Investigating public health emergency response information system initiatives in China

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Summary Infectious diseases pose a great danger to public health internationally. The outbreak of SARS has exposed China's fragile public health system and its limited ability to detect and respond to emergencies in a timely and effective manner. In order to strengthen its capability of responding to future public health emergencies, China is developing a public health emergency response information system (PHERIS) to facilitate disease surveillance, detection, reporting, and response. The purpose of this study is to investigate the ongoing development of China's PHERIS. This paper analyzes the problems of China's existing public health system and describes the design and functionalities of PHERIS from both technical and managerial aspects.
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1. Introduction

Recent years have witnessed a number of microbial threats which have greatly jeopardized public health in many areas of the world. One of the most publicized cases is severe acute respiratory syndrome (SARS) whose outbreak and rapid spread in more than 25 countries in early 2003, claimed numerous lives and caused tremendous economic losses. Other public health threats include the recent anthrax attack and outbreak of avian influenza in the United States. It is predicted that new pathogens, originating either naturally or from bioterrorism, will continue to emerge and cause new public health emergencies [1]. In order to contain the spread of infectious diseases, preparedness planning, a vigilant health system, strengthened domestic, and global disease surveil-

lance, and strong interdisciplinary partnerships are needed. Admittedly, information technology which facilitates access to critical information at the opportune moment will play a strategic role in improving the delivery and effectiveness of quality patient care, and helping domestic and international communities to adequately respond to medical emergencies in a timely and efficient manner.

After the first patient at China's Guangdong province was infected by SARS, this strong contagious disease was transmitted to health care workers and family members in Hong Kong, Vietnam, Singapore, and Canada within days, providing a vivid illustration of the rapidity and ease with which infectious disease can spread to pose a global public health threat [1]. Therefore, response to public health emergencies should be regarded as a global issue and a close worldwide co-ordination is needed. Particular attention should be paid to developing countries that have relatively fewer resources to deal with public health emergencies. China was one of the countries that were the most affected by SARS. Among the 8445 cases re-

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ported to the World Health Organization (WHO), 5327 (63%) were from China [2]. Exploiting many effective control measures, China was able to successfully deter the outbreak in a relatively short time [3]. Nonetheless, the rampancy of SARS in the early stage of the outbreak has resulted in a chaos and exposed the fragility of China's public health information systems. As Qiang Gao, the secretary of the Ministry of Health (MOH), admitted [4]:

> In terms of our work, MOH was not well prepared against the sudden public health hazards and its epidemic prevention system was relatively weak. Following the outbreak, the Ministry failed to institute a timely and unified mechanism for collecting, processing and reporting the relevant information nationwide and it did not give out clear cut instructions or effective guidance. . . . Due to a lack of a sound system of information collection, surveillance reporting and contact tracing there have appeared major weaknesses in statistics compilation on the epidemic on the part of the relevant agencies and accurate figures have not been reported to higher authorities in a timely manner.

Realizing the weakness of its public health systems, China is undertaking tremendous efforts to improve its public health system by leveraging the power of information technology. The Chinese central and local governments have appropriated sizable financial resources to build a public health emergency response information system (PHERIS). The purpose of this paper is to investigate the on-going development of China's PHERIS. The paper reviews the literature regarding emergency response information systems, analyzes the weakness of China's old public health system, and describes the design and functionalities of PHERIS from both technical and managerial aspects.

2. Literature review

A large portion of past research and development on emergency response systems has been conducted in the United States mostly because of the past and potential future terrorist attacks [5—8]. In order to identify the relevant literature, we searched research databases including PubMed, IEEE Explore, and ACM Digital Library. The search was performed, using different combination of keywords, such as ''public health'', ''emergency system'', ''emergency response'', ''emergency response systems'', ''surveillance'', and ''bioterrorism''. We also collected information from the official websites of organizations, including the Centers of Disease

Control and Prevention (CDC), the Agency for Healthcare Research and Quality (AHRQ), and the Health and Human Services (HHS), which have been sponsoring emergency response information systems initiatives. In this section we will review some major IT development and research initiatives that have been completed or are currently undergoing in the US. It should be noted that this review does not represent a comprehensive coverage of the entire body of research and practice relating to public health emergency information systems, as we only selected those that we believed are most relevant to the topic of this article.

