africa. Trop. Med. Int. Health 2001; 6:826–38.
21. Wong D, Meyer J. 1993. A spatial decision support system approach to evaluate the efficiency of a meals-on-wheels program. Prof. Geogr. 45:332–41.
22. Rai PK, Nathawat MS. GIS in Healthcare Planning: A Case Study of Varanasi, India. Forum geographic 2013; XII(2) :153-63.
23. Derekenaris G, Garofalakis J, Makris C, Prentzas J, Sioutas S, Tsakalidis A. Integrating GIS, GPS and GSM technologies for the effective management of ambulances. Comput. Environ. Urban Syst. 2001; 25:267–78.
24. Fletcher-Lartey SM, Caprarelli G. Application of GIS technology in public health: successes and challenges Parasitology 2015; 1-15.
25. Njau, JD, Stephenson R., Menon, MP, Kachur SP, Mcfarland, DA. Investigating the important correlates of maternal education and childhood malaria infections. The American J Trop. Med. Hygiene (2014); 91: 509–19.
26. Schneider M, Aguilera X, Barbosa DSJ, Najera AS, Brooker S. Elimination of neglected diseases in Latin America and the Caribbean: a mapping of selected diseases. PLoS Neglected Trop. Diseases 2011;. 5(2), e964.
27. GIS in Healthcare Industry - Mapping, Tracking, Discover - (igismap.com) (accessed on 1 January 2023).
28. Bergquist R., Rinaldi L. Health research based on geospatial tools: a timely approach in a changing environment. J Helminthology (2010);84:1 –11.
29. Caprarelli G, Fletcher, S. A brief review of spatial analysis concepts and tools used for mapping, containment and risk modeling of infectious diseases and other illnesses. Parasitology 2014; 141: 581–601.
30. Boulos M. Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom. Int. J Health Geographics 2004; 3: 1.
31. Mcgeehin M, Qualters J, Niskar A. National Environmental Public Health Tracking

Program: bridging the information gap. Environ. Health Perspectives 2004; 112:1409–13.
32. Beale L, Hodgson S, Abellan JJ, Lefevre S, Jarup L. Evaluation of spatial relationships between health and the environment: the rapid inquiry facility. Environ. HealthPerspectives 2010; 118:1306.
33. Mclafferty S. GIS and health care. Ann. Reviews Pubic Health 2003; 24: 25 –42.
34. Khashoggi BF, Murad A. Issues of Healthcare Planning and GIS: A Review Int. J. Geo-Inf. 2020; 9,352 1-27
35. Ramasubramanian L.GIS implementation in developing countries: learning from organisational theory and reflective practice. Transactions in GIS 1999; 3:359–380.
36. Clements AC, Reid HL, Kelly GC Hay SI. Further shrinking the malaria map: how can geospatial science help to achieve malaria elimination? The Lancet Infectious Diseases 2013; 13: 709–18.
37. Wang F. Why public health needs GIS: a methodological overview. Ann. GIS 2020; 26(1):1–12.
38. Ruiz1 MOH, Sharma AK. Application of GIS in public health in India: a literature-based review, analysis, and recommendations. Indian J Public Health 2016; 60(1):53-8.
39. Joshua V, Elangovan A , Selvaraj V , Ahluwalia TP, Mehendale S.Public health & GIS: Views & opinions of Indian users. Indian J Med Res, August 2012:299-300.
40. Geospatial word forum. Dimensions and directions of Geospatial Industry, 18-21 January 2011 held at Hyderabad. Computer Aided Utility Mapping Project. Available from: http://www.geospatialworldforum.org/2011/ proceeding/pdf/ Mahalakshmi.pps (accessed on December, 2022).

How to cite this article: Shahina Yasmin, Archana Krishna Murthy, Shilpashree KB et.al. Geographic information system (GIS) and healthcare: an overview. *International Journal of Research and Review*. 2023; 10(2): 286-294. DOI: *https://doi.org/10.52403/ijrr.20230236*

******