29. GIS in Health and Human Services

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The chapter begins with a general overview of how GIS has evolved in the health and human services over the last several decades providing readers with important definitions and descriptions (Sects. 29.1, 29.2). Sections 29.3, 29.4 uncovers how GIS became an important tool for epidemiologists in the work of tracking infectious diseases and perfecting the study of population health. Readers will also learn that GIS adoption by hospital marketers and planners in the United States accelerated rapidly after the 1970, when US Census data became relatively freely available in digital form. The importance of the legendary work of the Dartmouth Health Care Atlas Project and its founder Jack Wennberg. In areas where high GIS adoption rates occurred, such as in public health, we feature key applications such as immunization management, disease tracking, outbreak analysis, disease surveillance, syndromic surveillance, emergency preparedness and response, community health assessment, environmental health, chronic disease prevention, and animal and veterinary health. The final Sect. 29.5 describes how GIS education has expanded across the academic fields of public health, healthcare administration, and social services. It is pointed out that the material presented in this chapter is not intended to be an exhaustive examination of the history of GIS, but rather, a brief introduction and overview which will generate further interest and self-discovery.

The increasing utilization of Geographic Information Systems (GIS) technology over the past several decades has transformed health and human services (HHS) and given *new eyes* to public health professionals, researchers, and hospital and health system employees – as well as the public they serve. While maps and spatial analysis have a long history in the field of health and human services, the early 21st century is a time when health professionals and the public have many powerful spatial analytic tools at their disposal. This chapter begins with definitions of health and public health (Sect. 29.1), followed by a brief history of geography and GIS in health and human services. It provides numerous examples of health and human services challenges and how GIS benefits them. The chapter includes a special focus on GIS for several specific disease programs. It concludes with a summary of GIS in HHS education. Overall, it takes a selective approach due to space limitations.

29.1 What Is Health?

Everyone agrees that health is important, but what is health? Shortly after World War II, the World Health Organization (WHO) defined health as *a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity* [29.1]. This holistic view incorporates total well-being under the concept of health. Over the years there has been debate over what should be *in* and what should be *out*, but in practice it has been a challenge to measure the current WHO definition of health due to its broad scope. While the world has an International Classification of Diseases (ICD) [29.2] it does not yet have an international classification of health. So while nations have agreed how they will classify diseases and other health problems, and the ICD provides a basis for national health statistics that can be compared across nations [29.3], in the early 21st century there is not yet a worldwide system for measuring health.

No matter how governments and organizations may define health (positively or negatively, holistically or narrowly), improving health appears to be a universal priority. Several decades after WHO formulated the above-referenced definition of health, the Lalonde Report (a working paper from Canada's Minister of Health and Welfare) made quite an impact on the global health community. It noted that most of society's efforts and expenditures to improve health had been focused on health care organization. Yet, analysis revealed that the main causes of sickness and death in Canada were rooted in three other elements: human biology, environment, and lifestyle [29.4]. The paper urged society to reconsider spending vast sums of money *on treating diseases that could have been prevented in the first place* and introduced a framework of four broad determinants of health.

1. Human biology
2. Lifestyle
3. Environment
4. Health care organization.

The Lalonde report recognized that the existing health care delivery system could do *little more than serve as a catchment for the victims* of the other three determinants. It propelled the field of health promotion and influenced many significant initiatives to prevent morbidity and mortality from the major determinants of health (highlighted later in this chapter).

29.1.1 What Is Public Health?

Defining public health is also a difficult task. *Winslow*, one of the leading figures in public health history, defined public health in 1920 as [29.5]:

> *... the science and art of preventing disease, prolonging life and promoting health and efficiency through organized community effort for the sanitation of the environment, the control of communicable infections, the education of the individual in personal hygiene, the organization of medical and nursing services for the early diagnosis and preventive treatment of disease, and for the development of the social machinery to insure everyone a standard of living adequate for the maintenance of health, so organizing these benefits as to enable every citizen to realize his birthright of health and longevity.*

Other definitions have been proposed over the years, but Winslow's has stood the test of time. Two key differentiating factors between public health and clinical medicine are

1. Public health focuses on prevention (as opposed to *sick care*).
2. Public health takes a community or population-based approach, instead of focusing at the individual level.

The *organized community efforts* and *social machinery* in Winslow's definition include not only governmental public health agencies at the national and local levels, but also a broad array of non-governmental organizations (NGOs – aka civil society), universities, and other partners.

29.2 A Brief History of Geography and GIS in HHS

Merriam–Webster defines geography as [29.6]:

> *a science that deals with the description, distribution, and interaction of the diverse physical, biological, and cultural features of the earth's surface.*

One of geography's subdisciplines is medical geography, which [29.7]:

> *focuses on patterns of disease and death – of how diseases spread … and how variations in morbidity and mortality rates reflect the local environment.*

A recent editorial in the *Journal of the American Board of Family Medicine* [29.8] reminds us that as early as 400 BC, Hippocrates said that one's health depends on the air one breathes, the water one drinks, and the environment in which one lives [29.9]. In this sense, geography has always been a part of individual health – and public health. Maps and mapmaking have helped the medical and public health community understand the role of geography in outbreaks and pandemics of plague, cholera, typhoid, malaria, and numerous other infectious diseases. The study and control of epidemic spread at a variety of appropriate scales is inherently geographical [29.10]. Maps and mapmaking have also helped health officials and researchers analyze and understand chronic diseases such as cancer and heart disease, which represent a growing disease burden in developed nations as well as low-income countries. Whether one is looking at electronic web-based maps and globes portraying the recent H1N1 pandemic … or a 1694 map of plague … one thing is clear. Depending on the mapping and spatial analysis capabilities of the time and place, public health and medical professionals have utilized geography in their work. More recently geography is becoming embedded in routine business processes of health and human services organizations (e.g., route planning for a fleet of vehicles).

In *Cartographies of Disease Koch* describes many interesting chapters in history of medical geography, both before and after *Finke*'s *Medical Geography* [29.11, 12]. The formal discipline of medical geography started as early as 1792 … Koch suggests that mapping and mapmaking *let us study the interpretations of selected aspects of spatially grounded, interrelated processes.* [29.11, p. 6]. As we think about classes of discrete events (e.g., people with specific illnesses or symptoms) in the context of potentially relevant data (e.g., location, income, exposures) we are better informed to demonstrate or disprove a causal relation [29.11, p. 5].

Most of the works *Koch* describes in [29.11] are not simply disease maps, but rather *mapped arguments about disease incidence and the environments that produced it* [29.11, p. 31]. The maps listed in Fig. 29.1 range on a continuum from descriptive to highly analytic. Some maps were trying to analyze the root causes of a local outbreak of disease at the scale of neighborhood or local jurisdiction; other maps were charting the progression of a disease around the world. Some maps were showing risk for a particular disease based on known causes (e.g., malaria and mosquitoes), others were showing the distribution of a particular disease at a national level (e.g., cancer). It is very clear from Koch's work that the history of medical mapping is tied not only to advancements in medical science and public health, but also to advancements in the technology of mapping.

Much attention in the history of medical geography has been focused on John Snow, the *father of epidemiology*. Snow mapped the relative density of cholera deaths in relation to water sources, as part of a process identifying the infamous Broad Street pump (Fig. 29.2) as a likely source of contaminated water [29.13]. Koch reminds us that this work by Snow was part of a larger movement for better statistical and graphic analysis – which culminated in a series of extraordinary studies of cholera outbreaks in the 1850s, including the work of Snow (p. 38). While Koch focuses significant attention on John Snow, he also describes many other chapters in the history of medical geography, before and after the 1850s, and beyond London. Reading this history, it becomes clear that over the last few centuries mapping has helped physicians, sanitarians, boards of health, and high level health officials (such as the Surgeon General of the United States) contain disease outbreaks and understand the worldwide spread of a disease. However, perhaps more provokingly, Koch makes the case that *maps and spatial analysis were critical in establishing the notion that public health was in the public health*

1700
1694 map of plague in Bari, Italy
1792 Finke's *Medical Geography*
1800
1798 map of yellow fever in New York City
1819 map of yellow fever in New York City
1821 map of typhoid fever in New York City
1820s mapmakers add demographic data to map surface in an attempt to determine the nature of disease outbreak
1832 map of progress of cholera around the world
1832 map of cholera in Exeter
1836 map of cholera in Hamburg, Germany
1840 map of hernias in France (good example of medicostatistical mapping)
1841 map of sanitation in Dublin, Ireland
1850 map of cholera in London
1854 map of cholera in South London
1854–55 numerous maps of cholera in Soho
1856 world map of health and disease
1875 maps of cholera in New Orleans, Memphis, Nashville and USA
1876 map of cholera in East Africa
1878 map of offensive odors in Boston, MA
1885 maps of typhoid in Plymouth, PA
1885 map of sever outlets in Harrisburg, PA
1886 map showing distribution of population in State of Pennsylvania (in first annual state report on health)
1892 map of smallpox epidemic in Western Australia
1892 map of the distribution of cancer in British counties
1900
1901 maps from Sedgwick's *Principles of Sanitary Science and the Public Health*
1925 map of sandfly fever in Peshawar, India
1950s maps from the Welt Seuchen Atlas
1960 map of cancer in Horrabridge, England
1961 maps from May's *Studies in Disease Ecology* (including world distribution of important malaria vectors, and a worldwide schematic of plaque foci)
1960s maps of the death rate in England
1962 map of Burkitt lymphoma in Africa
1969 map of schistosomiasis in South America
1971 maps of influenza in England
1972 map of bronchitis in Leeds
1977 map of hepatitis in Tasmania
1986 map of influenza in the United States
1988 map of malaria in India
1988 map of leukemia in India
1980s–90s maps of outbreaks of AIDS in Ohio and US
1989 map of HIV in Eastern Tennessee
2000
2000 CDC releases EpiMap to display data from EpiInfo as maps
2002 map of AIDS in Thailand
2002 map of dengue fever in Pennathur, India
2004 map of AIDS in the United States