Motivated by a series of naturally occurring and manmade disasters, federal and state governments, as well as private companies, have implemented numerous initiatives to create co-ordinated systems for surveillance, detection, and response. Given the wide recognition that the application of information technology (IT) provides previously unfathomed opportunities to improve public health practice [9—11], many of these initiatives have sought the exploitation of IT to resolve public health threats. According to the Agency for Healthcare Research and Quality (AHRQ), there exist 217 information technologies and decision support systems of potential use in the event of a bioterrorist attack or other public health emergencies involving naturally occurring epidemics [12]. One of the most important applications of IT is public health surveillance which encompasses the ongoing systematic collection, analysis, and interpretation of health-related data for use in planning, implementing, and evaluating public health practice [13,14]. Some example surveillance systems include a national retail data monitor which was designed to collect and analyze sales of over-the-counter health products to detect outbreak of disease [15], a clinical data warehouse which was used for hospital infection control [16], a data mining surveillance system which can provide sophisticated capability to control hospital infection and public health [17], and a real-time outbreak and disaster surveillance system which was utilized for early detection of disease outbreaks [18].

In order to integrate isolated information systems which support communications for public health labs, the clinical community, and state and local health departments and to capitalize on the potential for a cross-fertilization of data exchange, some national level projects have been implemented in the US for early detection of public health threats. The Public Health Information Network (PHIN) is a framework created by the Centers of Disease Control and Prevention (CDC). Based on defined data and vocabulary standards and strong collaborative

relationships, the PHIN will enable consistent exchange of response, health, and disease tracking data between public health partners. The PHIN is composed of five key components: detection and monitoring, data analysis, knowledge management, alerting, and response. Other federal initiatives include: (1) the National Electronic Disease Surveillance System (NEDSS) which is an initiative that promotes the use of data and information system standards to advance the development of efficient, integrated, and interoperable surveillance systems at federal, state and local levels [19], (2) the BioNet which is a national network of public health laboratories and federal food regulatory agencies helping the CDC to rapidly detect and determine possible links between disease agents during terrorist attacks [20], and (3) the National Health Information Infrastructure (NHII) which is an initiative set forth to improve the effectiveness, efficiency and overall quality of health and health care in the US, a comprehensive knowledge-based network of interoperable systems, and the set of technologies, standards, applications, systems, values, and laws that support all facets of individual health, health care, and public health [21]. The commonalties of these national level initiatives are the focus on data integration and standardization which intends to facilitate the information sharing among various healthcare partners and enables early detection of public health threats.

Prior research has addressed various issues related to the design of public health emergency response information systems. An integrated disease surveillance framework has been proposed for rapidly detecting, tracking, and managing public health threats [22], which contains six functions: data collection, detection, alert and early warning, resource planning, response assessment and evaluation, and investigation and modeling. Another public health emergency response system was proposed as a decentralized model which gives states responsibility for collecting and disseminating all necessary information and co-ordinating surveillance and response [23]. According to this model, systems in different states must be compatible on the basis of common data standards so that the federal government can oversee a national network, and each state should cope with emergencies at a micro-level. In addition, some researchers contended that state and local health departments should build dual- or multiple-use public health information infrastructure [24], suggesting that the public health information system should be able to respond and detect not only bioterrorism, but also other infectious disease outbreaks, chemical spills or leakages, food and water contamination scenarios, and animal disease outbreaks.

Based on experiences of the ''Emergency Management Information System and Reference Index'' (EMISARI) at the Office of Emergency Preparedness (OEP), Turoff [25] asserts that ''an emergency system must be viewed as a structured group communication system where the protocols and communication structures are provided, but there is little content about a particular crisis situation except as an integrated electronic library of external data and information sources'' (p. 30). As a consequence, the design of emergency information systems should focus on the group communication process by accommodating how humans collect, contribute, and utilize data in a time-urgent manner [25]. Given that Turoff's remark is about generic emergency response information system, it is applicable to public health emergency response. It suggests that public health emergency response information systems can also be viewed as structured group communication systems. Turoff et al. [26] have articulated five criteria for the design of such a group communication system: metaphors, roles, notifications, context visibility, and hypertext. Metaphors, which pertain to the interface design, are the mental models of the system that help users to create a cognitive map between task objectives and interface elements. Roles reflect various parties' responsibilities in an event, and this concept should be built into the design of the group communication system by offering specific privileges and tools to different users. Notifications are relevant alerts to a user of change in status, data, or other information. The group communication system should raise appropriate notifications when events or actions of other users take place to cause the change. Context visibility refers to the idea that the components of the meaningful data objects are presented in a context that relates to the understandings of the user, that is, when the user activates a certain object the system should be able to know the user's intention and provide a list of relevant action choices. Hypertext refers to ''the possibility of multiple two way linkages with semantic meanings that allowed a person to utilize any item in the content of the application as a set of menu alternatives to move to another content or functionalities in the interface'' [26]. The criteria recommended by Turoff et al. assume the existence of communications networks and computing technologies and focuses on the software and interface design features.

