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LEVERAGING E-GOVERNMENT INFRASTRUCTURE FOR CRISIS MANAGEMENT: LESSONS FROM MANAGING SARS OUTBREAK IN SINGAPORE

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ABSTRACT

When the SARS virus broke out in Singapore, it posed a challenge to its crisis managers. The government mobilized its e-government infrastructure as a platform to manage this crisis. The Defence Science and Technology Agency (DSTA) provided IT support for contact tracing operations, a key part of containing the spread of the virus. DSTA developed an information system in two weeks to manage data and coordinate several agencies. Through a qualitative case study of DSTA and its role in supporting Singapore's crisis management, in this paper, we detail how Singapore deployed its e-government infrastructure in the face of a national crisis. Crisis management needs an infrastructure for effective information sharing, and e-governments posses such an infrastructure with a strong reach across several agencies. The development of Case Management System (CMS) and its use highlights some user behavior towards data and new functionality developed to cater to the needs of the crisis. We suggest that such lessons grounded in Singapore's experiences provide a useful direction for developing future crisis management infrastructures.

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INTRODUCTION

In the electronic commerce (e-commerce) era, citizens and business owners having had increasing exposure to offerings of the Internet and other digital tools such as wireless telephony now expect the same immediacy from one of their most important and often challenging relationships - with their government (Ho 2002). From web-based portals to digital kiosks in public buildings, governments at all levels are attempting to provide real time interactive lines of communication (Layne and Lee 2001). To support these activities, governments are investing in national information infrastructures (Wilson 1997; Nambisan & Agarwal 1998). These infrastructures provide the foundation for development of services that reach several sections of the society for a variety of purposes (Wilson 1997). Beyond national infrastructure advanced e-governments provide transactional services through integration across several organizations at various stages of e-government (Moon 2002; Layne and Lee 2001). With extensive infrastructure, e-governments go beyond IT to organizational routines and processes with embedded knowledge to help governments maximise their returns on investments (Wimmer and Traunmuller 2001).

Singapore invested in information technologies through a series of infrastructural development programmes within the government since the late 1970's (Gurbaxani *et al*. 1991) through coordinated policy development (Mechling 1994; Ein-Dor, Myers, and Raman 1997). Through the 1990's, Singapore developed its e-government action plan delivering its services electronically with

CONTRIBUTIONS

This paper discusses the events surrounding the crisis management of SARS outbreak in Singapore. Singapore's advanced e-government infrastructure provided an opportunity to quickly deploy its IT resources to support various crisis related activities. This research explores the development of e-government infrastructure as more than an electronic service delivery medium. E-governments have primarily focussed on delivering electronic transactional services. The events in the case study suggest that e-government infrastructure can, in addition, serve as a crisis management platform. Crisis management requires interaction of several agencies, efficient and rapid information exchange, knowledge sharing and integrated process management to coordinate several activities. E-governments generally possess extensive IT infrastructure, and can serve as a crisis management platform from which to coordinate, communicate and share information during a crisis.

Preparing for a crisis, however, is a difficult task due to its random nature. This also implies the need for an extensive infrastructure that can be used during crises. Towards this purpose, we contribute to crisis management literature by exploring the use of e-government infrastructure to support crisis management activities. The case demonstrates the deployment of IT capabilities which Singapore channelled towards efficient crisis management. This paper further contributes insights into some issues related to end users of the crisis management systems deployed during the SARS outbreak in Singapore. Data formats and user interfaces are critical issues since end users would prefer simpler input interfaces and its complexity may affect data quality, a critical issue in any information system.

