Global Healthcare Crises:

How Information Technology can Address Pandemics and Disasters

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Foreword
In 2003, Toronto, Canada and numerous cities in Asia reported cases of a deadly virus called Severe Acute Respiratory Syndrome (SARS). Over 8,000 people were infected with the virus, 900 of whom died. The epidemic permeated all aspects of life from halting the day-to-day activities of citizens to the ensuing devastation of local economies.

While post-crisis inquiries revealed the courage and dignity of the people in the affected areas, they also discovered that many actions by emergency authorities were not as prompt and in some cases, as appropriate as they should have been. There were problems with surveillance systems, early warning systems, decision-making processes, and communications with stakeholders throughout the crisis period.

This report, which presents an information and communication technology framework for the prevention of, and response to health-related crisis, is an important contribution to the crisis management literature. It addresses many of the aforementioned issues and problems associated with the SARS outbreak. It also outlines the basic components of a National Health Information Infrastructure and discusses the requirements for intra-national and international operations. This report will be particularly useful and timely for countries as they develop a coordinated response to the H5N1 avian influenza threat.

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Executive Summary

An international outbreak of a deadly virus that mushrooms into a worldwide pandemic is more than science fiction. Today, the H5N1 avian influenza virus ("bird flu") is spreading around the world. Bird flu was initially limited to Asia. More recently, poultry flocks in Europe, Africa, and India have been reportedly infected by the virus. The global march of bird flu is creating a sense of urgency in the international community. It has accelerated the search for effective strategies for combating health-related crises through prevention and early response.

The success of any strategy depends on the use of information technologies that provide timely and accurate information from local settings to international ones. However, the corresponding information challenges are formidable. One challenge countries face is generating and disseminating accurate and relevant baseline health information. At the same time, they must meet the challenge of developing effective surveillance and information analysis capabilities. In the event of a health-related crisis, countries must then be prepared to respond rapidly to incidents and coordinate across organizational boundaries and governments.

These information challenges impose two critical needs on any system designed to prevent and respond quickly to health-related crises. First, countries must develop an infrastructure for information collection, exchange, analysis, and dissemination. The other critical need is for interoperability that facilitates information sharing between organizations, regions, and governments. The ability of countries to meet the critical needs of infrastructure and interoperability can be mapped in the form of a maturity model that identifies their current state of information capacity and their readiness to deal with health-related crises. The maturity model provides a map for getting to progressively higher levels of maturity for effectively preventing and responding to health-related crises.

A mature national health information infrastructure is a system driven by common standards across an established telecommunications network. However, this stage is preceded by paper-based systems in which data is inconsistent and the telecommunications infrastructure is nonexistent or limited. Countries can begin moving from this rudimentary stage to higher levels through investment in its telecommunications infrastructure. They can also develop health information standards for capturing and processing medical information, beginning with basic patient and illness/condition data. Countries should first connect their major health information hubs (health departments of large cities, provinces, or states) to a national center. They should then expand the reach of the network to rural governments and remote communities.

A mature interoperable system is service-oriented, adaptive, and interoperable across levels of governments and national borders. This is preceded by an ad hoc, fragmented, and limited coordination stage. At this stage, health units have no protocol to exchange information. In a health crisis situation, local health units may not even know to whom they should report. Countries can begin establishing a basic level of interoperability by developing standards for the collection and storage of health data and a protocol for reporting health-related incidents. To move to a higher level of interoperability, they need to improve access to and use of health-related information acquired by different levels of government. Countries should also adopt a service-oriented architecture, which uses a common standard that permits all kinds of information systems to interface, allowing for interactions of stakeholders with different system specifications and for greater scalability.

Information infrastructure and interoperability for biosurveillance and response are capacities that should be built over time. A life-cycle management approach can facilitate incident-based learning. It also has the advantage of starting with basic capacity and growing through experience. This approach can be applied at either national or global levels. In building capacity over time, countries can decompose their systems into four manageable subsystems or stages: preparation; surveillance and detection; response and monitoring; and recovery and improvement.
**Vignette: A Hypothetical Scenario**

It started with a persistent cough and other flu-like symptoms that later included a rash on the cheeks and a swollen tongue. Within two weeks, 78 percent of diagnosed patients died of respiratory failure. Within three weeks, 800 patients were confirmed in the country. Almost simultaneously, the news broadcast that similar cases were identified but unconfirmed in neighboring countries numbering in the twenties.

The government in “Tajistan” (a fictional Asian country) reacted swiftly, having learned from the SARS crisis in 2003. It alerted the World Health Organization (WHO) and neighboring countries once it realized the disease’s threat. Borders were closed, flights cancelled, and several cities quarantined. As a result, the economy in Tajistan was devastated as citizens were required to remain home and businesses halted operations. Several Tajistanese hospital systems were also completely overrun, as 30 to 50 percent of healthcare workers caught the virus.

Even the swiftest action by the government in Tajistan had not prevented the disease from spreading beyond the region. The virus had already infected passengers aboard outbound ships before the disease was identified as a new form of the flu. The European Union (EU) decided early on that ships coming to their countries would be halted at sea or quarantined at port. Doctors in Hazmat suits boarded cargo ships with portable labs checking if passengers were infected by the same illness that had already killed so many in Tajistan. Despite these and other efforts, the virus was reported in Odessa, Amsterdam, and Hamburg.