Fig. 29.1 Timeline of medical geography: Highlights from *Cartographies of Disease* (after [29.11])

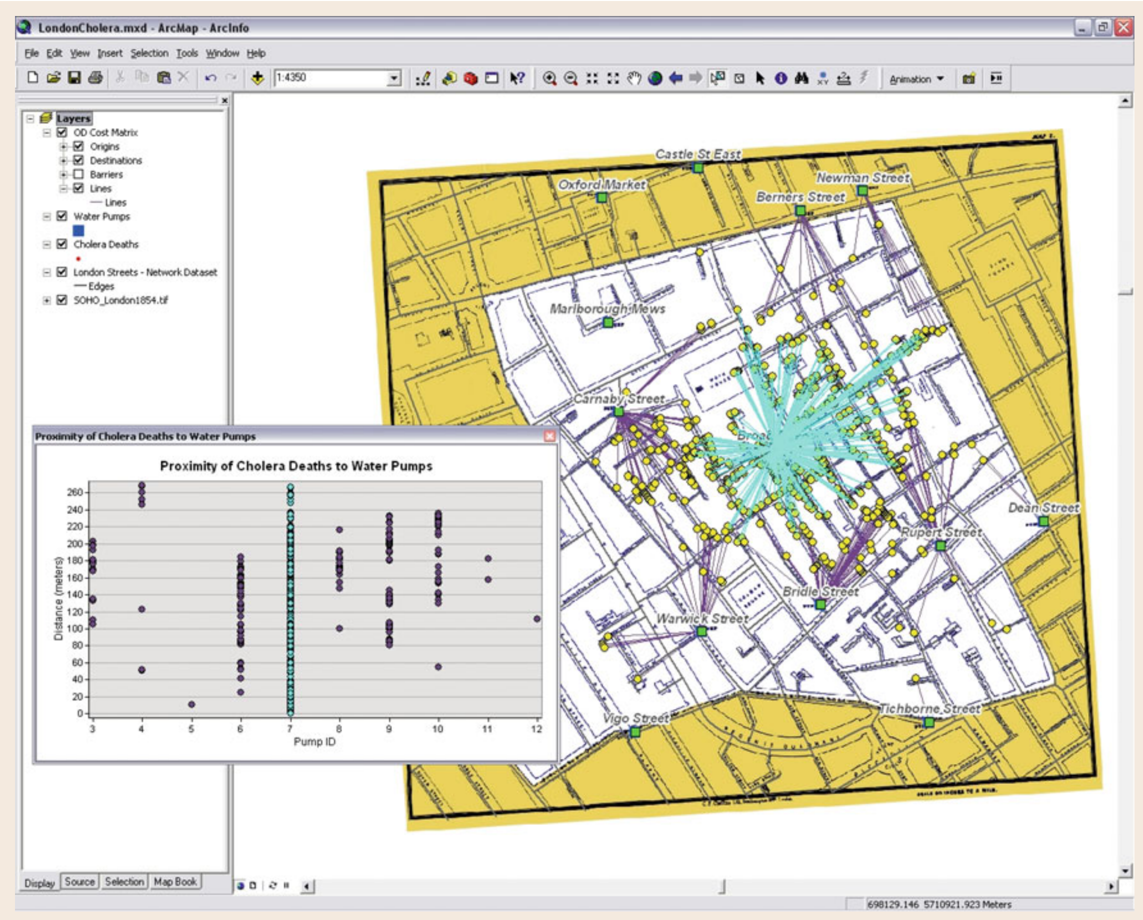

Fig. 29.2 John Snow mapped cholera deaths in proximity to the water pumps in London's Soho district in 1854. His map identified the likely source of the cholera outbreak as the Broad Street Pump. Upon the pump handle's removal, cholera cases tapered off substantially (after [29.14])

interest – hence the rise of public health and sanitary science as a discipline. One notable event in this history is the International Sanitary Conference of 1874 in Vienna. During that conference, maps of the spread of cholera were shared among attendees from many nations, well before the advent of the today's International Health Regulations and the regional and international Health GIS conferences that take place routinely each year.

29.2.1 The Early Years of GIS in Health and Human Services

In 1970 *Cline* commented that aerial photography was already in use by some epidemiologists for demographic purposes, the selection of random or systematic population samples, and to describe study areas [29.15]. He rightfully predicted that there would be future uses of remote sensing techniques within epidemiology. Aerial photography had been used in the past to identify and map disease vector habitats (e.g., as early as 1949 when *Audy* published a study on the distribution of scrub typhus in parts of Southeast Asia [29.16]). Much of this work was manual in nature and the advent of GIS technology over the intervening decades facilitated many epidemiological investigations that would have not otherwise been possible.

The launch of ERTS-1 (Earth Resources Technology Satellite) in 1972 provided the first opportunity to acquire global remote sensing data on a regular basis [29.17]. Through the 1970s and 1980s there were an increasing number of research projects utilizing remote sensing and GIS to investigate the epidemiology of diseases. In 1990 Louisiana State University (LSU) hosted the first International Conference on Applications of Remote Sensing to Epidemiology and Parasitology. LSU has become a collaborating center of the WHO in this field.

One of the first uses of GIS in hospitals occurred shortly after the release of the 1970 Census of Population in the United States. The US Census raw data was not available to the general public before 1970. However, in 1970, the US Census Bureau granted public use access to its raw data collection. This meant that for the first time, researchers and commercial entities could work with relational data for small geographic areas such as ZIP Codes, census tracts, and block groups. By liberating the finely grained census data, health and human services organizations were able to begin to use the population data at the local levels.

Around the same time, the US Census Bureau released two important products that would forever change the way GIS or computer mapping programs would be focused. The programs were called Admatch and DIME. Admatch was a computerized address management program that would link a street address to a specific geography; DIME was a master reference file called the Dual Independent Map Encoding. The combination of these two programs ushered in the first *industrial* strength geocoding technology (as we call it today), which is one of the central components of a modern-day GIS. However, one must remember that approximately 40 years later (i. e., in 2010) similar address level geocoding is still not available in many countries of the world.

In early 1973, the Ford Foundation Fund granted a non-profit organization called DUALabs (a data-use access laboratory) the resources necessary to understand how the Census Bureau's raw data tapes could be disseminated in a useful and efficient way. The DUALabs legacy was that it provided a business model for most of the commercial demographic companies in the USA and paved the way for mapping census data. Clearly without the release of the public use files of the US Census of 1970, the commercial mapping industry of the USA would have been significantly smaller and would have taken much longer to become an established way to analyze geographic and demographic data.

In 1973 *Davenhall* et al. [29.18], using the software and data products available from the US Census Bureau, created the first patient distribution map of emergency room patients from St. Joseph's Hospital in Lexington, Kentucky. Creating the map required the use of the DIME file, the Admatch program, and the master patient history file from the hospital processed by an IBM 360 mainframe computer. Fortran was used by a programmer for a six-month period to produce what was known as a dot density map in black and white depicting the dossier of patients in various small areas of the Lexington metropolitan area. The current value of the project in today's dollars would be about $ 250 000. The one map that was created from taping about 30 8 1/2″ by 11″ sheets of paper was used by the hospital management to make an important decision in that community concerning expansion of the emergency room. In the course of the decade of the 1970s, great strides were made in the use of demographic and geographic data across a wide range of private and public interests, continuing to improve every aspect of GIS data and software use in the health and human services sector.

In the second half of the 1970s the US Department of Health and Human Services (DHHS) sponsored a major demonstration and research project in Jefferson County, Kentucky, called Human Service Coordination Alliance (HSCA). The HSCA project had as its goal service integration on a massive community scale – across several geographically contiguous counties in Kentucky serving the Louisville metropolitan statistical area (MSA) – a population of just over 1 000 000 people. The project consumed large amounts of agency service data, including beneficiary demographics, service delivery characteristics, and service performance measures. GIS (called computer mapping) was introduced into the project to illustrate the various market segments being served, as well as to provide visual communication of patterns and trends to health services agency leadership. The project included every concurrent human service activity from nutrition service to family service to personal addiction therapy.