The previous studies have provided insights into public health emergency systems. However, they are almost solely based on experiences in the U.S. Few papers examine the initiatives in public health

emergency systems in developing countries. Given the important role China plays in the global public health arena, an investigation of China's public health emergency information systems will significantly contribute to the existing knowledge of public health emergency response.

3. Methodology

Given the complexity of China' PHERIS and the lack of previous research on this topic, a case research method was employed by this study. Interviews with two professors at Health Science Center of Beijing University, three healthcare informatics experts, and six healthcare IT practitioners were conducted to collect data of the development of China's PHERIS. Additional documents were reviewed to retrieve pertinent information. These documents include government IT policies and regulations, meeting minutes, reports, development plans, media reports, and news. The credibility of the governmental documents is guaranteed, since they were either obtained from government officials or downloaded from official government websites. The quality of media reports and news is likely to be questionable. Nevertheless, this is not considered a problem, since the triangulation method was employed in this study. Triangulation is a widely accepted case research method which requires collecting data from multiple information sources and posits that multi-source data will corroborate each other and increase validity [27]. Using the triangulation method, we only included in this article the information that appeared consistently in multiple sources and discarded the conflicting information. In addition, the manuscript of this paper was reviewed by a leading health informatics researcher in China who has worked with China's central government on major public health information technology initiatives, including the PHERIS project. His review has largely ensured the validity of this paper by verifying the information gathered from interviews and non-governmental sources, such as media reports and news. The rest of this paper is mainly based on the analysis of the data we collected from interviews and documents.

4. Results

4.1. Problems of the former public health information system

China's public health information system (PHIS) has a hierarchical structure consisting of four layers: county layer, city layer, province layer, and cen-

tral government layer. The primary objectives of the system are disease surveillance and monitoring. Major public health data collected by the system include epidemic report, disease surveillance, causes of death statistics, food hygiene, environment hygiene, school hygiene, women and children hygiene, profession hygiene, and public health resources allocation. The outbreak and spread of SARS have uncovered five deficiencies inherent in the PHIS, which are described as follows.

4.1.1. Timeliness problems
The disease reporting and surveillance have not been carried out in a timely manner. Due to the hierarchical structure of China's PHIS, disease surveillance data are reported by following a bottom-up path and the reporting is performed on a 10-day or monthly basis. Despite the establishment of a virtual private network in 2000 for electronically transmitting disease surveillance data among the four layers of the PHIS, communication between the PHIS and the sites where source public health data are collected is carried out through snail mail or telephone. In addition, surveillance reports have to be approved by relevant officials at each layer before they can move up to the next layer. As a result, the reporting cycle time is prolonged and local officials' interference could affect the accuracy of the reports. During the SARS event, it took 8—9 days on average to report a SARS case from the patient's location to the MOH, and 3—4 days to report a diagnosed SARS case from hospitals to the MOH. The delayed reporting has largely contributed to the rampancy of SARS in China.

4.1.2. Insufficient networking with local users
The coverage of the PHIS is relatively small. The network of the PHIS comprises a variety of centers of disease control and prevention (CDC) which are at the county level and levels above. Although, these organizations are able to shape a national net on which public health information can be exchanged in real time, the mesh size of this net is too big to catch timely disease information. Health care organizations at the grassroots level are usually the sites where public health emergency occurs, however, these organizations are not part of the PHIS network.

4.1.3. Insufficient information flow
The information flow in care providing organizations is inefficient. Should a public health emergency occurs, it is critical to gather accurate information regarding exploitable medical resources, such as hospital beds available, transportation capability, physicians available, care giving capability, medi-

cal devices and equipments, medications, and preventive equipments, so that the emergency situation can be managed to the maximum. Due to the inefficient inter-organizational information sharing in China's hospitals as well as the inefficient communication between hospitals and disease control organizations, the admission and transfer of SARS patients during the SARS event was chaotic.

4.1.4. Inadequate regulatory oversight

The public health regulatory system is insufficient. In China, only a few regions have established regulations to mandate and monitor the development and use of public health information systems. There are no unified regulations at the national level to enforce the exploitation of IS in disease surveillance and public health.

4.1.5. Lack of a standardized information platform

There is no standardized national platform for public health information exchange. China did recognize the importance of standard building, but little progress has been made on the development of health data standards, coding schemes, and communication protocols. Although, information systems have been widely used in the health care providers, disease control and prevention organizations, and health management authorities, the implementation initiatives are largely piecemeal, and lack a unified framework. As a consequence, health information is confined inside boundaries of these entities and effective health information sharing could not be easily realized due to the nonexistence of a standardized platform.