Having had several weeks of notice; North and South American countries were largely able to stop the killer flu at their doorstep as they halted flights and ships from suspected hot spots. However, they were not immune from the effects of the virus. There was a general panic as citizens began to hoard medications. And businesses that embraced sourcing from and outsourcing to countries in Asia were dealing with the aftermath: production lines coming to a grinding halt, skyrocketing prices for parts, declining revenues, etc.

This scenario could have taken a different turn had Tajistan moved sooner to develop a proactive biosurveillance and response capability. Hospitals and healthcare providers, using established protocols, would have been entering real-time information about disease incidents into the central public health database. Real-time analysis of disease incidence would have triggered a rapid response to the unusual pattern of reported illnesses. The discovery of the unusual pattern would have triggered health alert bulletins across computing and telecommunications networks throughout Tajistan and abroad.

Within a few days, the Tajistanese Center for Disease Prevention and Control would have mobilized its scientific personnel to identify the virus with assistance from public health agencies around the world. In the meantime, city and national staff would have identified and alerted health resources to prepare for mobilization. Upon identification of the disease, health resources would have been mobilized using public and private networks and mobile telecommunications capacities. Public health agencies around the world would have also received information on the disease. In addition, transportation carriers, who would already have been alerted through private networks, would have taken appropriate steps for the outbreak. In a matter of a week, the health crisis would have been under control and fears and economic repercussions would have been minimized.
Informational Challenges for Preventing and Responding to Global Health-Related Crises

The global march of the H5N1 avian influenza (“bird flu”) has heightened the sense of urgency in the international community for strategies to effectively prevent and respond to health-related crises. This paper focuses on the information dimensions of these strategies. Prevention of an epidemic or pandemic relies on the time-honored methods of surveillance and response as articulated by Dr. John Snow, the pioneer of modern epidemiology. His mapping of the 1859 cholera outbreak in London to identify the source of the outbreak is still relevant today as a way of illustrating the use geographic information to understand the critical paths of a disease’s diffusion.

The principle of prevention and early response also applies to natural disasters. The common thread is the role of human action in mitigating the impact of natural disasters such as tsunamis, floods, droughts, hurricanes, tornadoes, etc. For example, floods may be caused by the lack of soil conservation or over development in flood plains. Tsunamis cause catastrophic casualty and property damage when they hit densely populated coasts without warning. As a result, disaster experts have called for early warning systems and education. Long-term solutions, which involve preventive measures to diminish or eliminate the consequences of natural disasters altogether, require tackling property and development issues (WHO, 2006).

Countries are faced with information challenges in effectively preventing and responding to naturally (e.g., existing diseases and illnesses, such as the increased incidence of diabetes mellitus; variants of existing ones, such as the emergence of drug-resistant forms of tuberculosis in the 1980s; and new ones, such as AIDS beginning in the early 1980s) and artificially occurring (e.g., bioterrorism) public health crises:

• Collect accurate and relevant health and healthcare resource baseline information.
• Generate critical information on the possible spread of conditions or illnesses.
• Collect response information and assess the effectiveness of the response.

These specific challenges are discussed next.

Generation and Dissemination of Accurate and Relevant Health Information

Two kinds of health information are critical for the prevention and response to health-related crises. Baseline information about disease and illness is essential for identifying unusual events. For instance, any unusual surge of flu-like symptoms in a geographic area can be detected only after a baseline is established for that area. Information about healthcare resources at various points of health service delivery is also critical (e.g., the number of healthcare professionals, hospital beds, and vaccines).

These kinds of information should be regularly collected at the local level with a common standard (or protocol) to ensure the quality of the information. Data collection points should go beyond urban hospitals that typically have the resources to collect and digitize health data. A country should also allocate resources to collect health data at rural hospitals, clinics, health stations, and mobile health units. Data entry should follow a common standard, preferably a standard form including required data elements and fields for additional notes. A standard format can improve data quality and allows for automatic digitizing. Health information ideally should be collected at the time of service rendering if a computerized system is available. If not, regular updating should be required.
The generation and timely dissemination of accurate health information to the right people requires attention to both digitizing health information and the mobile nature of health service rendering. The guiding principle is to start with digitizing the most critical medical information such as blood type, major medical conditions, and drug reactions. Several countries including Britain and Singapore are considering having such information embedded in a health identification card for all citizens. Then, the digitizing effort should move on to the next constellation of health information that gives a country the best return on its investment. Building a national digital health information system enables the detection of diseases. The mobile nature of health services means that using mobile devices and wireless networks will enhance the real-time collection and dissemination of data.

**Surveillance and Information Analysis Capability**

A second set of information challenges involves processing and analyzing relevant data to detect a particular condition or illness. In comparison to the national healthcare information referred to above, the surveillance system relies more on matching information about conditions/illnesses. It involves the monitoring of known illnesses and conditions and their spread over space and time. For instance, most countries in Asia now have a system in place to monitor SARS (Severe Acute Respiratory Syndrome). The goal is early detection to ward off any major outbreaks.

An effective surveillance strategy requires the integration of health data with other, often diverse databases such as airline passenger lists, family contacts, and more. The level of integration varies among countries. A more mature surveillance system will have established links to these databases or some form of collaborative information infrastructure to facilitate information exchange. Moreover, such a system devotes resources to ground-level intelligence gathering such as sending out teams to affected areas for even more targeted surveillance.