More Affordable Software and Data

Through the 1980s, there was an explosion of relatively moderately priced software and data packages and services created by both public and private organizations to exploit the extensive data offering of the US Census. These new tools and data services greatly expanded the assessment (i. e., sensory) capacities of epidemiologists, as well as public health planners, environmental health professionals, monitoring and evaluation specialists, hospital marketing departments, and many others.

Graduating from Innovative to Standard Practice

In 1990, the Agency for Toxic Substances and Disease Registry (ATSDR – a sister agency of the Centers for Disease Control and Prevention (CDC) began using GIS to evaluate the demographic characteristics of populations around sites, identify features in the community that were relevant to the protection of populations, monitor health-related data and health complaints by community members, and overlay contaminant distribution with census data to characterize subpopulations that might be potentially susceptible to site contaminants due to their age, sex, race, or socioeconomic condition [29.19]. CDC's use of GIS expanded over time beyond ATSDR to the National Center for Health Statistics (NCHS) and many other centers, institutes, and offices within the agency.

Throughout the 1990s, health and human services organizations were able to acquire low-cost software and data bundles, which provided an attractive analytical solution. Public health agencies, hospitals, and social service agencies began to purchase these bundles and incorporate geographic thinking into the operational activities – largely at the desktop computer level.

The anthrax attacks and events of September 11, 2001 in the United States accelerated the CDC's and HRSA's nascent public health emergency preparedness programs as well as these agencies' cooperative agreements with state and local health departments across the USA. Given increased resources and responsibilities, health departments hired more epidemiologists and deployed robust information technology to support public health preparedness and response. Many health departments recognized the capabilities of desktop GIS software for public health preparedness. This was also the time frame during which both robust internet mapping software and mobile GIS software (e.g., ESRI's ArcPad) were launched. Well before the advent of applications such as GoogleEarth, federal health agencies such as CDC and HRSA, as well as numerous state and local health departments, began publishing internal and public web-based data query systems (i. e., interactive health atlases) and web-based services locators. These agencies also enhanced electronic disease surveillance systems, immunization registries, and cancer registries with mapping and spatial analysis capabilities. However, it would take another decade for web-based situational awareness systems to emerge as standard practice.

29.2.2 The Early Adopters

As indicated in the above-referenced paragraphs, there were a number of different early adopters of GIS in health and human services, including epidemiologists, biostatisticians, vector control professionals, environmental health professionals, hospital planners, and human services professionals, among others.

Epidemiologists, the disease detectives of public health, saw the potential for GIS software very early since they consider the triad of person, place, and time in their investigations and analyses. Epidemiologists are responsible for responding to disease outbreaks, as well as other community health problems. Early on, they used GIS to collect data, geocode it, and then analyze the data – often as the result of a disease outbreak or a poorly understood community health problem. Having all this data in a GIS helped them understand disease diffusion as well as to provide situational awareness to leadership (often through static maps) so decisions could be made regarding where resources needed to be deployed. GIS also provided analytical tools for exploratory analysis of potential sources of outbreaks. Static maps produced through GIS software showed study areas for epidemiological research papers and presentations. For most of these purposes, GIS has been viewed as an analytical tool that served a narrow slice of the overall public health functions.

Biostatisticians working on large datasets (e.g., cancer registry) also appreciated the capabilities of GIS for data management, analytical functions, and visual display/reporting. Biostatistics is a branch of applied statistics and is concerned with developing and using techniques to summarize and analyze medical and biological data [29.20]. Biostatisticians are responsible for analyzing data and designing research studies. Early on, they used GIS to geocode data and then analyze large datasets – proactively looking for clusters or other spatial (aberrations) and also responding to calls for investigations. Biostatisticians have also used static maps produced through GIS software to share visualizations of their work with colleagues and the public.

Environmental health professionals, responsible for inspections and data collection covering large geographies – such as those working in vector control – saw the applicability of not only desktop GIS, but also mobile GIS. Such programs (sometimes independent of public health agencies) have workflows that are inherently geographical. Vector control staff were some of the first to use mobile GIS on a routine basis. Environmental health professionals use desktop and mobile GIS to manage large inventories of facilities and sites under regulation ... and also to meet numerous regulations (i. e., an assurance function).

Individuals working in the marketing and planning departments of hospitals also recognized how GIS could help them analyze service/catchment areas and locate best sites for new services. In social services, information technology staff had the vision that helping case managers see the client in the context of their environment would help them actualize the core functions of social work.

The vignettes mentioned before highlight some of the pioneers, but today the story is vastly different. Most health departments in the USA and a growing number around the world, use GIS in their daily work – and it is not just epidemiologists searching for clues to difficult outbreaks or biostatisticians working on disease registries. Public health professionals use GIS to analyze chronic disease trends (e.g., heart disease, diabetes, cancer), analyze access to public health services (e.g., vaccinations), analyze the built environment, respond to natural and man-made disasters, and design community health communications programs. While there is still a heavy desktop GIS presence in health departments, increasingly it is also found residing within an organization's IT department supporting web-based applications (both internal and public-facing). The most recent GIS servers allow GIS functionality to be deployed on mobile devices across the entire organization, so it is expected that not only vector control but also many other field-based programs will move in this direction.

29.2.3 GIS Starting in Hospitals

In hospitals, GIS gained acceptance in the early 1990s as an essential analytical tool for strategic planning and marketing, largely in the USA. Analytical studies of patient origins and resident destinations, health facility site locating, and market demographic analysis headed up the list of most useful applications. Also, many hospitals hired marketing and planning consultants who could bring the mapping tools and demographic tools with them. As hospitals came under greater pressure to slow the cost increase largely through reduction in work force in *non-essential* departments, computer mapping and demographic analysis were outsourced to large consulting firms. The deployment was almost exclusively desktop, and seldom was GIS part of an enterprise approach to IT.

It is worth noting the use of GIS by public health and hospitals has been inextricably related. The hospital is still a large data generator for public health, while public health is a hospital's single most consumer of its complete data collection. Without each other's contributions of data and analysis, the adoption of modern GIS would have been seriously compromised. While hospitals in the USA are often not that close to the philosophical underpinning of public health, outside the USA this artificial separation is almost non-existent. In the decades ahead a greater synergistic relationship between those in acute care and those in prevention will drive greater utilization of GIS as resource allocation, community accessibility, and government accountability increase. There are many good examples of this data and analytic synergy, as highlighted in the following scenario.

An emergency room physician is exasperated by the number of motorcycle and traffic-related injuries coming through the hospital's emergency room. This physician, in collaboration with injury prevention staff at the health department, obtains traffic accident reports from the department of transportation, geocodes all the locations of incidents and conducts several analyses (e.g., density analysis). Based on the results, the physician and public health department agree on several possible interventions – such as traffic calming measures, other road safety improvements, and an education campaign. In this scenario, GIS is a tool for the analysis, and the maps that are the outputs of the analysis serve as an advocacy support tool.

Perhaps the best example of the data and analytic synergy GIS provides between hospitals and public health can be seen in the seminal work of the Dartmouth Clinical Evaluation Research Center, in conjunction with the Dartmouth Medical School (covered in detail in the following section).

29.3 Geography Is Destiny in Health

According to Goodman, *geography is destiny in health*. This quote is based on years of experience analyzing data from the Dartmouth Atlas of Health Care. Beginning in 1973, *Wennberg* and colleagues began studying small area variations in health care delivery [29.21]. Since then, Dartmouth researchers have been studying the differential utilization, cost, quality, and outcome of health care delivered to medicare beneficiaries across the USA. Focusing on small area analysis, Dartmouth researchers began to use census data at very small geographic levels to examine the patterns in medical claims data, principally from hospital utilization. This legendary research began with a geographic promise – that somehow the variations in how health care was delivered, priced, and evaluated varied by where it was taking place. According to *Goodman* [29.22]:

> *unwarranted variation in health care is variation that cannot be explained by patient illness, dictates of evidence-based medicine, or patient preference*

and

> *unwarranted variation is caused by differences in the effectiveness and efficiency of health care delivery systems...*

This body of research subsequently has come to help explain the wide variability in geographic terms so that local interventions would be encouraged and government policy could be used to alter the most undesirable effects of the health system [29.26]. The study of small area variations in health care has become a priority in Europe, and is one of the components of the ECHO Project (extension for community healthcare outcomes) [29.27].

