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Geographic Information Systems for Coronavirus Planning and Response

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Geographic Information Systems for Coronavirus Planning and Response

Executive Summary

Infectious disease experts have predicted a pandemic, saying it was not a question of if but when.

Drawing on experiences with severe acute respiratory syndrome (SARS), avian influenza (H5N1), and novel influenza A (H1N1), the World Health Organization (WHO) and other health authorities, such as the Centers for Disease Control and Prevention (CDC), urged nations and local governments to prepare pandemic response plans.

Many ministries of health and subnational departments of health around the world have activated those plans in response to coronavirus and are sharing data as required by the updated International Health Regulations.

Esri's work with health organizations and government leaders has proven location intelligence from **geographic information system (GIS) technology and data to be critical** for the following:

- Assessing risk and evaluating threats
- Monitoring and tracking outbreaks
- Maintaining situational awareness
- Ensuring resource allocation
- Notifying agencies and communities

The current coronavirus disease pandemic presents an opportunity to build on the experience and readiness of Esri's existing global user community in health and human services. Through real-time maps, apps, and dashboards, GIS will also facilitate a seamless flow of relevant data as a component of the response from local to global levels. A compelling case exists for building on top of the public health GIS foundation that is already in place both in the United States and around the world.

After reading this paper, leadership and senior staff should understand the following:

- The necessity to apply location intelligence to public health processes in coronavirus response
- How GIS can support immediate and long-term action
- What resources Esri provides its customers

Coronavirus Definition and Scope

According to the WHO, coronaviruses are a large family of viruses that may cause illness in animals or humans. In humans, several coronaviruses are known to cause respiratory infections, ranging from the common cold to more severe diseases such as Middle East respiratory syndrome (MERS) and SARS. The most recently discovered coronavirus causes the novel coronavirus disease 2019 (COVID-19).
According to the CDC, a vaccine or drug is not currently available for COVID-19. Community-based interventions, such as school closures, event cancellations, social distancing, and telecommuting, can help slow the spread of COVID-19.

Decisions about the implementation of community measures will be made by local and state officials, in consultation with federal officials as appropriate, and based on the scope of the outbreak and the severity of illness. Implementation will require extensive community engagement, with ongoing and transparent public health communications.

Importance of Location

Location information is critical to decision-making associated with large outbreaks. The CDC considers place to be a basic tenet of a field investigation:

Both the who and the when of disease are relative to and often dependent on the where. Geographic information science, systems, software (collectively known as GIS) and methods are one of the tools epidemiologists use in defining and evaluating the where.

The health-care community has long used maps to understand the spread of disease—initially in 1694 to communicate quarantine areas for bubonic plague and most famously in 1854, when Dr. John Snow connected location and illness with his history-making map of a London cholera outbreak. From disease atlases of the early 20th century to more recent web mapping of Ebola and Zika infections, health-care professionals have considered mapping—more recently done using GIS—a critical tool in tracking and combating contagion.

For example, GIS is critical to answering many infectious disease-related questions including the following:

- Where are current cases in the community; and where will the virus likely spread?
- Do we have schools in socially vulnerable areas?
- Which neighborhoods are distant from a testing site?
- Do we have communities or specific population demographics that are at greater risk?
- Which facilities and staff are in harm's way?
- What does surveillance data on the number of hospitalizations and deaths suggest regarding the following?
    - Distribution of hospital supplies and hospital beds on a regional or statewide basis
    - How quickly local and regional hospital resources are being depleted

While most public health organizations recognize the importance of location, location-based information is not always collected in routine public health practice. With the

widespread implementation of electronic health records, the intrinsic value of a patient's address for public health reportable conditions should be recognized and preserved. Accurate geographic information should be embedded as part of any international, federal, state, or local health information system solution. For reference, note the Geospatial Data Act of 2018.

Following are several examples of situations that highlight the need for location intelligence:

- A disease outbreak has rapidly progressed to widespread status in a community, and public health officials can no longer hope to contain the outbreak through contact tracing and quarantine. A series of community-level interventions must now be evaluated and implemented to contain the outbreak. Location-based information can be used to support multiple, specific community interventions and activities. Common and helpful GIS applications include mapping and data collection apps to track cases, spread, vulnerable populations and places, and hospital capacity; dashboards for real-time situational awareness; and web apps for keeping the public informed. Health officials may overlay outbreak data with other location-based information such as public gathering places, schools, health facilities and services, and transportation centers. GIS supports possible interventions such as

    - Sharing situational awareness to monitor and evaluate impact.
    - Canceling public events, meetings, and gatherings.
    - Closing schools, public places, and office buildings.
    - Restricting use of public transportation systems.
    - Identifying potential group quarantine and isolation facilities.
    - Enforcing community or personal quarantines.