4.2. China's PHERIS development plan

In order to be able to better manage future public health emergencies, China's central government has called for the establishment of a public health emergency information system (PHERIS) within 3 years. The PHERIS development project encompasses three phases. The first phase, which ended at the end of 2003, mainly aimed to meet the requirements of dealing with SARS and to build the foundation for the future development of public health information systems. During this phase, CDCs and health care organizations at the county level or above and some health care organizations at the village level have deployed SARS reporting systems and established SARS clinical examination and alert systems. The SARS reporting system is a secure Web-based application which allows users to report SARS cases electronically to a central database. In addition, the disease surveillance system and the command center were designed in this phase and preparations were made to roll out these systems. The second phase is planned to finish at the end of 2004. One of the major objectives in this phase is to build a national computer network infrastructure to support public health data exchange. A five-level computer network will be constructed to connect health administrative agencies, CDCs, and health care organizations at the national, province, city, county, and village levels. Another major objective of the second phase is to complete the development of the disease surveillance system so that the online reporting system not only covers SARS but all types of public health emergencies. Moreover, the second phase also intends to develop some national public health databases which can be used as knowledge bases for healthcare providers when they encounter public health emergencies, and to start and partially complete the development of the command center. The third phase is planned to complete at the end of 2005. The objective of this phase is to complete all the tasks of the development of PHERIS and realize information sharing and co-ordination among relevant organizations so that the public health emergency can be handled efficiently and effectively.

4.3. China's public health emergency taxonomy

According to the MOH, public health emergencies refer to events that occur unexpectedly and can cause or potentially cause mass destruction to the public health. The Public Health Emergency Response Regulations defined four categories of such events: (1) serious epidemics, (2) mass diseases with unknown causes, (3) large scope food or profession poisoning, and (4) other events that can severely affect public health, for example, leaking of infectious bacteria from laboratories. The public health alert system in China has three levels: yellow alert, orange alert, and red alert. Fig. 1 depicts the structure of this alert system. Two levels of public health emergency response plans are triggered by emergency alerts: the provincial and the national. If the public health emergency is confined within a certain region of a province, the provincial plan will be appropriate. If the public health emergency is diffused across provinces and endangers the national public health, the national plan will be needed. Specifically, in the event of a yellow alert, the provincial public health emergency response will become ready; in the event of an orange alert, a provincial public health emergency response will be started or the national emergency response will
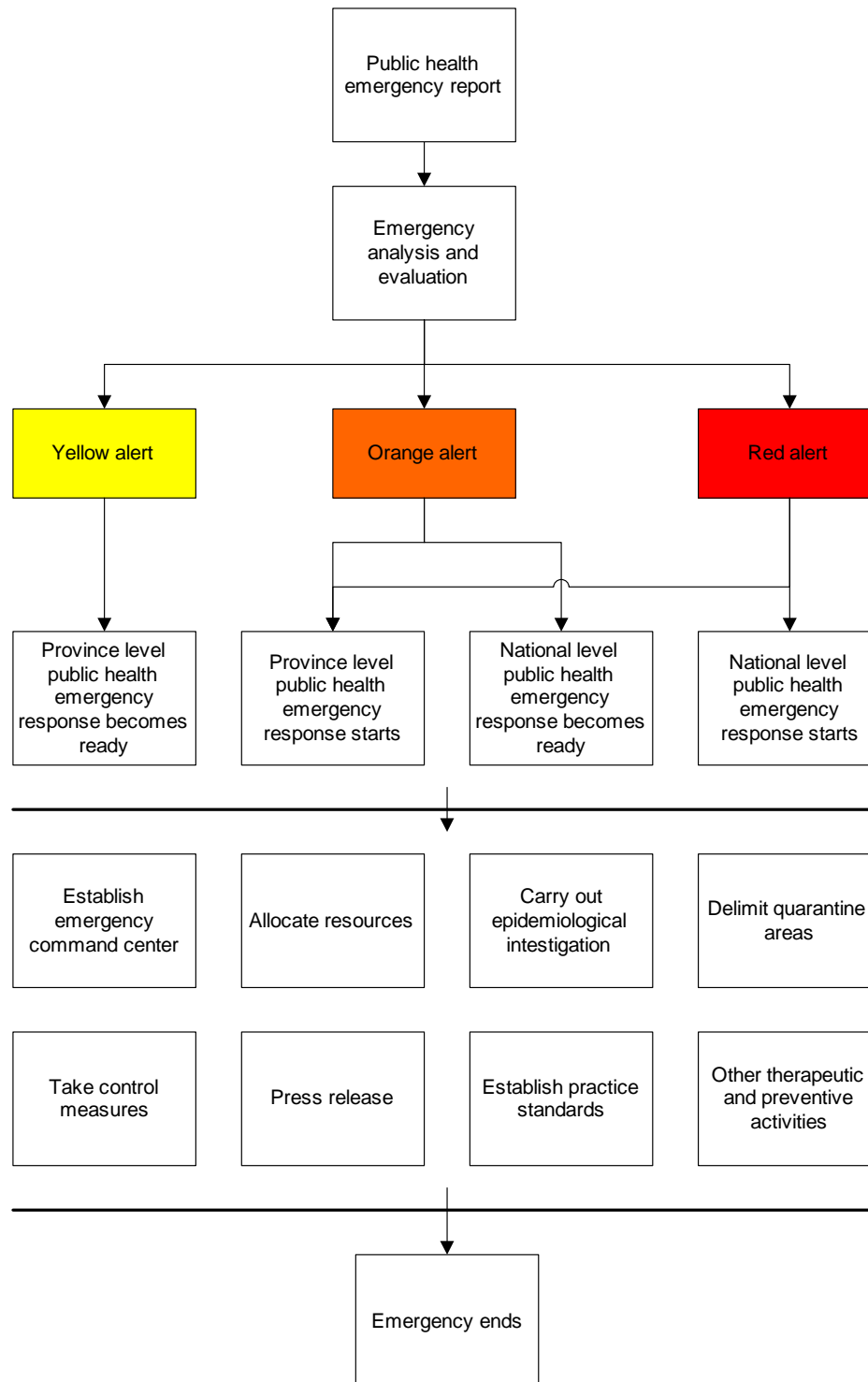
Fig. 1   China's public health emergency response procedures.