Table 29.1 Determinants of health and their relation to GIS

Geographical feature	Determinant of health	Applicability of GIS
Biology	Human biology	Mapping genetic variations (Fig. 29.3) Mapping the human body [29.23, 24]
	Animal/plant biology	Remote sensing Controlling vector-borne disease Mapping food availability
Cultural	Lifestyle	Behavioral risk factor mapping Targeting health promotion Segmentation analysis *Place* studies
Physical	Environment	Investigating toxic exposures Controlling vector-borne disease Analyzing the built environment Analyzing the food environment
	Health care organization	Analyzing accessibility of health care services Routing vehicles Workforce studies Hospital-acquired infections Bed management Laboratory services

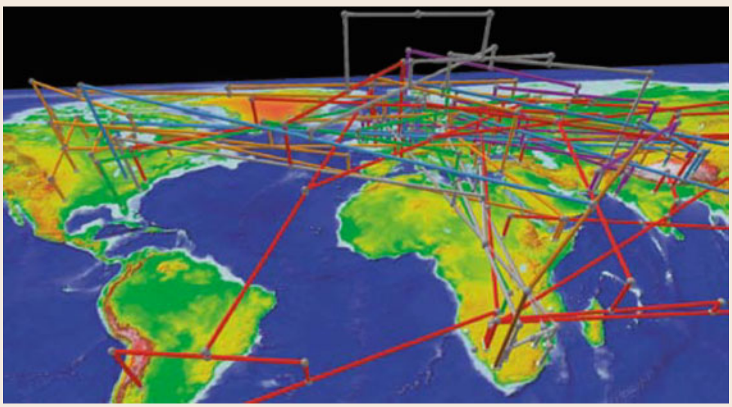

Fig. 29.3 This example depicts the global distribution of *Bacillus anthracis* (the bacteria that causes anthrax). Matching anthrax strains are geographically connected (after [29.25])

29.3.1 Growth of GIS in Health and Human Services

There are many drivers for the growth of GIS in health and human services, as detailed earlier in this chapter. Given the recent increased policy interest in the social determinants of health, it is worth discussing how GIS aids in the analysis of the four determinants of health referenced by *LaLonde* [29.4] several decades ago. Table 29.1 describes this notion at a high level. It is not meant to be a comprehensive catalog, but just to make the point that the major geographical features of the earth's surface (physical, biological, and cultural) mesh well with the determinants of health (human biology, lifestyle, environment, and health care organization).

Over the past 15 years many leading health organizations, including WHO, World Bank, US Agency for International Development (USAID), and CDC have acknowledged the utility of mapping and spatial analysis in tackling some of the world's greatest health problems including the HIV/AIDS pandemic, malaria, tuberculosis, maternal and child mortality, and other devastating diseases. The majority of ministries of health (MOH) around the world, and all 50 state health departments in the USA have leveraged geographic information systems to assess and protect the health of the populations they serve. According to *Miranda* et al. [29.28]:

> *Many GIS-based projects have been successful in supporting public and environmental health practice, including those investigating toxic exposure, vector-borne disease, health information access, and the built environment.*

WHO states that GIS [29.29]

- Allows policy makers to easily visualize problems in relation to existing health and social services and the natural environment and so more effectively target resources.
- Is highly suitable for analyzing epidemiological data, revealing trends and interrelationships that would be more difficult to discover in tabular format.
- (Is an) ideal platform for the convergence of disease-specific information and their analyses in relation to population settlements, surrounding social and health services and the natural environment.

29.4 GIS Relevance to Public Health

As referenced throughout this chapter, GIS applications have been used extensively in health-related research and practice. This section takes a broader look at many of the major programmatic areas of public health, hospitals, and human service organizations and includes selected examples of the use of GIS to support.

- Immunization
- Disease Surveillance, outbreak Investigation and syndromic surveillance
- Public health preparedness and emergency response
- Community health assessment, planning and profiling
- Environmental health
- Chronic disease prevention and control
- Infectious disease
- Animal health/veterinary health
- Human services case management
- Hospitals and health systems.

This section then provides some additional context and examples of the application of GIS for disease-specific programs in public health.

29.4.1 Immunization

GIS has a long history of providing support in immunization campaigns around the world. Public health officials need to answer questions such as

- What are vaccination rates in this area?
- Where should we concentrate our future efforts (i. e., are there pockets of need)?
- Where are the vaccines available?
- How can we best communicate information with partners and the public?
- Is our vaccination delivery network sufficient?
- Is there any clustering of adverse events?

Public health officials also need to communicate much of this information with partners and the public. Location information is critical to vaccination needs assessments, intervention planning, and visualizing/monitoring results. Following the recent H1N1 pandemic, there has been an increased recognition of the utility of GIS for mass immunizations, better management of vaccine logistics, and the analysis and visualization of adverse events reporting.

Leading public health organizations around the world have validated the utility of GIS for immunization programs. Even in the most resource-constrained settings, WHO and UNICEF have encouraged hand-drawn mapping as a way for health professionals in local facilities and district health officers to understand unmet needs and monitor progress [29.30]. WHO's Regional Office for the Eastern Mediterranean (EMRO) has included GIS in guidance for overall patient safety [29.31]. This *Strategic Plan for Patient Safety* from WHO EMRO suggests GIS can be useful in assessing the scope of patient harm. It suggests MOH develop a GIS system that can capture the geographical and frequency distribution of adverse events *especially when the occurrence can be sporadic*. It suggests the findings of the GIS may highlight the magnitude of some adverse events at the national level. An example from a specific country plan is also available [29.32].

USAID has supported a number of GIS capacity building initiatives around the world that have enhanced vaccination efforts (e.g., Yemen [29.33]). Recently, the USAID-funded project DELIVER project has reviewed ESRI's network analyst for use in developing countries. Their positive review suggests that *all* countries may consider using such solutions to improve delivery and logistics [29.34] of numerous public health programs, including immunization. GIS has also been helpful in analyses of immunization coverage in conflicts, including Afghanistan [29.35]. CDC has piloted a GIS tool for increasing urban vaccination rates in India. That project helped dramatically increase the number of vaccination service centers, and GIS was crucial in managing logistics and personnel [29.36]. Domestically, CDC's immunization program has encouraged state health departments to utilize GIS alongside of immunization registries in order to analyze *pockets of need* (i. e., areas of under-immunization). CDC has also used GIS internally to detect spatio-temporal clusters of adverse reactions to vaccinations [29.37].

Health departments have used GIS applications to track stockpile shipments (including vaccines) in real time [29.38]. GIS has also proved to be a useful analysis tool in the administration of mass vaccination in local jurisdictions [29.39]. According to one presentation, GIS helped a local health department

- Determine who was treated (geocode patient information).
- Determine who needs to be treated (spatial join with population information, calculate vaccination rates).
- Notify those who need to be treated (activate automated telephone reminders in low vaccination rate areas).

29.4.2 Disease Surveillance, Outbreak Investigation, and Syndromic Surveillance

GIS has a long history of providing support to traditional disease surveillance. Most electronic disease surveillance systems now include a mapping module so that analysts and public health leaders can visualize disease outbreaks on the map. When an outbreak is detected and public health personnel go into the field for additional investigation, GIS strengthens local data collection, management, and analysis. From the beginning, GIS provides a baseline for monitoring and evaluating outbreak investigation activities. Mobile GIS allows field personnel to leverage GPS

devices to navigate more efficiently and quickly to locations for data collection. This is critical when time is of the essence. Surveillance of case locations is maintained more effectively, so the geographic progression of the disease is continually monitored. High-transmission areas (e.g., gathering places) or areas with environmental conditions ideal for disease vectors (e.g., standing water) are more easily identified when field staff have maps, imagery, and descriptive metadata at their fingertips.

GIS also facilitates targeting of prevention and control measures based on priority locations. For example, recent research has shown the effectiveness of implementing integrated vector control within a defined distance buffer of known dengue case locations [29.40]. GIS has also proved to be a cost-effective technology for controlling animal outbreaks (e.g., avian influenza) [29.41]. In other outbreak situations, GIS is a valuable tool for designing economically feasible population-based public health investigations (e.g., generating a spatially random sample during rapid needs assessments) [29.42, 43].

Syndromic surveillance systems have been used for early detection of outbreaks, to follow the size, spread, and tempo of outbreaks, to monitor disease trends, and to provide reassurance that an outbreak has not occurred [29.44]. GIS supports syndromic surveillance not only as a visualization aid, but also in detecting abnormalities based on spatial queries. Examples include the use of dead bird reporting to predict West Nile virus in humans, and analyzing chief complaint data from hospital information systems to determine spikes in gastrointestinal or respiratory complaints.

With accurate location information, GIS can provide spatial visualization of complex relationships between cases, contacts, and objects in the environment in both time and space. Spatial visualization helps in identifying disease sources and the best implementation of countermeasure and response strategies.

29.4.3 Public Health Emergency Preparedness and Response

GIS has been used for decades in response to natural disasters such as floods, earthquakes, wildfires, and hurricanes. Following events such as 9/11, the anthrax attacks, and hurricane Katrina, the debate ensued regarding exactly what public health emergency preparedness was and how it should be measured [29.45]. Regardless of one's definition of public health emergency preparedness, it is clear preparedness and response depend on location-based information, such as the location of incidents, where responders are, and where emergency services and health facilities are located. GIS supports emergency preparedness through

- Needs assessments and planning.
- Evacuation route planning.
- Modeling chemical spills.
- Targeting emergency notifications.
- Determining sites for points of dispensing (PODS).
- Enhancing the utility of emergency operations center (EOC) software.