This research aims to provide a descriptive case presentation of the role of an information system in Singapore's management of the SARS crisis. Such a case study research should be of interest to e-government researchers and crisis management researchers. E-government researchers may consider the implications of using e-government infrastructure for multiple purposes and the implications for deploying IT capabilities. Crisis management researchers may be interested in the potential that e-governments hold for crisis management and the rapid deployment of technology by Singapore's government. To IS and IT practitioners, this research presents an insight into extensive technology use in the face of a crisis, and the advantage of an integrated long term approach towards its management.

transactional capabilities (e.g. Devadoss, Pan and Huang 2003), earning itself second place in global e-government rankings (Accenture 2003).

The extensive use of information technologies also covers healthcare information systems that cater to several strategic needs (Liang 2002). The severe acute respiratory syndrome (SARS), in particular, posed new demands in managing information. The SARS outbreak affected several countries around the world from China to Canada in several ways. The spread of the infection was seen as a threat to public healthcare, as well as to economic activities of the regions (e.g. Chien and Law 2003).

Singapore managed the emergency effectively, deploying considerable resources from several agencies. These agencies were coordinated through its e-government infrastructure and rapidly developed information systems to handle crucial communication and data exchange which were necessary during the crisis (Kun and Bray 2002). Post SARS outbreak, these systems have now become part of public crisis management tools to monitor or even predict epidemics or bio-terrorist threats through an early warning system (Straits Times 2004).

Singapore's successful experiences thus raise two interesting research questions that guide discussions in this paper: "What was the role of e-government infrastructure in managing the national healthcare crisis?" and "What were the key challenges in managing this crisis that were addressed through information systems?" In this paper we discuss in detail how Singapore leveraged its e-government infrastructure to manage the SARS crisis quickly and efficiently. These discussions are grounded through a descriptive case study. In the next section, we present a discussion of our case study and data collection methodology. We then present a brief overview of Singapore's e-government initiatives and the scope of our study to provide an understanding of the context for our case discussion. The presentation of the case is followed by a discussion of the implications for e-governments and crisis management, with three key lessons from this research. We conclude this paper by discussing future research possibilities and presenting final conclusions.

RESEARCH METHODOLOGY

Case study research is most appropriate in scenarios where the research question is exploratory in nature and focuses on the examination of contemporary events that occur beyond the control of the investigator (Yin 1994). Qualitative research emphasizes the processes and meanings that are not easily quantified. It stresses how social experiences are created and given meaning (Denzin and Lincoln 1994). Interpretive methods of research are "aimed at producing an understanding of the context of the information and the process whereby the information system influences and is influenced by the context" (Walsham 1993). Hence an interpretive case study methodology has been adopted for this study, to obtain insights into the activities during the management of the crisis. Further, Klein and Myers (1999) discuss principles of interpretive research, which help researchers understand the importance of the interpretive technique in applying the global context of the case study to its parts and present an insight into our understanding of the events.

The case study was conducted during the period of August to October, 2003. Data triangulation method (Stake 1994) was used in data collection to help verify occurrence of events (Yin 1994). Primarily, 20 personal interviews were conducted to obtain a breadth of information, opinion and experience (Fontana and Frey 1994). The researchers visited the DSTA offices to conduct interviews with the interviewees. Data collected during personal interviews focused on understanding participants' role, their contribution, experiences and perceptions. Each interview lasted an hour and an half, approximately. All interviews were taped with the participants' permission and transcribed. The transcribed interview was filed together with notes and comments made by the researcher. The interviews were focused, unstructured and exploratory in nature, to elicit detailed information from the users on a breath of issues related to the case. The participant's perceptions, experiences and opinions on the events they witnessed during the crisis were

predominantly the content of such interviews. Due to extensive coverage of the outbreak in Singapore, abundant secondary data were collated to triangulate the information. Secondary data included press releases from a host of organizations involved in the SARS crisis management, reports on events, newspaper reports on events, and daily situation reports from participants. The secondary data helped in constructing an outline of the events in Singapore during the crisis and in verifying recollections. The data gathered from this case study was open coded (Strauss and Corbin, 1990). The coded data were then grouped into themes and sub-themes. Three major themes emerged from the analysis, which relate to e-government, unique issues to the SARS crisis management and end user related issues.