Another challenge is the capability to conduct complex analyses of voluminous data with temporal and spatial dimensions. Conducting complex analysis requires the combination of two things: (a) human intelligence that embodies the experience and intuition on the nature of the problems to generate hypotheses on the origin and spread of the health problems; and (b) artificial intelligence that utilizes data mining and pattern recognition software programs for quick testing of these hypotheses. Models and software programs that utilize geo-spatial information over time are useful in identifying patterns.

**Rapid Incident Response and Cross-Boundary Coordination**

The nature of information challenges shifts once the health problem becomes a crisis where rapid response is critical. At this stage, the information needs are similar to an emergency management situation. First, real-time information gathering and dissemination is needed as the situation may evolve rapidly. The SARS experience taught us about the public health, societal, and business costs associated with the delay of information gathering and dissemination.

Second, a health emergency response system should have information about incidents and resources available to effectively respond to them. This will include information on emergency responders, healthcare resources, and baseline health information (as stated earlier). It will also include information on responders’ respective responsibilities in a crisis situation. For instance, first responders need to know where their responsibilities begin and end and how they coordinate with healthcare professionals. As evident in the Global Outbreak Alert and Response System sponsored by the World Health Organization, there is a need for combining both alert and response information for dealing with health-related emergencies.

Lastly, the information challenge is the one of exchanging, verifying, and integrating information from multiple sectors (public, private, and nonprofit) and from all levels of government. As vividly shown by experiences with SARS and the bird flu, health crises knows no boundaries and respects no political jurisdictions. A Canadian woman carried the SARS virus from Hong Kong to Toronto Canada in less than a day. A Chinese-American businessman transported the virus from Hong Kong to Hanoi, Vietnam. A timely exchange of information first requires the identification of relevant parties that should be involved in responding to health-related crises. Such identification may not be institutionalized in many countries. Then, it requires a platform or system for involved parties at all levels to share information. However, in the case of SARS, barriers such as cultures of secrecy, bureaucracy, and poor information and communication infrastructures have impeded coordination.
A Maturity Model for Addressing Information Challenges

The information challenges point to two important dimensions of capacity building for dealing with prevention of and response to health-related crises. The first dimension relates to information infrastructure for information collection, exchange, analysis, and dissemination. Drawing upon the experience with SARS, this infrastructure should be in place even before the emergence of a health crisis for “domestic and international exchange and decision-making” (Ursacki-Bryant et al., 2005, p.3). The scope of information needs should correspond to the scope of problems. Scholars and practitioners working in the areas of emergency management have argued for the need for a scalable information infrastructure to facilitate the exchange of information (Comfort, 2005). Both the temporal and spatial dimensions should be included in an information infrastructure.

The other dimension is interoperability that facilitates information sharing across governments and sectors. Interoperability is the ability of information systems to exchange information in order to effectively operate together to achieve a common objective. One of the major problems facing many governments around the world is the lack of interoperability among systems. In the United States, the prevalence of private providers of healthcare services does not allow easy integration of health information across hospitals or healthcare providers. The United States Congress is currently considering a regional approach to voluntary sharing of information. The need for integrating information from multiple sectors and units of governments further compounds the problem. The problem manifests itself when a crisis demands that emergency units work together and share relevant information.

A maturity model that incorporates infrastructure and interoperability is illustrated in Figure 1. This model helps enable countries to identify their current state of information capacity and readiness in order to deal with health-related crises. In addition, it provides heuristics for moving to a higher level of maturity. In the next two sections, we address the two dimensions—health information infrastructure and interoperability—in greater detail.

Figure 1. A Maturity Model for Information Technology Readiness for Health Related Crises

Building a Health Information Infrastructure: From Rudiments to a National System

Information infrastructure has two interrelated components. First, a governing infrastructure prescribes data and information processing standards. Second, a technical infrastructure contains computing and telecommunications networks, applications, and data centers. When building a national health information infrastructure, countries typically occupy one of three stages.

Stage 1: Paper-based, Inconsistent, and Disparate Health Data with Limited Computing and Telecommunications Infrastructure

At this first stage, countries primarily have a paper-based health information system; developing countries are usually at this stage. There are no state/provincial or national standards available to guide the development of forms for the collection of health information. As a result, the data on these paper files is typically inconsistent, particularly for emerging health issues. This may be less the case for more standard medical procedures and common symptoms. Accessing this paper-based information is time consuming and labor intensive.

Poor computer and telecommunications infrastructures further exacerbate the problem. Computer equipment and software applications for storing and organizing
health information in digital format are likely to be in short supply. Even if some health information is digitized and easy to transmit over long distance, poor telecommunications infrastructure, such as reliable phone and internet services, continues to present significant barriers.

The limited reach to rural communities is an additional complication. Small rural communities are at a significant disadvantage in their computing and telecommunications infrastructure as compared to large cities. An urban hospital is more likely to have and utilize modern computers and applications to digitize and collect health information. A robust telecommunications infrastructure may also exists between this main hospital and several satellite offices in nearby cities. In contrast, remote rural communities may only have a mobile health station which periodically visits. This is particularly problematic when health-related crises often originate in remote communities where health facilities and knowledge are limited.