During a public health emergency, there will be dozens, perhaps hundreds, of response efforts going on simultaneously through both the public and the private sectors. Besides helping all responders and those directing them attain situational awareness (by seeing response activities *on the map*), flexibility is one of the most useful features of a GIS. By altering the planning assumptions that are entered into the GIS, public health officials can conduct analyses quickly and efficiently on any issue for which data are available [29.46].

> *Using GIS (including data analysis pre and post mapping) helps to sensibly choose the best places to locate our limited resources in order to improve service to the public that we serve [29.47].*

For disaster planning [29.48]:

> *The analysis revealed many opportunities for improvement and as a result, GIS has now become a pivotal tool in the County's planning process.*

Many public health authorities now have EOCs in order to increase situational awareness, collaborate with other first responders, and mount a more effective response. Increasingly, public health is seen as a first responder like fire, police, and public safety. There are many roles for GIS in health EOCs. The WHO Regional Office for the Western Pacific states that *information is the lifeblood of an EOC* in [29.49]. The guide suggests an action plan should include support-

Table 29.2 Essential and static data layers for a health EOC (Emergency Operations Center)

Essential data layers
• Event locations
• Hospitals and health facilities
• Public health departments
• Shelters
• Schools
• Roads
• Public transportation
• Restaurants and regulated facilities
• Major administrative boundaries
• Census data (especially demographic data, languages spoken, poverty, elderly, etc.)
• Post offices
• Municipalities
• Counties
• Surrounding state counties
Static health layers
• Advanced and basic life support
• Acute and non-acute care hospitals
• Points of distribution
• Blood banks
• RSS medical stockpile locations
• Health departments
• Hospitals from surrounding states
• Long term care facilities
• Command centers

Table 29.2 (continued)

Real time feeds (dynamic layers)
• Incidents/events • Weather/traffic • Medical stockpile • SitStat surveys • Hospital divert status • Ambulance locations
GIS coordinators within EOCs perform essential functions including the following
• Provide situational awareness to leadership and partners • Map real-time spread of incidence / clustering • Determine stockpile pod locations • Locate and identify vulnerable populations • Provide real-time mapping and analysis of vaccine inventory • Monitor bed capacity/surge capacity in hospitals • Help infected people locate treatment • Facilitate mobile response and routing, especially in rural areas • Identify gathering areas in high cluster areas • Call up volunteers and staff by location • Map distribution of care providers

ing materials such as a map of the event area; and the checklist of recommended equipment and supplies also includes maps and aerial photos. In any emergency response, the EOC will ask many *where* questions.

1. Where are the incidents? Where are they headed (e.g., wildfires, storms, chemical spills)?
2. Where are the people at risk?
3. Where are the health assets (fixed, such as hospitals and clinics)?
4. Where should we send our employees (e.g., during H1N1, the EOC at CDC in the USA coordinated the deployment of 1100 CDC employees [29.50])?
5. Where are the mobile healthcare resources (e.g., ambulances) and other first responders?

Health departments have begun leveraging GIS as part of their EOCs, some developing stand-alone applications [29.51] and others using GIS in conjunction with products such as WebEOC.

Some data layers are event-specific, while others tend to be important regardless of the scenario. Examples of data layers more specific to the type of event include first responder locations (e.g., real-time feeds re ambulance or helicopter locations), hospital diversion status, flood plain/zone boundaries, the extent of smoke plume (wildfires), electrical utility information, POD locations, etc. Many health agencies have reinforced how important it is to be able to determine neighborhood level population estimates during emergencies. It is worth noting that many of the *essential data layers* should not need to be collected from scratch. . . , rather, many are available already within the health department or from other governmental agencies. Some are likely to already be geocoded.

29.4.4 Community Health Assessment, Planning, and Profiling

Many health departments have used GIS to visualize the results of community health assessment activities. Community health assessment is a required activity for those local health departments seeking to be accredited in the USA. Moreover, hospitals are being asked to do more with community health assessments under the current health reform initiatives in the USA. More recently, health departments are recognizing the utility of GIS in many phases of the process. For example, a local health department in Texas has commented, *use of a GIS proved crucial in the planning, administration, and analysis of the community needs assessment* [29.52]. That same health department has suggested,

> *The utilization of a GIS in orchestrating the community needs assessment efforts was essential in achieving the desired outcome of usable data.*

Lifestyle was one of the four determinants of health referenced earlier in the Lalonde report – and is an important component of community health. One of the ways lifestyle is analyzed is through behavioral risk factor surveillance surveys. The CDC's Behavioral Risk Factor Surveillance System (BRFSS) was established in 1984. It is the world's largest continuously conducted telephone health surveillance system. BRFSS monitors state-level prevalence of the major behavioral risks among adults associated with premature morbidity and mortality. By 1994, all states, the District of Columbia, and three territories were participating in the BRFSS. Many other countries have recognized the value of the BRFSS and have asked CDC to help them establish and evaluate similar surveillance systems [29.53, 54].

Given the wide recognition of lifestyle as a determinant of health status, it is surprising there has not been more utilization of commercial lifestyle segmentation data by public health agencies and researchers. There have been some efforts in this area, but according to a GIS committee of the National Association of Central Cancer Registries [29.55]:

> *Within public health, the roles of these lifestyle data are controversial. One of the problems with the use of these data are the lack of metadata about the procedures used to generate them (e.g., the data are developed using proprietary methods). Another problem is that the marketing terminology is perceived as politically incorrect (i. e., could not be used in a report to the public).*

29.4.5 Environmental Health

Environmental health (EH) addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behavior not related to environment, as well as behavior related to the social and cultural environment, and genetics [29.58].

Environment was another of the four determinants of health referenced earlier in the Lalonde report. Environmental Health is one of the most well established areas of GIS utilization. Environmental health agencies

Table 29.3 GIS relevance to essential environmental Public Health Services

Essential service	GIS relevance
#1: Monitor environmental and health status to identify and solve community EH problems	GIS is a tool for EH assessment, analyzing trends, and communicating EH problems and risks to the public through static or interactive maps. GIS also has many functions helpful for exposure assessment, data aggregation, data management, and other linkages
#2: Diagnose and investigate EH problems and health hazards in the community	GIS supports EH surveillance systems with more efficient data collection methodologies, better understanding of disease transmission dynamics, and a framework for outbreak investigation and response. There is universal consensus that a GIS can be a useful aid at the beginning of an environmental epidemiology or risk assessment study [29.56].
#3: Inform, educate and empower people about EH issues	GIS facilities targeting health communication geographically and demographically. Desktop GIS and web-based portals such as ToxMAP (http://toxmap.nlm.nih.gov/toxmap/main/index.jsp) and South Carolina community assessment network (SCAN – http://scangis.dhec.sc.gov/scan/) educate and empower people to understand EH issues
#4: Mobilize community partnerships and actions to identify and solve EH problems	Maps are great tools for community engagement. Desktop GIS and web-based portals such as the ones listed above help mobilize community partnerships. Another example is the *rat information portal* in New York City (http://www.nyc.gov/html/doh/html/pest/rats.shtml). GIS provides a framework for analyzing and solving many other EH problems (e.g., lead poisoning mitigation and prevention; integrated vector control to prevent malaria, dengue, etc.)
#5: Develop policies and plans that support individual and community EH efforts	The quote *Documenting need is not enough; documenting* where *there is need is critical to intervention strategies* [29.57] holds true for EH practice. GIS has helped policymakers understand the scope of environmental health emergencies, the built environment, and the *zone of influence* of mobile sources of air pollution. GIS also plays a central role in public health impact assessments (see www.sfdph.org/phes)
#6: Enforce laws and regulations that protect EH and ensure safety	GIS-based methods help measure compliance with local laws (e.g., environmental setback regulations in jurisdictions); compliance with spatial advertising restrictions in local and national laws (e.g., no tobacco advertising near schools). GIS-based methods are also utilized to geocode facilities and sites under regulation, route inspectors who regulate them, and track progress. GIS-based models allow planners to consider the safety of citizens when planning routes and testing preparedness plans

Table 29.3 (continued)

Essential service	GIS relevance
#7: Link people to needed personal EH services and assure the provision of healthcare when otherwise unavailable	GIS helps identify underserved populations, barriers to service, and to coordinate service delivery among multiple agencies. GIS-enabled services locators help citizens understand what services are available in their area and which offices are responsible
#8: Assure competent EH and personal healthcare workforce	Agencies and researchers have utilized GIS to assess workforce gaps in many different professions, including the EH workforce in California (see 163-page PDF at http://www.llu.edu/llu/sph/ophp/documents/eh_report2006.pdf) [29.59]. Geospatial analysis can characterize the pattern of deployment of the EH workforce and (with statistical modeling) analyze factors associated with the deployment pattern
#9: Evaluate effectiveness, accessibility and quality of personal and population based EH services	GIS provides a framework for monitoring and evaluating programs and services. One of the most popular applications of GIS in health and human services is analyzing access to services
#10: Research for new insights and innovative solutions to EH problems	GIS enables testing and considering options in both temporal and spatial contexts. Geospatial accuracy provides EH professionals and research partners with a more specific baseline for implementing and evaluating EH interventions and programs. GIS helps researchers aggregate data – and understand complex, multidimensional relationships between pollution and disease

at all levels of government and the partners that support them are increasingly using GIS technology to assess and protect the health of the populations they serve, understand the impacts of the environment on human health, and to improve environmental health services delivery. Environmental health organizations are interested in increasing their overall GIS capacity so they may enhance environmental health practice both across programmatic areas (e.g., air pollution, water, toxics and waste, built environment, etc.) and across common business functions such as assessment, policy development, and assurance.