The interviewees were from the Defence Science and Technology Agency (DSTA) who handled the technology issues during the crisis and coordinated with all other agencies and users. The Defence Science and Technology Agency was formed by the Government of Singapore as a Statutory Board under the Ministry of Defence (MINDEF) in March 2000. Apart from defence technology support, DSTA's development work in IT involves various applications with expertise in providing enterprise systems solutions, knowledge engineering, mobility, military command and control and e-government systems (Devadoss, Pan and Huang 2003). The participants interviewed consisted of the CIO, managers, project managers, developers and users. The interviewees were involved in the planning, design, implementation and use of the CMS during the outbreak. The interviewees were selected for their knowledge in the process of deciding the system design, development and implementation during the crisis. The CMS is currently developed and managed by another agency for the Government of Singapore.

BACKGROUND TO THE STUDY

E-government in Singapore

Singapore is one of the early adopters of information technology. In implementing its policies towards becoming a hub for electronic commerce, Singapore readily re-engineers its processes to optimize them for efficiency. A clear plan for the development of infrastructural facilities has enabled it to be rated second only to Canada in e-government efforts (Accenture 2003). An innovator, leader and early adopter of technology, Singapore earned its place through implementing about 1600 initiatives under the e-government banner.

Through the eighties, Singapore deployed information technologies at its agencies to support its business activities. The 'IT 2000' master plan guided its policies on electronic transactions during the nineties, among other computerization plans. Through this period, Singapore established interactive services for business and citizen services. Through its E-government Action Plan, several services were delivered electronically with a 'customer-centric' focus. These services were then consolidated to be delivered as integrated services where possible. The new E-government Action Plan proposes delivering greater consolidated services to present a seamless, always available government to its citizens.

In summary, Singapore's e-government action plan focuses on developing an IT infrastructure to enable delivery of electronic services. Such services present a "One government" vision to its citizens. In the process, Singapore has not shied from experimenting with new technologies thus developing extensive IT capabilities.

Crisis Management

In the context of its emergency response planning, Singapore had not developed information architecture to respond to such a healthcare crisis. The National Environment Agency (NEA) had a business process to manage a crisis, but limited technical infrastructure in the form of spreadsheet based information management. When the crisis struck, NEA automatically became the agency to coordinate information though Ministry of Health (MOH) was directing the operations due to the health related nature of this crisis. Spreadsheet based data management was not sufficient to meet the needs of the SARS outbreak. Despite being the first sector to exploit broadband technology from 1996, Singapore's healthcare sector has largely focused on patient

healthcare costs through strategic use of technology and data exchange among the research networks (Liang 2002). In other words, there was a shortcoming in the crisis management readiness in Singapore.

Thus, Singapore's e-government focus on interactive electronic services was not yet in place among the healthcare services (Healthcare community networks for efficient patient information exchange were only recently launched in 2004 in Singapore). Further, the crisis highlighted shortcomings in crisis management preparation in Singapore. Among the hospitals, standard operating procedures in the event of a medical emergency at this scale were not available.

This experience thus highlighted the need to develop Singapore's crisis management, and motivated the long term planning that was evident in the management of the crisis. In the following section, we present a description of the case, tracing the circumstances leading to the development and implementation of crisis management system.

Scope of this Study

Singapore's response to the outbreak of the crisis involved a host of activities. In the short term, Singapore attempted to contain the spread of the infection through efficient management of the strategy to identify and isolate infected patients or vulnerable people who came in contact with such patients. A number of other initiatives were pursued to complement the management of the outbreak such as a dedicated television channel with SARS related information, video-conferencing at hospitals for visitors and patients (to avoid direct contact), developing a non-contact based fever detection system (using infrared temperature detectors) etc. In this case study we report one important part of Singapore's crisis management. A significant part of managing the outbreak was to identify and isolate potential virus carriers. CMS was developed to assist in this process.