To move up on the ladder of maturity, countries must first address basic health information infrastructure issues. Investment in telecommunications infrastructure with special attention to health information is a starting point. Some countries can “leapfrog” by utilizing wireless networks rather than building a land-based fiber-optic or phone-line based network. The other main task is the development and implementation of health information standards. A practical approach may begin with developing standards for capturing and processing the most critical medical information such as weight, height, and diseases for individuals. Development of patient record information standards should go hand-in-hand with information standards for recording agreed upon incidents of conditions and illnesses.

**Stage 2: Standards for Digital Health Information Collection and Processing and Some Basic Health Telecommunications Infrastructure**

Data is the most basic building block of any modern health information infrastructure. Without common data definitions and processing standards, these building blocks cannot be integrated to serve a specific citizen (patient). Imagine a scenario where the primary identifier (i.e. social security number, name, automatically created number, etc.) of a patient is not consistently entered in two different hospitals. A query aiming to integrate that patient’s information would fail without additional labor intensive work to reconcile differences. It is also important for health workers to use common clinical terms when creating health records so they are able to communicate accurately and efficiently.

Data definitions include data type, length, format, among other characteristics. Building common standards for data constitutes the most important organizational process for facilitating the portability and integration of data elements at various levels. File format is another challenge. The healthcare sector has a myriad of data files including text, graphic, audio, and video files with various formats for each. One patient alone may have basic medical information and appointment records in text format, X-rays, ultrasonic graphics, audio or video files, etc.

Processing standards constitute an integral part of information standards. A primary objective for these standards is the protection of patient confidentiality. Security measures taken in delivery, dissemination, and exchange of health information are meant to protect the desired level of confidentiality. Each country is likely to have its own standards depending on the level of confidentiality that it wishes to provide for its citizens. In European Union (EU) countries, the EU Directive on the Protection of Personal Data created in 1998 is likely to serve as a framework. In the United States, the Health Insurance Portability and Accountability Act of 1996 (HIPAA) provides some guidelines for processing health information.

This second stage covers a wide spectrum of health information infrastructure readiness. Countries at the beginning of this stage have national rules and regulations about basic standards for health information processing. The other key characteristic for those at the lower end of this maturity level is to have a functional computing and telecommunications infrastructure that covers major health facilities in major population centers. As countries move toward building health information telecommunications infrastructure, they will first connect their major health information hubs (health departments of large cities, provinces or states) to a national center. Then, they will expand the reach of the network to local governments and remote communities.

China serves as a model example of moving aggressively from the lower to the high end of maturity at this stage. After the SARS outbreak in 2003, the Chinese Ministry of Health acknowledged specific areas for improvement in the public health information system such as streamlining reporting, establishing national health information standards, and providing network connections to local
The main objective of a national health information infrastructure is to provide the information necessary to help keep its citizens well and to offer better care to citizens (or patients) in a timely fashion when they need health services. The infrastructure should serve as the platform for the generation and exchange of healthcare information in times of normal operations, as well as crises. It should first allow the collection of healthcare information for all citizens to establish baseline information and an inventory of healthcare resources. In its design, emergency health information should be documented at the level of patients (individuals). Figure 2 illustrates the basic elements of a national health information infrastructure.

![Diagram of National Health Information Infrastructure](image)

**Figure 2. National Health Information Infrastructure**

The national health information infrastructure includes both information standards and infrastructure. Information standards have both data standards and information processing standards. The infrastructure deals with the technical capacity and the network of systems to facilitate information gathering and exchange in a distributed environment that covers various levels of health service delivery units and vast geography. This infrastructure should provide speed, reliability, and security.

Computing and telecommunications networks (or a network of local networks) are critical in enabling access to a centralized or virtual national data center that receives information feeds from various databases following common information processing standards. A unique challenge facing healthcare service providers is the bandwidth requirement for data intensive health records such as image files. This network is usually a combination of public (Internet) and private networks. Private networks have the advantage of having dedicated bandwidth for

**Stage 3: National Health Information Infrastructure with Common Standards and a Mature Network and Telecommunications Infrastructure**

Health units (Ministry of Health, 2003). China has since completed a nationwide information system for disease control and prevention with the investment of 10.5 billion Yuan (1.28 billion U.S. dollars) (Xinhaunet, Jan. 6, 2006).

A primary guiding principle in building this national health information system is the development of common standards. Information standards include data definitions, information processing standards, and information exchange protocols. These standards should be followed by all levels of governments to ensure compatibility.

Health information communications networks are multi-layered. In China, for instance, the health information communication network consists of five levels that correspond to five levels of governments and health units: municipalities, prefectures (counties), cities, provinces, and national government (Ministry of Health, 2003). At each level, there is two-way communication between health departments and local health units such as hospitals and mobile health stations. At the lowest level of government, the health units can connect to systems at the county level or above through dial-up telephone or other connections. They can obtain basic information on disease control and submit incident reports. For some county governments that have the resources and computing facilities, they can connect directly into the national public networks or access them through a dial-up. They are responsible for collecting information, compiling reports, and conducting analyses.

City governments are responsible for coordinating information exchange in addition to reporting and information analysis. They form the most basic platform where they not only produce health information databases but also coordinate public health information exchange during health-related crises. At this level, the responsible health department has a dedicated connection into the national public health information network. At the provincial level, health departments have responsibilities similar to those of city governments. The only difference is scope and coverage. The health data and coordination efforts are made for the province as a whole. At the national level, the health information system includes the infrastructure (platform) for information exchange, data centers, and incident command centers.