- International airline passengers are screened by public health officials at a large urban airport and asked to complete a standardized health status questionnaire and submit to temperature checks for fever. Passengers are asked to state both origin and destination addresses. Subsequently, a disease cluster is reported in another country, and public health officials need to identify how many people have traveled from or recently visited that same location. Using GIS, public health officials are able to apply the information collected in the questionnaire in their estimate of exposures and to prioritize investigations. A digital solution to capture the questionnaire data, including a standardized method to geographically reference each passenger's place of origin and travel destination, will save the public health community valuable time in understanding the transmission dynamics and potentially containing the outbreak.

- A patient seen in a hospital emergency room is tested for coronavirus, but the test ends up being a false negative. Days later, when the lab test results are confirmed to be positive, the public health agency is notified to investigate, only to discover that the patient's address is not valid, has been mistakenly recorded, or does not exist—and vital time is lost in locating the patient. GIS technology provides a mechanism for validating the address against an existing address database at the time it is recorded. GIS gives the ability to rapidly capture standardized and geocoded addresses for confirmed cases, suspected cases, and case contacts during the critical early phase of the pandemic period,

providing essential support for attempts to slow the spread of disease throughout the community.

Challenges Faced by Governments and Public Health Officials

Public health leaders recognize the extraordinary logistical challenges communities face in response to the novel coronavirus. During the current pandemic, there are hundreds of response efforts going on simultaneously in communities throughout both the public and private sectors.

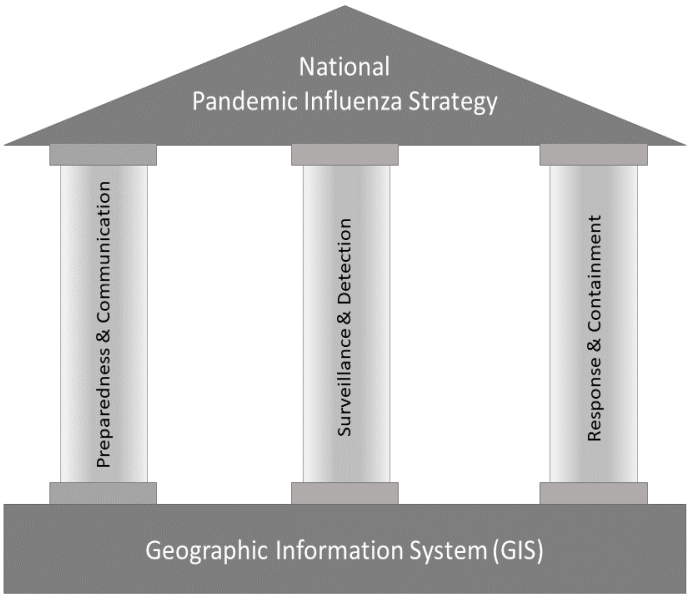
Maintaining situational awareness at any level of government is a tremendous challenge. It is also difficult for traditional surveillance, case management, and outbreak response activities to sufficiently scale to meet the demands.

Additional necessary capabilities follow:

- Using available data to make community outbreak containment decisions (including appropriate balance of social distancing measures from event cancellations to shelter-in-place requirements against economic and educational disruption to communities)
- Prioritizing and managing interventions
- Increasing and maximizing the surge capacity of medical response and other required services in a community or region
- Communicating with partners and the public
- Deciding how and where to deploy limited staff

Every nation's pandemic plan is different, but all share many similarities. The national strategy of the United States is supported by three core pillars: Preparedness and Communication, Surveillance and Detection, Response and Containment.

These activities are community based, thereby requiring in-depth awareness and understanding of location and, specifically, the spatial representation of the community. GIS serves as a foundation on which these pillars rest (as illustrated below).



What Is GIS?

GIS is an enterprise technology framework for collecting, managing, analyzing, and sharing data to achieve location intelligence.

Rooted in the science of geography, GIS integrates many types of data (including demographics, big data, imagery and feeds from Internet of Things [IoT] sensors and social media) and deploys them in real-time maps, apps, models, dashboards, and analysis tools. With its unique capabilities and flexibility, GIS reveals deeper insights into data, such as spatial patterns, relationships, and situational awareness that help users make smarter decisions.

Millions of people around the world—including staff in most governments, the CDC, the WHO, and numerous other public health organizations—rely on GIS to visualize and map data, perform analysis, share information, and ultimately help solve complex problems.

An enterprise deployment of the leading GIS technology, the Esri® ArcGIS® platform, supports the broad needs of public health preparedness and response. In fact, Esri technology can deliver many of the required capabilities outlined in each of the CDC's six key public health preparedness domains: information management, countermeasures and mitigation, surge management, biosurveillance, incident management, and community resilience. By developing its technology in close collaboration with users, Esri engineers software that makes workflows more efficient, effective, and adaptable.