The National Environmental Public Health Performance Standards [29.60] from the CDC are an important benchmark for participating agencies to measure the capacity of their local environmental public health system or program. Below is an overview of the relevance of GIS to Essential Environmental Public Health Services.

Recently, a number of countries have initiated environmental public health tracking initiatives. CDC defines environmental public health tracking as the ongoing collection, integration, analysis, and interpretation of data about the following factors.

1. Environmental hazards
2. Exposure to environmental hazards
3. Health effects potentially related to exposure to environmental hazards [29.61].

Initiatives such as EPHT have resulted in not only national but also state level EPHT portals [29.62], as well as the ongoing development of specific GIS extensions such as rapid inquiry facility tool (RIF). RIF is an automated tool that provides an extension to ESRI ArcGIS functions and uses both database and GIS technologies. Its purpose is to rapidly address epidemiological and public health questions using routinely collected health and population data. RIF was developed by the Imperial College London in collaboration with CDC [29.63]. More recently, there has been an emphasis on the built environment's impact on human health, including obesity and chronic diseases.

29.4.6 Chronic Disease Prevention and Control

GIS also supports numerous other chronic disease prevention and control activities. As mentioned throughout this chapter, GIS is utilized to support the work of cancer registries. GIS is also helping support heart disease programs, stroke registries, diabetes registries [29.64], and even the siting of defibrillators. There has been extensive research into the impact of the built environment, including the *food environment* [29.65], on risk factors and health outcomes. Recently, the CDC launched a chronic disease GIS exchange [29.66] that may highlight many of these efforts. It is also anticipated that GIS will contribute to the emerging field of *exposomics* [29.67].

Tobacco Control and Prevention

Tobacco control and prevention is a priority in many public health agencies, and GIS supports this winnable battle in numerous ways. GIS has been used to analyze tobacco advertising and compliance with the law [29.68–70], better understand level tobacco prevention efforts [29.71], prioritize communities for intervention [29.72], and model the impacts of tobacco taxes [29.73]. GIS has also been used to visualize policy efforts and policy changes in schools [29.74]. More recently, New York City Health Department used GIS to monitor nicotine replacement therapy and found that the GIS analyses provided a unique, near real-time visual method of assessing participation patterns as well as the impact of media and outreach strategies [29.75].

Cancer Prevention and Control/Cancer Registries

Cancer and mapping have a long history together. Haviland's map of the distribution of cancer in British counties in 1892 reminds us that the cancer registries of today continue long tradition in mapping cancer. Cancer registries were early adopters of GIS since the geocoding, data management, and spatial analysis capabilities of GIS benefit a wide range of cancer registry research questions and investigations.

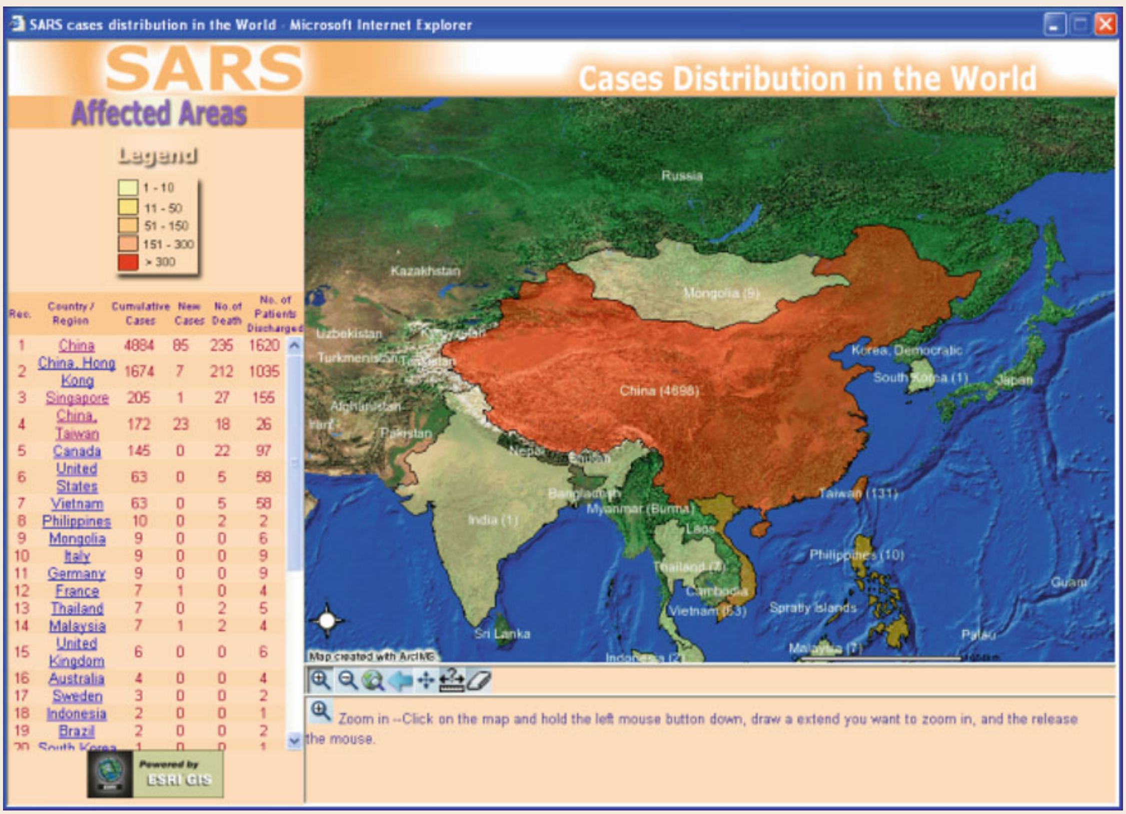

Fig. 29.4 In 2003, WHO and the Hong Kong Department of Health launched an interactive web mapping application to provide up-to-date, accurate information ont eh distribution of SARS in Hong Kong, China, and other parts of the world

29.4.7 Infectious Diseases

GIS for SARS and H1N1

Early 21st century chapters in the history of mapping and GIS in public health are the severe acute respiratory syndrome (SARS) outbreak of 2003 and the H1N1 pandemic of 2009. During the SARS outbreak in 2003, many organizations used desktop and server GIS as a means of assembling and analyzing information on the spread and distribution of the disease. According to WHO, during outbreak response to SARS it used a custom-made geographical mapping technology to assist in the location of cases and rapid analysis of the epidemic's dynamics [29.76]. A number of organizations produced web-based interactive maps with SARS information at various levels of geography. Such mapping efforts educated the public (including travelers to potentially at-risk areas), assisted public health authorities in analyzing the spatial and temporal trends and patterns of SARS, and helped authorities assess and revise control measures [29.77].

Based on experiences with SARS and a recognition of the growing GIS capacities within governmental public health, many authors of national and subnational jurisdictions' pandemic influenza plans highlighted the importance of location-based information and real-time situational awareness during public health emergencies. Therefore, prior to the H1N1 pandemic of 2009 many preparedness plans included references to the need for GIS personnel in response efforts and considered ways GIS would be utilized to visualize and analyze incoming data in relation to key geographical information.

Planning and reality often are different. During the H1N1 pandemic itself, GIS was helpful in more ways than public health planners had anticipated. At a high level, it helped visualize large amounts of rapidly changing data as the event progressed through time. At a local level, geocoding cases helped validate whether or not they were in a health department's jurisdiction [29.78].

In practice, health organizations used GIS to accomplish many functions. Table 29.4 is based on periodic interviews with GIS colleagues in state and local health departments in the USA.