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the transmission of critical medical data and the ease of information security implementation. Public networks are more open and available for quick and low-cost access.

The infrastructure requires an integrated and holistic configuration of data centers and networks. The goal is to maximize healthcare professionals and individuals’ ability to address health problems and emergencies both in isolation and collectively. Citizens should be able to access critical medical information such as summaries of major medical conditions and drug reactions. Healthcare professionals should have access to all relevant patient records. These records may be in different formats and generated from various healthcare units around the country.

Very few countries have reached this stage of maturity. Countries usually start with the capital city or the major metropolitan region to first gain experience with establishing a national network with common standards. For instance, Denmark is expected to complete a comprehensive health infrastructure around Copenhagen by 2007 (The Economist, 2005).

The model effort in the area of building a national health information infrastructure for the creation and distribution of health information is the National Health Service (NHS) in Britain. The information strategy of NHS also iterates the goal of meeting healthcare information needed to provide better care to patients (Burns, 1998).

Setting information standards at the national level is the approach taken by the NHS (Burns, 1999). A Clinical Data Standards Board is responsible for prescribing common standards. These standards govern data definitions and file formats for all information needs. This effort is not only about the generation of new health information but also about historical information, which is managed by the National Electronic Library for Health. More fundamentally, it is about the creation of health-related knowledge so that it is accessible by healthcare professionals and citizens alike in dealing with health-related problems. NHS’s information strategic plan articulates the need for common data and processing standards. These standards build the foundation for an electronic health record system. This system supports self-health management by individuals, delivery of routine care by healthcare professionals, and 24/7 emergency health services (Burns, 1999).

The National Health Service’s experience is also instructive for setting up a telecommunications infrastructure. It opted for a dedicated network for moving healthcare data. It is the NHS “information superhighway,” called NHS Network (NHSnet) to transfer clinical information. This infrastructure gives every clinician and support staff in the NHS broadband access (>128kbps). It has an increased bandwidth to minimum 2 Mbps between trusts and across the NHS Net Gateway (DOH, p.5). This network also enables the delivery of telemedicine. At the same time, the NHS also recognizes the value of the Internet to enable a community of knowledge networks that span beyond clinical information.

The telecommunications infrastructure supports the operation of several national information systems for health services. The national health record service system, which maximizes speed and access, is the main system. It is a two-tier structure. The national tier has core medical information for quick access and display. It is particularly useful in dealing with medical emergencies and the mobile nature of healthcare services. The local tier has full record access and is linked to the national data spine via reference links. These reference links allow healthcare workers to drill down to get more detailed information from the national data spine. The local tier consists of five regions, London, North East England, North West England and the West Midlands, East England, and the South. Each region is responsible for upgrading its information systems and data migration. As a result, each region is able to feed the national health record service system with historical and current clinic information in digital format.

Another information system is the national electronic booking services. With the system fully implemented, individuals are able to check availability of doctors and procedures and make appointments accordingly. This system has full clinician and patient functionality. This service is integrated into a Web portal, Digital TV, and wireless device to provide easy access on the patients/citizens’ term. Moreover, there are information systems such as Electronic Transmission of Prescriptions (ETP), Picture Archiving and Communication Systems (PACS), Quality Management and Analysis System, and the Contact e-mail and Directory Service (NHS, 2005).

Realizing Interoperability across Levels of Governments, Sectors, and National Borders

A national health information infrastructure makes significant contributions to the prevention and response to health-related crises in two ways. First, it provides the infrastructure for early detection of any health-related problems, known or unknown. For example, frontline healthcare professionals can report suspicious cases
when conducting routine health checks in a remote area or a clinic. Second, it provides vast amounts of health information for analysis of problems and mobilization of healthcare resources. For example, epidemiologists can analyze the spatial dispersion of cases to identify the path along which flu spreads. They are then able to develop and implement effective responses.

Although the national health information infrastructure is essential for effective response, it is not sufficient for addressing global health crises. An effective national response to even a localized health crisis requires the mobilization of police, schools, fire departments, emergency management systems, etc., in addition to health information accessible through the national health information infrastructure. Global health crises further require coordination of national governments, for example, in information sharing and control of transportation nodes.

A fully interoperable system, as indicated in Figure 1, covers all levels of governments with interactions with nonprofit, private, and government entities for emergency response. Moreover, such a system allows a country to exchange information with other countries in real time to effectively address global health crises. Three stages in the maturity of interoperability are described so that countries can identify their current stage and take necessary measures to move to a fully interoperable system.

**Stage 1. Ad-hoc, Fragmented, and Limited Coordination**

At this stage, coordination for the exchange of health and emergency information is conducted on an ad-hoc basis. There is no protocol for or automation of health information exchange. In a health crisis situation, healthcare workers and emergency personnel have very limited access to health information in other parts of the country. Government officials or healthcare workers are left to improvise with limited resources. In the end, the reporting of an incident may take days or weeks to reach the appropriate authorities. This is particularly apparent when remote communities are involved in the reporting. The experience of SARS in China shows that the process of moving a report through various layers of government may take eight to nine days (Ministry of Health, 2003).