be ready; in the event of a red alert, the national emergency response plan will be activated. The national public health emergency response plan signifies the highest level of public health threat, and China responds to this type of crisis by gathering relevant departments in the State Council and military to form a national emergency command center. One of the leaders of the State Council, that is, the premier or a vice premier, will be appointed as the commander to direct actions resolving the emergency. The command center co-ordinates and allocates national resources, makes major deci-

sions, determines outward statements in press conferences, and possibly resorts to police and military forces. On the other hand, the provincial public health emergency plan is determined by the provincial government. A command center with the provincial government leader as the commander will be organized to direct emergency response activities. The difference between the national plan and the provincial plan is mainly the scope of the response activities. In addition, it should be noted that when a public health emergency response plan becomes ready, it does not necessarily have to be activated. In this scenario, the major task would be to continue carrying out disease surveillance and epidemiological investigation to examine how the emergency develops. Related stakeholders are informed to make preparations and some resources might be allocated. But if the emergency shows no sign of escalation or is controlled before it escalates, the alert would be cancelled.

The major responsibilities of the MOH are supervising and co-ordinating a wide range of activities relating to the emergency, such as organizing public health surveillance and reporting, applying for approval to start the national public health emergency response plan from the State Council, organizing and co-ordinating professional organizations to conduct field investigations, treating infected patients, tracing, sterilizing, or quarantining people who were in contact with infected patients, developing technological standards, declaring new infectious disease as legal infectious disease according to pertinent laws (only legal infectious diseases can trigger public health emergency alerts), and

many other activities. The MOH is a department under the State Council. The secretary of the MOH is usually a member of the top management team of the commander center in an event of public health emergency. The MOH also plays a vital role in cooperating with the military force. For example, during the SARS crisis, the XiaoTangShan Hospital was established to be a specialized SARS hospital. All the healthcare professionals in this hospital were from the military hospital system. The MOH was critical in making this effort successful.

4.4. Data and network of PHERIS

The fundamental technical features of PHERIS are described from two aspects: data and network. Six databases need to be created to support the functioning of PHERIS: (1) geographic and natural environment database, (2) national socioeconomics database, (3) national public health risk factor database, (4) national morbidity and mortality database, (5) national emergency resources database, and (6) natural disaster database. Table 1 shows the content of each database. The data collected for PHERIS are heterogeneous. They are of a wide range of types, such as socioeconomics, humanity, hydrology, meteorology, environment, natural disaster, and health care. They could be numbers, texts, figures or pictures, and they could be real time data or historical data. Data from various sources will be integrated under the Microsoft .NET framework.