Explore the Esri resource Public Health Preparedness: A Geographic Approach for more information.

Applying Location Intelligence and GIS to Business Processes Critical to Pandemic Response

Surveillance, Situational Awareness, Logistics, and Communication

The spread of disease, especially infectious disease, is inherently spatial. One of the greatest challenges in the war against disease is humanity's increasing mobility. Today, a person can pick up a virus in one place and share it in any other location on the planet within hours. Among the jet set, there's the potential to become a superspreader, infecting a large number of people across a large geographic area.

While technology to create vaccines has become incredibly advanced, it still takes months to formulate an effective vaccine for a new virus. Within that time frame, the virus can easily reach every corner of the world.

When disease can travel so quickly, information has to move even faster. The CDC recommends applying GIS to collect, visualize, analyze, and share this information for internal and external purposes.

Access Necessary Data

The COVID-19 outbreak has been more data transparent than any other major outbreak in history, and a variety of information products already exist. The challenge is in selecting data that is authoritative, reliable, and updated. With that in mind, data can be sorted into three tiers:

- Tier 1 (*Excellent*): This often comes from government-sponsored sources and agencies and includes (*but is certainly not limited to*) data from CDC, Food and Drug Administration (FDA), state and local health departments, US Census Bureau, and WHO. These agencies are mandated to provide quality data, and they often make it available to the public.
- Tier 2 (*Considered reliable*): This would include data that is highly documented from a reliable source, like major companies, universities, and trustworthy media outlets. Expect to find information like sales data or media alerts on the relevant topic. While the data may be of an extraordinary quality, these groups are typically not mandated to provide it.
- Tier 3 (*Useful for reference*): This is the data that is typically provided by individuals. While it might contain actionable information and be easily accessible, it should only be used to corroborate with tier 1 and tier 2 sources. This may include casual survey data or crowdsourced information.

Esri has aggregated a large store of tier 1 and tier 2 data and information products on the COVID-19 GIS Hub, ArcGIS Living Atlas of the World, and Esri Maps for Public Policy. This includes the leading international dashboards, sorted by category, and their underlying layers.

Additionally, Esri provides a variety of other information that can help answer questions such as the following:

- Where are the latest-reported COVID-19 cases?
- Where are the most socially vulnerable populations?

- Where are the most densely populated areas in the US?
- Where are the health-care facilities in the US?
- What areas of the world are under travel restrictions?

Map Current Cases

To keep track of the evolving coronavirus situation, public health and government officials, as well as business leaders, can map key data using the following GIS technology applications:

- ArcGIS Dashboard: A localized dashboard, similar to the WHO dashboard and Johns Hopkins University global dashboards, will give leaders the information they need to make critical decisions about quarantines, travel restrictions, school closures, etc.
- ArcGIS Hub: An interactive community engagement platform or hub—external facing and/or for public use—can be set up to ensure that key stakeholders have the tools they need to respond. Esri created the COVID-19 GIS Hub to gather and share relevant and authoritative, community-driven resources from around the world.

Monitor Disease Spread

To date, many organizations have been mapping cumulative cases of coronavirus within their jurisdictions. It is important to look at the speed and geographic spread of the disease as well. Doing this spatially will complement the traditional epidemic curve showing case counts per day. Combining this information with other relevant datasets, like transportation information and areas where people congregate, can provide additional insights. Esri recommends deploying location analytics for dynamic data exploration and hypothesis generation.

Identify Vulnerable Populations and Places

Some people may be more susceptible to developing serious illness with COVID-19, and some places may be especially challenging for maintaining social distancing as a protective measure. The CDC Social Vulnerability Index provides 15 US Census-derived measures of potential stressors on human health at a census tract level. Using this data combined with other geoenabled risk factors, like older age and comorbid conditions, helps pinpoint locations of higher-risk populations.

High-risk places are also important to consider, such as areas with especially high population density, homeless encampments, Disneyland and other places of entertainment, and prisons. Mapping vulnerable people and places allows decision-makers to tailor messaging and interventions to improve equity and population health outcomes.

By creating a coronavirus impact planning report, organizations can better understand demographics and other information in context and optimize resource allocation decisions.

Assess Capacity

Knowing how health-care officials, businesses, and governments can respond to a large-scale outbreak is important. This work can involve creating maps of hospitals

and health systems including public, private, veteran, and Native American facilities with license types suitable for pandemic influenza surge.