The DSTA provided technology support to the crisis managers when the magnitude of contact tracing operations needed to be scaled up. The CIO and managers from DSTA advised the crisis managers on various technical issues. Such issues included the need and structure of information systems, data requirements, business processes for tracing operations, technical support, design and development, and advice on upgrading technology infrastructure in some crisis related agencies.

In this research, we explore the role of leveraging e-government infrastructures towards the development of a crisis management tool through DSTA's experiences in providing such support during the SARS outbreak in Singapore. Consistent with our research questions, DSTA contributed in the key areas of developing a system that leveraged e-government infrastructure and addressed several issues in the process which are elaborated in the following section. Following the case description, we discuss some key lessons from the case study.

SARS OUTBREAK IN SINGAPORE

SARS in Singapore

In February 2003, several people were diagnosed with a severe form of pneumonia in the Guangdong province of China. On the 12th of March 2003, the World Health Organization (WHO) issued a global alert on the outbreak of a severe form of pneumonia. Following the alert, Singapore's Ministry of Health (MOH) issued a national alert, requesting doctors to be on the look out for flu like symptoms and respiratory problems in patients. The disease, named SARS by WHO, spread by close contact and was an airborne virus. During the early days, identifying and isolating infected patients was considered the best course of action to contain the spread of the virus. Contacts with every patient had to be traced and suspected carriers were quarantined at their homes to monitor their health status over the 10 day incubation period of the virus.

Soon more cases of the disease surfaced. Contact tracing became increasingly difficult with the growing number of index cases (primary carriers who infect others). On the 19th of April a new cluster of infections was discovered, which meant an entire wholesale market had to be shutdown and over seven hundred people were contacted to check for symptoms. Some infected patients had visited several General Practitioners and *Sinsehs* (Doctors in Chinese Medicine) before visiting a hospital.

Airports were monitored to help screen passengers as they arrived in Singapore. The Immigration and Checkpoint Authority (ICA) worked in conjunction with the National Environment Agency (NEA) to trace passengers who needed to be quarantined, such as in the case of the 4th index patient who flew into Singapore with symptoms of SARS. The Ministry of Education (MOE) was working with the educational institutions to help trace contacts within educational institutions and implement screening measures to identify flu-like symptoms early.

Tracing Contacts

Information was passed on to the contact tracing operations centre, when a patient was identified as a suspected SARS case. The MOH did its own follow up and sometimes obtained information from other relevant agencies. For example, MOE provided some information on a student's school, etc. The information was consolidated and sent to the operations centre, which traced contacts. A list of people to be issued with an HQO (Home Quarantine Order) was then delivered to CISCO. MOH contracted CISCO, a statutory board specializing in security services in Singapore, to help in issuing and verifying compliance of an HQO by 8pm everyday. CISCO's staff then traced people in their list and issued an HQO. An Internet enabled camera was connected and social support provided through various agencies such as counselling, food delivery etc. Thus, the complete process of identifying suspect cases, their contacts and issuing the HQO involved at least four major agencies, namely, MOH, hospitals, NEA and CISCO.

This procedure had to be completed by midnight or early morning in order to ensure immediate compliance with the HQO. Non-issuance or non-compliance only meant a potential increase in the number of people to be traced. "We found CISCO's staff doing detective work trying to locate residents, because information given to them was often incorrect and it meant backlog", noted a manager.

MOH contacted MINDEF on the 24th of April 2003, after the wholesale market incident (where an entire wholesale market had to be shutdown since an employee there was diagnosed with SARS), to set up a bigger operations room for contact tracing operations. DSTA prepared an operations room with 120 stations within 48 hours. Each station was equipped with email (through the Government Electronic Mail System), file and print services and internet connectivity. Video conferencing became a critical and useful tool to link these agencies. The capacity was subsequently increased to 250. A technical support team operated in shifts at the operation centre.