From the network aspect, a ''five-layer and three-level'' network structure will be developed

Table 1 Databases of PHERIS

| Database	Data Content
The geographic and natural environment database	Geographic data, geomorphologic data, transportation, hydrographic net, vegetation, climate, radiation, precipitation, etc
The national socioeconomics database	Population demographics, gross domestic product, industrial structure
The national public health risk factor database	Manufacturers and inventories of toxic chemicals, nuclear stations, nuclear devices, manufacturers and inventories of bacteria and poisons, host animals and animal carriers of infectious diseases
The national morbidity and mortality database	Infection rate of infectious diseases, infectious disease monitoring data, mortality data, causes of death
The national emergency resources database	Data about healthcare organizations, medical devices, healthcare professionals, laboratories, ambulatory care, preventive medication and devices storage, biological agents, and blood banks
The natural disaster database	Data about natural disasters that can cause outbreaks of infectious diseases, e.g., flood, hurricane, and fire
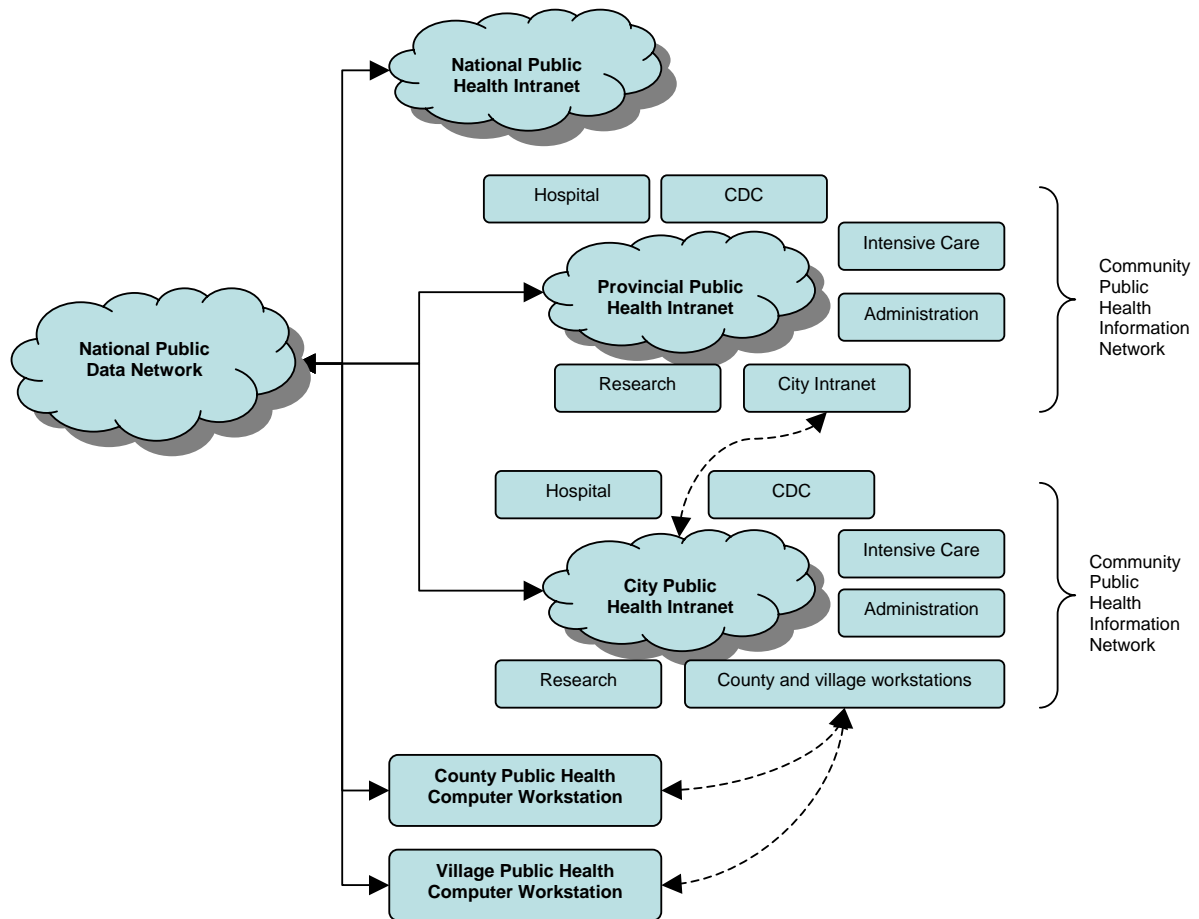
Fig. 2 The ''Five-Layer and three-Level'' network structure of PHERIS.

as the underlying infrastructure for PHERIS. The five layers refer to CDCs, health administrative agencies, and healthcare organizations at the levels of: (1) villages and towns, (2) counties and districts, (3) prefectures and cities, (4) provinces, and (5) nation. They are connected to the national public data network by broadband fiber lines, digital microwave, satellite communications, modem, and public telephone systems, thus forming a public health information virtual environment. The choice of communication method depends on the financial capability of different areas. The three levels refer to the establishment of major public health intranets at the city (or prefecture), province, and national level. A hierarchical star topology results from this network structure, where many villages and counties connecting to one city center, many cities connecting to one provincial center, and many provinces connecting to the national center. Fig. 2 depicts the topology. In addition, the provincial and city intranets provide network services and data services to public health related local organizations and form various community public health information networks.