Many developing countries are at this stage of interoperability. Countries can take several specific steps to establish some basic level of interoperability. First, they need to develop a protocol for reporting health-related incidents. At minimum, local healthcare officials should know to whom they can report public health matters. Second, countries can begin introducing information standards for the collection and storage of health data. Making telecommunications equipment available to local health stations is another important step toward increasing maturity. Lastly, countries need to examine the rules for units of departments that work together. This could include streamlining reporting and information exchange.

**Stage 2: Some Integration, Limited Number of Participating Information Systems**

At this stage, countries begin to see some integration of information systems across levels of government and among governmental units at the same level. This kind of integration depends on the willingness of jurisdictions and sovereigns to interface their information systems with others. It is well documented that one of the challenges facing information sharing collaborations is about access and use control. Local bureaucrats have incentives to hide information on health problems from higher authorities to avoid sanctions imposed by higher levels of government. Countries may decide to delay the announcement health problems either to avoid unwanted international attention or intervention.

Integration of health information systems at this stage is visible. It is most likely to be manifest in a national public health information system for keeping track of public health incidents around the country and in the option of direct reporting by local health units. A system supported by telecommunications networks would allow government officials to monitor the flow of medical supplies and availability of medical staff in times of health crises.

A major limitation of a biosurveillance information system at this stage is its ability to interoperate with other departments in charge of emergency management such as police, fire, and relief organizations. The participation of information systems belonging to other departments of government is limited. Another limitation is its interoperability with information systems of international organizations or those of other countries.

The biosurveillance systems in a large majority of countries now operate at this stage. To move to a higher level of interoperability, countries need to improve access to and use of health related information acquired by different levels of government as a way to facilitate...
information sharing. Improving access builds a trusted environment for governmental units to share information. This goes hand-in-hand with establishing the health information infrastructure that serves as a platform for information exchange.

Moreover, countries that integrate their health information systems with other emergency management information systems take another step toward greater interoperability. They can begin by conducting a simulation of a health-related crisis to identify the organizations involved and information needs from these various organizations. Using what they learn in simulations, countries can develop a set of guidelines and procedures for crisis situations. The preparatory work is likely to remove uncertainties and barriers to information sharing, especially at the times of crises. When fully developed, Britain’s NHS has a high interoperability of all health units at various levels of government. However, it still needs to make progress in the area of interoperability with the information systems of other sectors and countries, which is the thrust of stage 3.

**Stage 3: Service-Oriented, Adaptive, and Interoperable**

Countries at this stage integrate systems of organizations at various levels of governments and across national borders. Interoperability at this stage incorporates the two main characteristics of a sound emergency management system in its capability to handle information. First, the systems have the ability to gather both the basic and action information from all types of actors involved. Second, the systems can be scaled and integrated at various levels (from local to international) (Comfort, 2005).

A service-oriented architecture (SOA) promotes these two key characteristics. SOA is a promising method of improving interoperability for information systems built with different hardware platforms, operating systems, and programming language. The architecture provides the platform for uniform and universal interactions between information systems. The concept is particularly attractive in the provision of public services such as health and emergency management where a plethora of existing information systems and applications need to interact with one another in times of crises.

SOA allows for interactions of stakeholders with different system specifications. It uses a common standard that permits all kinds of information systems regardless of their basic designs to interface.

Scalability is another design feature of SOA. Systems can be integrated into or separated from the interface environment as needed by following established protocols. For example, through a web portal, individuals can get access to the system and share information.

The relationships between national information infrastructures and global networks for health crises are illustrated in Figure 3.

![Figure 3. National and Global Networks of Health Crisis Prevention and Response](image)

Interoperability for cross-boundary cooperation is particularly challenging. The World Health Organization, in fighting health-related crisis, has developed a loosely coupled Global Outbreak Alert and Response Network (GOARN). This is a network of United Nations organizations, national government health agencies, and nonprofit organizations engaged in information sharing and healthcare resource mobilization (WHO, GOARN). The guiding principles developed by GOARN are instructive for enhancing global interoperability. Specifically, these principles include the need for verification of critical information, deploying experts in the field for timely response coordination, involvement of nongovernmental organizations (NGOs), respect and quality of the process, and capacity building (WHO, Guiding Principles).

These principles are then implemented through the operational protocols for standardization of epidemiologic management, research, communications, and logistics support.

A better connection between GOARN and national health information infrastructures will allow the global community to better respond to global health-related crises. Individual countries can provide timely and detailed information such as the origin and spread of the
outbreak, availability of medical resources, and status of quarantines. More importantly, greater international interoperability will allow both affected countries and the global community to learn from experience what information is needed and to whom and how fast such information should be disseminated.

Service-oriented architecture at either the national or global level improves the affected countries and parties ability to interface and respond. One additional feature of SOA is its ability to adapt to changing environments. The focus is on the processes that support service. As a result, collaboration is possible among the participants regardless of the national or local information systems used as long as they can interoperate via a common language defined by the SOA.