The CIO of DSTA oversaw the operations and suggested that the infrastructure would still not help MOH scale its operations because its business process was not sufficiently streamlined. "Most of the information was in hardcopies or on

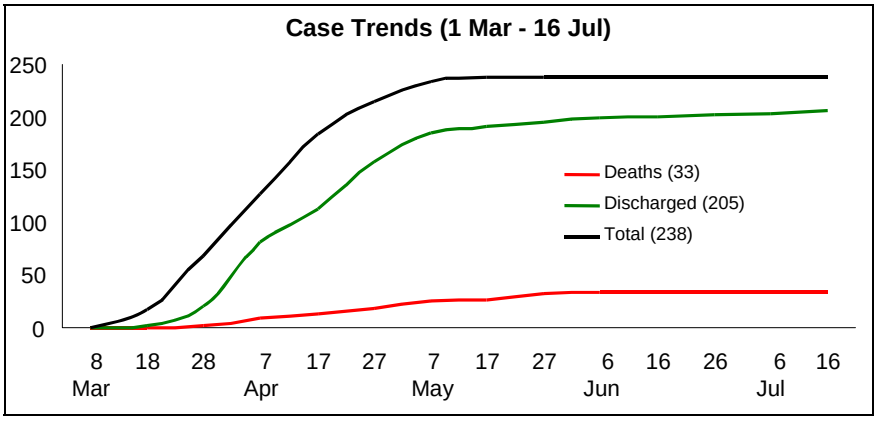

Figure 1. The spread of SARS infection in Singapore (adapted from data available at http://www.moh.gov.sg)

spreadsheets with unstructured data. It would be hard to do any sort of analysis based on that data" he said. DSTA recommended developing an information system to cater to information co-ordination and flow. "We wanted to build something that can help in responding to emergencies and can be further developed later", said the CIO.

Developing a Case Management System

DSTA targeted two weeks to gather requirements and develop. It began by assembling a team that was experienced in network technologies, database administration, systems development, and testing. Employees were invited to join the development team, and asked to drop all existing projects to complete the CMS (Case Management System) in two weeks. Most of the invited employees began work immediately, motivated by the crisis. Another reason cited by the developers was the challenge of having to develop a system in such a short time, and gathering development requirements as the system was being written. "It was like being in some kind of extreme programming competition!" suggested a programmer.

DSTA previously developed a casualty management system for the Singapore Armed Forces. The project managers had prior experience in developing this system and used it as a starting point. The developers chose Microsoft Windows™ since it took only a short time to deliver fully licensed servers to the operations centre, with MSSQL™ as the backend database. To help understand linkages among infected patients and trace contacts, another government agency provided DSTA with software to study cross-relationships among a given set of people.

There were no established procedures in the operations room, since data management up to now had been through spreadsheets and individual practices to monitor and manage tracing operations. "People at the operation centre had no time to talk to us, they would give us the data and we had to figure out the details. Sometimes they didn't know the complete process!" said a manager. The team coaxed information from the users, talking to them when possible and identified data sources, formats, security, and reports. Figure 2 represents information sources for contact tracing operations.

System requirements changed on a daily or even hourly basis. An example is categories of potential SARS cases. There were initially four, which were later revised to eight different categories. "Even as we hard coded the categories, the classification changed, so we later made it a configurable option", said a programmer. "Sometimes we'd make some changes on site, but forget to put those changes back into the development repository", reported another programmer.