4.5. Functions of PHERIS

Conceptually, PHERIS can be viewed as a composition of four major components: (1) a surveillance system, (2) a command center, (3) an action system, and (4) a supporting system. Fig. 3 illustrates relationships among these four components and their functional characteristics. The surveillance system captures public health emergencies and reports to the command center which assesses the emergency, raises alert, and makes decisions to respond to the emergency. The action system obtains orders from the command center and carries out the emergency response. The supporting system serves as a compulsory force to ensure all the activities of public health emergency response are undertaken properly. Lessons learned during and after a public health emergency will be incorporated into the knowledge body of improving PHERIS and reflected in future emergency detection and response.

4.5.1. Surveillance system
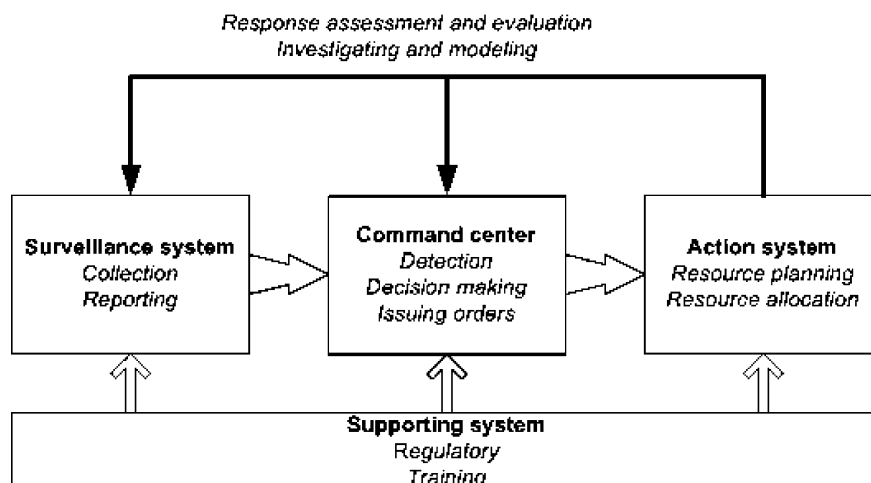The objective of the surveillance system is to replace the periodic manual reporting with online

Fig. 3 China's Public Health Emergency Response Information System (PHERIS).

reporting to meet the requirements of emergency alert and response. A standard national public health emergency reporting platform with an underlying central database was implemented. Starting from 2004, authorized reporting individuals and organizations can perform online reporting, and health administrative agencies and CDCs will be able to download reports of local epidemic events and public emergencies in real time. In order to facilitate public health surveillance, CDCs at the city and county levels will develop infectious disease databases and public health risk factor databases. Regular updates will be made to these databases on the basis of surveillance reports and epidemiological investigations. Given that many Chinese health care workers lack the ability to use computers, personnel training will be carried out along with the development of the surveillance system. The surveillance system is primarily an innovation of online reporting. The implementation of this innovation radically reengineered China's former public health surveillance process by removing many intermediate stops that the public health emergency data had to go through, thus resulting in a much more efficient process.

4.5.2. Command center

The command center integrates public health, disease surveillance, medical care, and health regulation information by using the network platform. It intends to utilize the advanced information technology to provide critical information to a central commander team so that appropriate decisions can be made to deal with public health emergencies. The system will monitor the entire process of the emergency and has such functionalities as data collection, crisis determination, decision support,

command, deployment, real time communication, and onsite support. The purpose is to make the most appropriate response to the emergency in the shortest time so that available resources can be effectively and efficiently allocated and exploited. The systems in command center encompass three application platforms and seven subsystems. The three application platforms are information platform, professional service platform, and decision making platform. The seven subsystems include database subsystem, geographic information subsystem, remote monitor subsystem, analysis and prediction subsystem, virtual reality subsystem, decision support subsystem, and search engine subsystem. Since, the command center is the central component of PHERIS, the three platforms and seven subsystems are described in more details in the following two paragraphs.