**Bio-Surveillance and Response Capacity Building: A Life-Cycle Management Approach**

The maturity model provides a map for countries to make progress along building health information infrastructure and interoperability. These capacities for biosurveillance and response need to be built over time. A life-cycle management approach provides an incident-based perspective that complements the maturity model. A country can examine its readiness in biosurveillance and response by looking at the phases of an incident’s life-cycle: preparation; surveillance and detection; response and monitoring; and recovery and improvement. Figure 4 illustrates the target of opportunities for each country to identify when building its biosurveillance and response capability. For instance, a country at stage I for health information infrastructure and interoperability can identify the tasks they need to accomplish in relation to preparation.

This life-cycle management approach has the advantage of starting with basic capacity and growing through experience. This management approach can be applied at either a national or global level. In building capacity over time, countries can decompose their systems into four manageable subsystems or stages: preparation; surveillance and detection; response and monitoring; and recovery and improvement. The process of capacity building is illustrated in Figure 5.

**Preparation**

Preparation should concentrate on both information infrastructure and interoperability. For information standards and processes, a country or jurisdiction can start with a limited set of standards. One option is to focus on the most critical medical information that a country typically saves in its data spine for the development of a common standard. That will give a country the immediate benefits of having vital healthcare information in times of emergency. A country can gradually expand its set of information definitions and processing standards to a growing array of health information depending on its respective added value. Moreover, it can build the telecommunications infrastructure to handle increasing traffic over time.

A service-oriented architecture is an effective way to quickly increase interoperability. A practical approach will begin with a limited number of information systems with manageable complexity. The number of systems chosen will depend on a country’s development time.
and resources. The development of a service-oriented architecture is also a learning process where issues with standards and the use of interface language can be identified and resolved. A possible starting point is to integrate the health emergency report system with the patient care systems of the leading hospitals in a country. This architecture can then be expanded to connect more hospitals. The next step is to include other organizations such as non-profit disaster relief organizations and other government departments (e.g., fire, police). The final step is to connect across national boundaries.

Emergency preparedness is enhanced by doing simulations such as “table-top” exercises and drills. Such simulations can be used to gauge the infrastructure and interoperability of the information system. A knowledge management system is also needed to take the lessons learned to continuously improve the information system’s ability to respond. One important guideline for testing is to go beyond the scope of routine activities and standard parameters. Testing is best done on a series of unstructured and organic events.

One capability of the system is to conduct vulnerability and threat analyses. By leveraging knowledge created in previous scenarios of health crises that occurred either locally or globally, countries can conduct vulnerability and threat analyses. These analyses should follow a risk management framework that classifies activities into high, medium, and low risks. As a result, governments can prioritize their resources to go into the high risk areas and increase infrastructure and interoperability to increase their preparedness.

**Surveillance and Detection**

Surveillance and detection are most effective when active scanning and analysis are regularly conducted. A less developed system is a rudimentary reporting system where doctors who have a suspicion of known virus cases report them to either a national government or international organization. It may take days or weeks for the accumulation of enough cases to trigger an appropriate level of surveillance and response using the more rudimentary reporting system.

A more mature surveillance and detection system has several features. First, it builds on a health information infrastructure and interoperability to gain access to health information at all levels. For instance, when a suspicious outbreak of an illness is identified, the system enables public health professionals screen health records for similar cases. This relies on a mature national health information infrastructure that covers even citizens in remote areas. Second, it has built-in automatic detection algorithms that are able to continuously scan suspicious cases for known viruses. Given the vast amount of the health information and cases, it is only feasible for setting up an automatic process for detection of potential problems.

In addition, a more effective system has the ability to analyze both spatial and temporal dimensions of the problem. In the case of bird flu, birds can carry the virus and travel long distance within 24 hours. Affected people can move from one distant point to another within 24 hours with access to an international airport. For instance, during the SARS epidemic an affected person carried the virus from Hong Kong to Toronto in less than 24 hours. Being able to show the cases not only spatially but also over time allows for effective surveillance. A geographic information system building on top of a national health information infrastructure or a more advanced version of GOARN gives the needed analytical power to give information on known cases spread over space and time as well as exploring various factors such as climate, transportation systems, and available healthcare resources in the vicinity.

**Response and Monitoring**

The deployment of an incident command system is an established approach to effective response and monitoring. The success of the information dimension of such a system depends on the extent to which a common information infrastructure is in place and the degree to which various systems are able to interoperate. At minimum, an incident command system requires a common terminology (DHS, 2004, 9-12). For example, what constitutes an incident of bird flu needs to be understood by all parties without any ambiguity. An incident can be defined as a person affected by it or a series of events associated with a particular infection. A common understanding of key terms is critical.
Integrated communications are a key part of the information infrastructure. Wireless and wired communication must be integrated. A basic system may only involve a radio dispatch system that allows respondents to talk to a central station. A more sophisticated system empowers each respondent to gain real-time response effort information as well as conduct online analytical processing.

The goal of interoperability is to achieve a common operating picture. Such a picture is critical for making an informed decision and rapid mobilization of resources. This common operating picture is only possible with information feeds from groups of participants (Comfort, 2005). The efforts made at the previous two stages of the life cycle play a determining role in the effectiveness of this phase. Information exchange agreements should have been worked out between stakeholders, including hospitals, government health agencies, fire and policy departments, and nonprofit organizations. Access control and management should be in place to offer role-based access. Depending on the assigned responsibility of the respondent, he or she should get access to relevant information.