Hospitals were an important zone in the battle against SARS. Every time a patient was identified as a SARS patient, contact tracing had to be carried out within the hospital to trace the movement of the patient and monitor the health of relevant staff and in-mates, often "taking two days", according to a doctor. This was a critical but time consuming process and data was often incomplete. The hospital staff, with their limited technical expertise innovated through the use of Microsoft Visio™ to plot the linkages to other contacts. Technology savvy doctors helped establish initial contact tracing data systems with spreadsheets to help trace patients and their contacts. These spreadsheets were emailed to MOH. When DSTA was invited to help, a meeting with the CIO's of all health sector agencies was held. This led to trying a system to help tag patients at Accident and Emergency (A&E) departments of the hospitals. "Using RFID (Radio Frequency Identification) made it easy to list contacts instantaneously" said a manager. However, the RFID system was deployed only on a trial basis at one hospital during the crisis and later extended to other hospitals. The data was stored in a separate database, and not linked to CMS. With a structured database, information was easy to retrieve when needed, which was the objective of the trials.

Design of Case Management System

The CMS was designed to cater to the immediate needs of managing the SARS outbreak, with a view towards providing a long term solution to similar crises. The frequent outbreaks of bird flu virus in other regions, possibilities of new virus forms and even a recurrence of SARS outbreaks are

realistic possibilities that the team attempted to cater to through the CMS. Sources of information for such a system ranged from hospitals, Ministry of Education (MOE), and MOH to General Practitioner Doctors and Traditional Chinese Medicine (TCM) practitioners. Information from all sources had to be collected into a database from where the system would perform case management should someone be identified as a suspected or confirmed SARS patient. Link Analysis connected confirmed cases with suspected and probable cases, to identify potential SARS patients and monitor their health status. This SARS database could also be used to provide exit control with the immigration authorities (as a commitment to regional safety) or with MOE to isolate students who inadvertently attend schools when they should be quarantined. The databases together were interfaced through the CMS and a Link Analysis system.

A reference database was created with simple contact information of as much of the population as was possible to help contact people quickly. This database was ineffective with no data to look up contact information. "I was told it might be impossible to gather such data, but I approached various government CIO's anyway, and they agreed. When one agency offered its data (subject to clearance by the Ministry), they cautioned me that it was at least 3 months old. But I was ecstatic because back then I had no data and any data was better than that!" said the CIO. The reference database is highly sensitive with contact information for a high percentage of the population. "It is not a free for all as far as data is concerned. We have norms to conform to in handling such data" reported the CIO. All data exchange is guided by government policies to protect the privacy of individuals. Data access in the system is tiered into multiple layers and access to tiers controlled by levels of authority.

The case data in CMS focused on patient information, infection status and relation to other patients or contacts. This information helped the managers develop a clearer understanding of the spread of the infection. It also gave the managers the ability to identify and contact potential people at risk through its linkage to the reference database.