- Map bed capacity (licensed beds, staffed beds, bed utilization, critical care beds) and use that information to model surge capacity needs. Two models receiving a lot of attention for COVID-19 include:
  - Penn Medicine's COVID-19 Hospital Impact Model for Epidemics (CHIME)
  - CDC's Flu Surge—Software to Estimate the Impact of an Influenza Pandemic on Hospital Surge Capacity

  Note: Both of the above models can be enhanced by deploying them geographically using the new tools in ArcGIS Pro*.*

- Map workforce capacity (general practitioners, infectious disease and critical care specialists, respiratory therapists, nurses, and others) for insight about shifting human resources as needed to meet demand.
- Use location intelligence to plan, site, implement, and communicate about testing centers for COVID-19.
- Determine where critical supplies exist for response efforts (IV fluids, oxygen, medicines, personal protective equipment, ventilators, and vaccines when available).
- Analyze mapped data to understand whether supplies are proximate to need.
- Use global maps to identify supply chain issues.
- Deploy a data collection app to get current capacity counts and other information from key facilities.

Maintain Situational Awareness and Communication

When leaders and officials combine some of the relevant components noted above, they can deploy one dynamic application to understand coronavirus impact on people and infrastructure.

During outbreaks and pandemics, organizations are stretched by multiple demands. They must coordinate activities with many partners, report to governing bodies and funders, and communicate with the public. At times, leaders must make decisions based on incomplete science. Situational awareness systems aggregate data from many sources into map-based interfaces that promote better understanding. Such systems enable public health officials and other leaders to

- Forecast the short- and long-term impact.
- Make emergency declarations.
- Make decisions about resource allocation.
- Communicate more effectively with other agencies.
- Notify vulnerable populations.
- Implement interventions such as quarantine and isolation.

Location intelligence is the core of many situational awareness systems, whether part of a hospital, emergency operations center, or a system accessed by multiple jurisdictions. GIS provides a common platform for the visualization and interactive mapping of static data, such as roads, health infrastructure, and stockpile locations, integrated with real-time data streams. These streams include outbreaks/incident locations, hospital status (diversion), first responder locations, traffic conditions,

weather forecasts, and 911 call data. Some systems have more advanced analysis and modeling capabilities.

Through maps, apps, and dashboards, GIS can assist communication efforts, ranging from sharing a situation assessment with the media and the public to helping the public locate health-care facilities. Through data visualization and narrative, story maps contextualize important factors such as age and social vulnerability. Many local governments are producing story maps to show residents what's happening in their area.

GIS maps also communicate emergency information regarding school closures, public meeting cancellations, and other community disease containment measures. Accurate public information is critical for risk communication and behavior changes including appropriate hygiene and social distancing recommendations. GIS technology is also now a standard component of mass notification systems, enabling community leaders to send out messages to staff, partners, or the public based on appropriate geographic boundaries.

Note: The GIS capabilities mentioned above are helpful not only for pandemic planning and response but also for other public health emergencies, including natural and human-made disasters.

While this white paper focuses on the health-oriented response to pandemic influenza, GIS is also an effective tool for managing the economic/business disruption that occurs under emergency circumstances.

Esri has developed a solution to support business continuity. This collection of maps and apps is designed to help businesses, utilities, and government agencies gain a better understanding of operational workforce capacity, monitor the status of facilities, and communicate disruptions to customers and stakeholders as needed.

How to Get Started

Organizations in need of software, support, training, or consulting can contact their account manager or local Esri distributor. As the situation surrounding coronavirus continues to evolve, Esri remains committed to our founding mission: to help solve some of the world's most difficult problems. In this, we support GIS users who work every day to respond to challenges, and we provide tools that empower intelligent, data-driven responses.

In addition to Esri's COVID-19 GIS Hub—a carefully curated collection of datasets, applications, and other useful content—Esri provides help through its Disaster Response Program. For more than 25 years, Esri has supported active emergency response and relief efforts with GIS technology and subject matter expertise. When organizations need help quickly, Esri provides data, software, configurable applications, and technical support for GIS operations.

Conclusion

Geography and location analysis have played crucial roles in better understanding and responding to the developments around COVID-19. Esri is here to support organizations as they use geospatial data in preparing for and responding to this global health and business concern. Leaders are encouraged to discuss opportunities for collaboration.

About the Author

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Dr. Geraghty is the Chief Medical Officer and Health Solutions Director at Esri where she leads business development for the Health and Human Services sector. Formerly the Deputy Director of the Center for Health Statistics and Informatics with the California Department of Public Health, Dr. Geraghty led the state vital records and public health informatics programs. There she engaged in statewide initiatives in meaningful use, health information exchange, open data and interoperability. While serving as an Associate Professor of Clinical Internal Medicine at the University of California at Davis she conducted research on geographic approaches to influencing health policy and advancing community development programs. A specific area of research focus involved pesticide safety. In addition to her degrees in Medicine, Medical Informatics and Public Health, Dr. Geraghty is also a board-certified public health professional (CPH) and a Geographic Information Systems Professional (GISP).

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