HIV/AIDS

According to WHO and UNAIDS, over 33 million people around the world are living with HIV. In addition to

Table 29.4 Pandemic influenza and GIS

Functional Area	Practical applicability of GIS
Disease surveillance and cluster analysis	Geocoding cases of H1N1 for disease surveillance, disease diffusion, and cluster analysis. Maps of syndromic surveillance (e.g., citywide influenza-like-illness data from emergency departments). Producing maps and other outputs as situational awareness tools for managers, public information
Vaccines and antivirals	Health departments determined shipment sites for vaccines based on census demographics; used Thiessen polygons to determine antiviral apportionment; mapped the equitable distribution of vaccines based on general and high risk groups vs. actual distribution of vaccines; mapped antiviral distribution achieved through activation of stockpiles; monitored the availability of vaccines and antivirals geographically, mass immunization outreach (geocoding and automated notification to under-represented areas), and created online vaccine facility locators
Situational awareness and decision support	Presenting maps to senior staff to apprise them of the changing situation (e.g., disease diffusion, school closures); where emergency rooms are located, where hospitalizations and deaths have occurred, determine populations in order to assist in calculating the number of supplies to be sent
Data verification and cleaning	Verifying postal codes, sorting by location, etc., in order to clean data going into numerous systems
Modeling and predictive analysis	Help predict where and how fast the pandemic will spread
Interactive mapping	Influenza vaccine locators and points of dispending on existing interactive maps for the jurisdiction

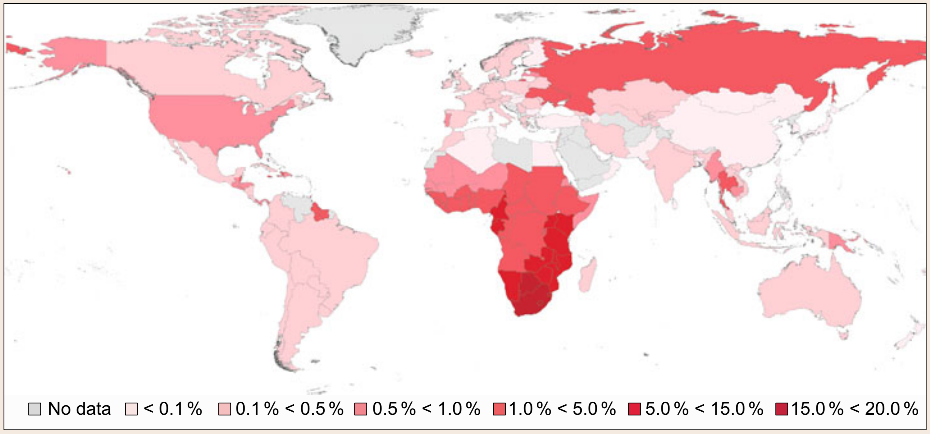

Fig. 29.5 2010: A global view of HIV infection. Note the UNAIDS map includes a companion chart as well as regional prevalence maps [29.79]

lives lost, there are many other substantial consequences of the HIV/AIDS epidemic including orphans and vulnerable children needing care, stresses on the health system, and lost economic productivity, among others. WHO suggests the HIV/AIDS epidemic still constitutes one of the greatest challenges to public health and international development [29.79].

According to [29.79], AIDS was the first major epidemic in recent world history that scientists were unable to follow in the spatial domain due to confidentiality issues. However, there have been numerous maps of HIV diffusion and in the early 21st century, GIS is an essential component of HIV/AIDS prevention and control. At the global level, HIV prevalence maps (such as the UNAIDS one) communicate the scope and distribution of HIV/AIDS worldwide and at the country. Diffusion mapping has not only been local; it is now well known that major roadways played a role in disease diffusion throughout many African countries.

The MEASURE (monitoring and evaluation to assess and use results) Evaluation project uses different strategies to collect and use data about health issues. For example, a tool for assessing and modifying HIV/AIDS prevention programs locally or nationally is called the priorities for local aids efforts (PLACE) method. The PLACE method can identify geographic areas that contain key HIV transmission networks.

The HIVspatialdata.net website has a collection of demographic and health surveys for many countries. GIS and GNSS help Ministries of Health, National AIDS Commissions (NACs) and their partners document the accessibility of services through nationwide health facility inventories. It also helps MOHs and NGOs understand subnational distribution of population – and populations at risk – so they may target resources effectively. This helps ramp up access to condoms, health communications, voluntary counseling and testing services (VCT), prevention of mother-to-child transmission (PMTCT) services, and anti-retroviral therapy (ART), among other things.

Malaria and Dengue

Public health professionals are using GIS in a wide variety of ways to tackle mosquito-borne diseases such as malaria and dengue. GIS is an essential component of malaria prevention and control. According to *Hay* and *Snow*, *maps are essential for all aspects of the coordination of malaria control* [29.80]. The Global Malaria Action Plan recognizes the utility of mapping, especially for monitoring and evaluation [29.81]. The WHO regional dengue plan for 2008–2015 [29.82] includes a string of GIS-related items under Expected Result 10. In the WHO dengue plan ministries of health are encouraged to conduct basic GIS workshops in 2009–2010 and to include GIS as part of their integrated vector management.

GIS enhances malaria and dengue surveillance and control at the national level all the way to the community level [29.83]. GIS and GNSS help NMCPs, dengue control programs, and NGOs understand subnational distribution of population – and populations at risk – so they may target resources effectively. This helps ramp up access to insecticide-treated bednets (ITNs), indoor residual spraying campaigns (IRS), rapid diagnostics tests (RDTs) and artemisinin-based combination therapy (ACT), among other things. GIS has also enhanced ITN marketing and distribution efforts [29.84]. Recent reports and articles provide strong evidence that GIS enhances decision-making for national malaria control programs (NMCPs, for an overview of such activities in Zambias [29.85]) as well as national dengue control programs [29.86]. In some cases vector control resources need to be targeted due to resource limitations. GIS helps here as well. Recent findings from Thailand suggest that integrated vector control programs using GIS-based foci based (i. e., conducting community intervention campaigns within a defined radius of sero-positive cases) are very effective [29.87]. Reference [29.87] also suggests using a history of reporting dengue cases may be a practical tool for producing a GIS map of the risk areas, through which future vector control efforts could be targeted.

29.4.8 Animal and Veterinary Health

Cline notes [29.88]:

> *while most pathogens transmitted in a human-to-human cycle are not constrained geographically, zoonotic and insect-transmitted diseases, in contrast, tend to be focal in distribution, with their maintenance cycles dependent upon exacting ecological conditions.*

This dependency makes zoonotic and insect-transmitted disease well suited to GIS analysis. Over the last decade, GIS has become central to the work of many agricultural and veterinary health agencies. Agencies around the world have built GIS into applications supporting management of animal disease epidemics [29.89, 90]. Some organizations have also documented cost savings as a result of using GIS.

29.4.9 Human Services

Around the world, over half a million social workers and human service professionals help vulnerable and distressed people every day. Their clients include foster children, the elderly, the mentally ill, the homeless, the disabled, and many others in need. Social workers and human service professionals accomplish their work through hundreds of different programs at governmental agencies, non-profit organizations, private practices, and other venues. These programs are in great demand due to the global economic crisis and numerous other drivers including changing demographics. Increased demand for human services and social services brings new attention to concerns regarding access to services, efficiency (e.g., routing and logistics), and program integrity (e.g., fraud detection).

The adoption of GIS in the human services sector is similar to that in hospitals and public health. Human services organizations used GIS to understand the extent and scope of their market, where their clients originated, and where resources need to match service demand.

There is a long history of the helping professions utilizing maps for assessment, planning and advocacy. Reference [29.57] suggests GIS can benefit social work by

1. Continuing and strengthening the social survey tradition.
2. Providing a framework for understanding human behavior.
3. Identifying community needs and assets.
4. Improving the delivery of social services.
5. Empowering communities and traditionally disenfranchised groups.

Hillier also argues [29.57]: documenting need is not enough; documenting *where* there is need is critical to intervention strategies.

If social work needs mapping, then human services agencies need GIS. In the late 1990s, *Wong* and *Hillier* [29.91] concluded there were outstanding potential rewards for human service agencies using GIS in terms of agency planning, data analysis, policy-making, fundraising, client information, outreach, and other management and direct-practice functions. Over the last decade GIS has emerged as a critical tool for planning and understanding community needs, empowering citizens to locate services, enhancing the ability of helping professionals to provide information and referral; providing analytical capabilities to staff (e.g., policy questions, case management decisions, service eligibility), helping manage large amounts of program and administrative data, enabling logistics and program support (e.g., routing efficiency), and enhancing fraud detection. Professionals working in human services agencies ask many *where* questions such as

1. Where are the people who need help – those *at risk*?
2. Where are our services located?
3. Where should we send our employees today (e.g., many state agencies have staffs numbering over 1000)?
4. What are the most efficient routes?
5. Where are the field staff located?
6. Where should we concentrate our limited fraud investigation capabilities?

One of the primary business functions of human service professionals is to provide case management for their clients whether in an agency office, at their clients' homes, or in other service delivery settings. Professional social work case managers are guided by standards [29.92] and routinely use computerized case management information systems. Such systems help track client history, progress toward meeting goals, and report results, among other functions. Case management systems with GIS at their core help human service professionals provide more effective and efficient case management. GIS leverages the power of place in establishing helping relationships, assessing complex problems, selecting problem-solving interventions, and helping clients to function effectively – all stated goals of case management. The *SchoolMinder* application in Illinois illustrates how adding server-based GIS tools to case management systems helps answer the *where* questions relevant to their cases and workflows. Since deploying the SchoolMinder application, the average distances for initial foster care placement in Cook County dropped from 15.9 to 4.0 km (median numbers dropped from 10.3 to 2.4 km) [29.93].