The information platform consists of the development of computer software and hardware, telecommunications infrastructure, data collection system, and data warehouses. The data collection system utilizes various technologies to capture images, graphs, statistical data, professional data, public health surveillance data, and textual data. Data storage technologies include both centralized and distributed database management models. The professional service platform is the core of the command center. Employing simulation techniques, this platform builds models to analyze the spreading processes of various infectious diseases. This exercise is largely based on the disease model database, the methodology database, and the public health knowledge base. The decision making platform is the presentation layer of the command center. All the activities involved in the public health emergency response, which includes monitoring, analyzing, investigating, predicting,
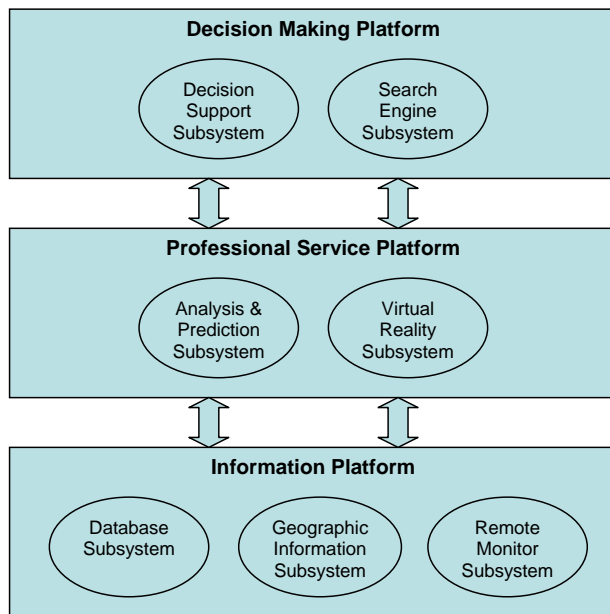
Fig. 4 The Command Center of PHERIS.

decision-making, executing, and getting feedbacks, are carried out at this layer.

The seven subsystems provide technical support to the three application platforms. As shown in Fig. 4: (1) the database subsystem, the geographic information subsystem, and the remote monitor subsystem supply data to the information platform, (2) the analysis and prediction subsystem and the virtual reality subsystem serve the professional service platform, and (3) the decision support subsystem and the search engine subsystem offer services to the decision making platform. The three platforms and the seven subsystems need to share information or exchange data on a regular basis. They are integrated together to support the public health emergency response and their performances are related with each other. It should be noted that China is interested in leveraging the virtual reality technology to display the spreading process of infectious diseases in three dimensional images, to model possible outcomes of emergency response decisions, and to simulate plans of medical resource allocation in the event of an emergency. The design of the virtual reality subsystem will continuously evolve given that the application of virtual reality in public health largely remains an open research filed.

4.5.3. Action system
The action system is an important component of PHERIS. It is related to healthcare provision, emergency rescuing, and CDC institutions. In the event of a public health emergency, the action system will report relevant information to the command center and execute orders from the command center to allocate medical resources, such as hospital beds, medications, medical rescuing equipments, telemedicine services, long distance training, and other healthcare services. Under normal circumstances, this system is utilized to manage public health, provide medical services, facilitate emergency room services, and conduct telemedicine and other health activities. The action system plays different roles in the ''peace time'' and the ''war time.''

4.5.4. Supporting system
The supporting system is primarily a public health regulatory information system. The purpose of this system is to monitor the behavior of health care administrative agencies and healthcare organizations in fulfilling their legal obligation of protecting public health. The supporting system requires the establishment of public health regulatory LANs and central databases at the provincial and national levels. All the public health administrative agencies need to connect to the two LANs through the national public data network. The standardized format of regulatory reports will be developed. In terms of data communication of legal issues, online reporting and digital data collection methods are not in place but will be created.

5. Conclusion

This article provides an insight into the challenges currently facing China's public health and describes the development of PHERIS to prepare for and respond to public health emergencies. China recognizes that surveillance and detection of disease outbreaks is a critical part of the solution and a dynamic system incorporating command, action, and supporting components is also needed to manage emergencies. The ongoing development of PHERIS will provide a complete package for China to rapidly detect emergencies, effectively share critical information among key stakeholders, and competently manage emergencies. Comparing PHERIS with the five criteria recommended by Turoff et al. [26], we find that the concepts of roles and notifications have been partly built into the system, while metaphors, context visibility, and hypertext are hardly realized in the system. This is not surprising, since China just started developing PHERIS and the system is still relatively rudimentary. At this stage, China's effort in developing PHERIS can be considered to be successful because of the radical emergency response process change re-

sulted from PHERIS and its associated performance improvement in public health surveillance and group co-ordination. China expects PHERIS to be an adaptable system which is able to adjust to the changing environment. Thus, PHERIS will play a significant role in protecting China's public health for years to come. In summary, this article contributes to the IS literature with a description of China's PHERIS development and should be beneficial to both IS researchers and practitioners, especially those who are interested in developing countries' public health emergency response information systems.

Acknowledgements

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