The emphasis at this stage of response is the ability to get the right information to the right person in real-time. The urgent nature of the response dictates the need for real-time information. Monitoring should also be conducted on a real-time basis. The use of visualization tools such as geographic information system for monitoring and response ease the burden of information processing on individuals. Visualization also allows for the exploration of various theories about better ways of responding to a crisis.

**Recovery and Improvement**

An effective recovery and improvement for health information technology is predicated upon the system’s ability to continuously learn. A basic use of technology at this phase may involve the use of teleconferencing tools to bring participants together to share the lessons learned. The summary of the exchange during those conferences serves as the basis for coping with similar health crises in the future. For instance, one of the lessons learned in Taiwan’s response to SARS was the need to establish an incident command system much earlier in the process.

A systematic learning effort involves several steps. First, it assesses the effectiveness and efficiency of the response to a health-related crisis. The assessment team will begin with a performance matrix to identify high impact activities and how effective these activities are in responding to a health-related crisis. For instance, the team can investigate any information channeling bottlenecks and delay in ground level response. Attention needs to be given to the infrastructure and interoperability issues discussed early in this report.

Second, systematic learning creates recommendations for closing gaps in infrastructure and interoperability. This forms a feedback loop to the preparation phase to complete the life cycle. For instance, if there were missed cases due to the confusion about the case screening criteria, better clarification and standardization of key terms and criteria are in order. If the problem was a communication breakdown due to the lack of mobile communication infrastructure to connect with a central incident command system, the recommendation will involve having a more integrated communication system that addresses the connectivity between networks.

The learning process needs to be supported by a knowledge management system that acquires, creates, shares, codifies, and stores knowledge. A systematic assessment done by countries individually or networks globally helps create knowledge about what does and does not work. What is important to capture, as knowledge management experts suggest, is the tacit knowledge that tends only to reside in people’s heads. A codified knowledge about the critical path of spread helps develop the algorithm to automate the detection of known patterns. The stored knowledge of individual countries can be shared and accessed for the development of a more responsive system in prevention and preparation for future health crises.
Conclusion and Recommendations
Countries around the globe have recognized the urgency to develop effective strategies to prevent and respond to health-related crises. This paper focused on the information technology as an integral component of this strategy. More specifically, it identifies the challenges of generating, collecting, and disseminating information for health-related crises. Moreover, it recognizes the challenge involved in analysis of information. To respond to crises, the ability to pull information from various sectors and levels of government is imperative, which constitutes another information challenge.

An integrated approach to meet those information challenges employs a maturity model. The maturity model serves as a map for countries at various levels of development in health information infrastructure and interoperability to move to a higher level of maturity. A life-cycle management approach offers a more detailed, complementary way to identify opportunities to build health information and interoperability capacity. A country can assess what opportunities exist in preparation, surveillance and detection, response and monitoring, and recovery and improvement.

Our recommendations for increasing maturity and managing life-cycles are summarized below.

Improving the Maturity of Health Information Infrastructure
To move from paper-based systems with inconsistent data and no telecommunications (stage 1) to standardized digital health information and basic health telecommunications infrastructure (stage 2):
- Develop health information standards by beginning with the most critical medical information such as weight, height, and diseases for individuals;
- Develop patient record information standards;
- Gradually increase investments in telecommunications infrastructure, giving special attention to health information.

To move from standardized digital health information and basic health telecommunications infrastructure (stage 2) to a national health information infrastructure with common standards and mature network and telecommunications infrastructure (stage 3):
- Create national rules and regulations about basic standards for health information processing;
- Connect major health information hubs (health departments of large cities, provinces or states) to a national center
- After major hubs are connected, expand the network outwards to remote locations.

Improving Interoperability Maturity
To move from interoperability characterized by ad hoc, fragmented and limited coordination (stage 1) to multi-level integration among limited participating information systems (stage 2):
- Begin by developing a protocol for reporting health-related incidents;
- Clarify reporting lines for local healthcare officials to report public health problems;
- Introduce information standards for the collection and storage of health data;
- Make telecommunications equipment available to local health stations;
- Review and begin developing rules for units of departments to work together;
- Conduct simulations of health-related crises to identify organizations involved and information needs for these organizations;
- Begin to integrate health information systems with other emergency management information systems.

To move from multi-level integration among limited participating information systems (stage 2) to service-oriented, adaptive, interoperability across levels of governments and national borders (stage 3):
- Create common standards that permit all kinds of information systems to interface;
- Incorporate service-oriented architectures that are scalable, allowing systems to be integrated or separated from interfaces by following established protocols.
**Building Capability through a Life-Cycle Management Approach**

To build capacity in preparation, a country can:
- Identify gaps in its health information infrastructure;
- Identify deficiencies in interoperability;
- Conduct simulation or table top exercise to map all information needs in response to health-related crises.

To build capacity in surveillance and detection, a country can:
- Make surveillance an on-going effort;
- Build surveillance and detection information gathering on health information infrastructure;
- Increase analytical ability to identify suspicious pattern in the health data across space and time.

To build capacity in response and monitoring, a country can:
- Develop an incident command system to generate a common operating picture for all parties involved;
- Build an integrated communication infrastructure to include organizations at various levels of government and belonging to different sectors.

To build capacity in recovery and improvement, a country can:
- Conduct review and assessment of the effectiveness of the response to health-related crises;
- Build a knowledge management system to capture learning;
- Feed the lessons learned into the next round of development and improvement.
References


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