29.4.10 Hospitals and Health Systems

In recent years, GIS has expanded beyond the planning and marketing departments of hospitals to include a number of other applications beyond the analysis of hospital service areas and market share. At a regional and national level, there has been more interest in using GIS for service locators (consumer oriented) and health facility assessments (policy oriented). A number of organizations also partnered to come up with a standardized approach for identifying a health facility [29.94]. It is also worth noting GIS can provide an inside view of the facility to determine when beds are available for cleaning after a patient discharge, where maintenance is needed on equipment and the positioning of assets throughout the hospital. All of this can be managed and viewed through a web based GIS tool. GIS can also help administrators and infection control professionals make better decisions about policies for the containment and immediate outbreak management response to secondary infections [29.95, 96].

29.5 GIS and HHS Education

The educational institutions that prepare the health and human services (HHS) workforce have recognized demand for GIS-related courses and programs. A large number of accredited schools of public health are offering semester long courses and summer institutes. Below are brief summaries of GIS within specific academic domains of public health.

29.5.1 Biostatistics and GIS

Biostatistics is the application of statistics to biological problems [29.97]. Since it often involves statistical analysis of large datasets, biostatistics benefits from GIS as a way of organizing large datasets (in a special context, by geographic identifiers) and also as a way of visualizing data for interpretation and hypothesis generation as an alternative to poring through spreadsheets or databases. One of the primary application areas of GIS to biostatistics is through cancer registries. It can be challenging to inform without misinforming, but researchers note that due to advances in the sciences of cartography, statistics, and visualization of spatial data they are constantly expanding the toolkit available to mapmakers to meet this challenge [29.98].

29.5.2 Community Health and GIS

Community health includes many programs such as maternal and child health, family health, health education, nutrition, and tobacco prevention and control. GIS adds value to community health in many ways, including

- Community health planning.
- Analyzing health disparities.
- Measuring access to health care and other services.
- Understanding demographic data in relation to neighborhoods.
- Mapping risk factors.
- Analyzing high-risk locations (e.g., concentrations of liquor stores).
- Prioritizing interventions such as lead poisoning prevention.
- Enforcing tobacco control legislation.
- Using GIS for tobacco cessation promotion.

29.5.3 Epidemiology and GIS

Epidemiologists have often used maps to describe their study areas, aggregate data, link to other relevant datasets (e.g., demographic data), and conduct exploratory spatial data analysis. The enhanced time awareness of commercial GIS software will make the application of GIS in epidemiology grow even more. To understand the role of GIS in epidemiology, it is important to remember that epidemiology is largely quantitative but also observational. Epidemiologists explore patterns of disease across populations. GIS technologies are powerful and useful tools in observational epidemiology (with its focus on person, place, and time) as well as analytical epidemiology (identifying point sources, and controlling disease outbreaks, with its focus on location-based response activities).

Epidemiologists use the mapping and visualization functions of GIS to define study areas. They use analytic functions such as geocoding, buffering, exploratory spatial data analysis, field data collection (navigating to locations as well as recording location), and outbreak investigation. Location is proxy for exposure in environmental epidemiology.

29.5.4 Global Health and GIS

Global health priorities are largely focused on HIV/AIDS, malaria, maternal and child health, and preventing leading killers like diarrhea in children. However, many of these initiatives in global health have developed as vertical programs. Recently donors have been calling for integrated approaches to combating disease and strengthening health systems. GIS has special capacity to integrate and analyze data from a wide variety of programs that address malaria, tuberculosis, child and maternal health, clean water, food and nutrition, and education. GIS provides strategies for spatial data use for decision making that support and strengthen linkages across health interventions towards the aim of overall health system strengthening. MOHs and the non-governmental organizations (NGOs) supporting them are using GIS in a broad range of programs and functional areas.

29.5.5 GIS and e-Health

There are a number of definitions for e-Health. The WHO defines e-Health as the use of information and communication technologies (ICT) for health [29.99]. HIMSS (Healthcare Information and Management Systems Society), a not-for-profit membership organization devoted to healthcare transformation through the effective use of health information technology, defines e-Health as [29.100]:

> *The application of Internet and other related technologies in the healthcare industry to improve the access, efficiency, effectiveness, and quality of clinical and business processes utilized by healthcare organizations, practitioners, patients, and consumers to improve the health status of patients.*

Since GIS is information technology (IT), it is covered by the above-referenced definitions for e-Health. Below are several examples of how GIS enhancing e-Health.

The geographic information contained in electronic health records and health information systems is one of the critical components for detection of disease outbreaks. More specific geographic information in health records increases options for detecting outbreaks (i. e., one can always aggregate up, but not down). Specific geographic information within health information systems also helps health officials determine the extent of an outbreak. With such knowledge, health organizations may use GIS to determine what resources are available in close proximity (e.g., facility diversion status, stockpile locations, volunteers). Such analysis is essential for the response and communication with the public. Surveillance is not just important for infectious/communicable diseases: chronic disease registries (cancer, stroke, etc.) also benefit from more specific geographic information. Specific and standardized location information embedded in electronic health records (and registries) facilitates more targeted spatial analyses across health information exchanges [29.101, 102].

GIS helps deliver the e-Health promises of fostering participation by consumers, as well as addressing disparities (e.g., in access to services and health outcomes). The strategic planning documents of numerous e-Health initiatives suggest e-Health is going to foster participation by consumers by allowing them to better manage their own care and be more informed in decision making. If this is going to be the case, then consumers need to know where services are located. Also, health authorities and community-based organizations need to understand where the consumers needing various services are located – and what disparities currently exist in not only their access to services, but also health outcomes and health risk factors. Such location data is not just for research, it has extreme practical value. The geocoordinates of health facilities are necessary for analyzing access to services, but may also feed public-facing services locators. Moving forward, it is anticipated that more consumers will utilize such services locators from smartphones and other mobile devices.

GIS helps us understand unwarranted geographic variation in health services delivery – supporting the e-Health goal of supporting providers in the delivery of safer, more effective, and more efficient healthcare. Numerous researchers have documented the unwarranted geographic variation in health services delivery [29.22], which not only has an impact on costs to consumers and governments but also on health outcomes. Many e-Health initiatives facilitate the increased availability of health services and health outcomes data. In helping place such data on the map, GIS provides new eyes to researchers, clinicians, and practitioners to understand and address unwarranted geographical variations.

GIS helps deliver e-Health's promises for more transparency – i. e., timely, accurate, and comprehensive reporting on health system activities and outcomes. MOHs, subnational health departments, and NGOs are on the front lines implementing health improvement initiatives around the world including chronic disease prevention and control; HIV/AIDS prevention, care and treatment; malaria prevention and control; and maternal and child health, among others. Elected representatives, governing bodies, taxpayers, and external donors want the health organizations they fund to design and implement successful programs. Health organizations (both governmental and non-governmental) also have increasing responsibilities to partner with other government agencies and NGOs (e.g., joint proposals), coordinate across vertical programs, and build local capacity. Therefore, they need tools that help them report on what they are doing [29.103] and collaborate with others. Health organizations are also moving from paper processes to using PDAs and mobile phones for data collection [29.104].

The WHO health metrics network has emphasized how important it is to map human resources, budgets, and expenditures at the national and district levels [29.105]. There are an increasing number of ArcGIS server applications that are examples of providing this type of transparency. Moving forward, it is anticipated that many MOHs, subnational health departments, and NGOs will map various health management information system (HMIS) data (whether it be operations data or health outcomes).

The personalization of health is not new. Medicine has always had a person at the center of its inquiry and practice. The Hippocratic oath has always had a single person in mind with its policy of do no harm. However, studying one person at a time is labor intensive and does not produce the generalizability that is required to impact large groups of people. This, of course, is where public health comes in by providing the broad brush approach to health problems and then raising awareness as to what requires our attention as a society. While the public health disciplines have studied population health at group levels, they seldom focus on individual levels. Geomedicine, on the other hand, provides a different type of analysis – it attempts to link the highly governable health information to the unique context of the individual. It proposes that factors in our environment have a substantial impact on our own personal health.

Geomedicine attempts to harness the power of a GIS to present environmental context in a scalable fashion – where the knowledge of medicine can impact how humans choose to engage with the underlying context. To assure that both the information upon which geomedicine is used is useful, health data must be geographically accurate, and accuracy is solely a function of how well computer systems registration software collects this data.

29.6 Summary

GIS continues to find its place in health and human services. Numerous research projects explore novel uses, while over time many GIS functions and operations are becoming standard practice within health and human service organizations. The value of GIS in HHS continues to enlarge. As more countries face uncertain economic times, these founding market segments must get more out of the data as well as their analysis.

The future of increasing use of GIS in health and human services is extremely bright. The increasing focus on electronic health records, and the corresponding geographic information contained within them will open up many new possibilities for population health analysis and planning. GIS has been found to be an essential technology in a wide variety of health and human services agencies and activities. Over 1000 case studies have been identified by just one GIS company. These case studies span the continuum of HHS organizations.

The advent of cloud computing will increasingly make GIS more affordable for every MOH, while allowing software developers to focus on creating custom, easy-to-use applications to serve specific needs while maintaining a framework to seamlessly share relevant information across the entire health and human services continuum. Location will be an integral part of every health and human service.

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