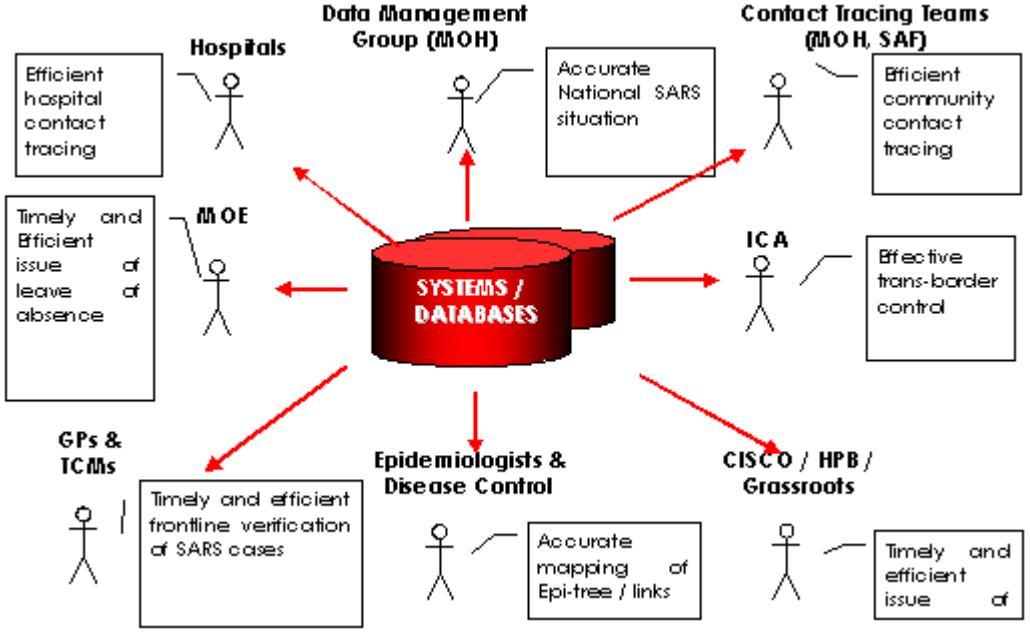

Figure 2. Information Management Needs that were identified for CMS

Within the CMS, due to often recurring inaccuracies in the NRIC (National Registration Identity Card) numbers of the residents, the records were indexed on unique numbers generated by the CMS. This reduced reliance on the NRIC numbers to identify users. "Often the registered address may not match with the actual contact address because people move. So we had to rely on our own indexing numbers for records, as well as rely on mobile phone numbers to contact people rather than land lines", reported a manager. High mobile phone penetration in Singapore made using mobile phones to contact people easier than using fixed phones in many cases. Figure 3 is a screen capture of the new case creation in the CMS.

Access to the system was limited to the operations room for the crisis management and the data management group at the MOH. Data from other agencies were received by the operations centre via email, and keyed in by its staff. This strategy reduced the need for extensive training across several agencies. Through a unified data entry system into the database, monitoring the status of the infection across the nation became feasible. The data from the CMS system were used to generate reports that gave the government an accurate update on the status of infections across the nation, including the quarantine numbers and their status. Further, daily press briefings were held during the crisis period, when situation reports were needed. This status report was delivered everyday through the press conference by the Minister for Health. CMS simplified the process of compiling such reports, handed out daily by the MOH.

Thus, CMS made it possible to efficiently assemble accurate status reports. Reports generated from the system on the status of the crisis were communicated back to the hospitals and other agencies. The numbers of new infections were dwindling in Singapore by the time CMS was fully operational. Within a month of CMS' deployment, Singapore was declared clear of SARS virus by the WHO.

Implementing CMS

The operations centre staffed by NEA's officers had developed their own data formats on spreadsheets. In addition they used spreadsheets forwarded by other agencies, which in turn were formatted as they saw fit. Thus with "virtually 200 different formats to resolve, data conversion was a difficult process" according to the project manager. The database team set about resolving these issues and populated CMS with the case data. DSTA set some members of its team the task of converting the data. "It was a tedious process, and we spent long hours trying to reconcile it to the new system" added a user involved in the conversion process. Another user commented that "this was perhaps the most complex part of entire implementation process because there was no structure to the data used in its spreadsheets".

The team worked on parallel implementation to ease the system in while converting data and training users during their breaks. The data input was through a web interface. "We kept the web interface as simple as we could, but some users thought spreadsheets were better because there were no restrictions in entering data" said the project manager. After intensive system testing, the operations centre switched over to CMS. DSTA then handed the system to MOH, satisfied with its stability. Following the containment of the SARS outbreak in Singapore, MOH contracted another agency to continue maintenance and development in accordance with its own procedures. Further development of these systems are planned, but are not finalized at the moment.

On the 30th of May 2003, Singapore was declared clear of the SARS virus by WHO. On the 9th of September 2003, a new probable SARS case was reported in Singapore. A post-doctoral student was infected while handling virus samples in a laboratory and visited doctors several times with persistent fever. Within 8 hours of having identified a probable SARS patient and activating tracing operations, about 60 people were traced and contacted and some were issued HQO's. The CIO reported: "I wasn't called to support, which means our system is working satisfactorily!"

Discussion & Implications

The SARS outbreak was a difficult challenge to Singapore, particularly in the context of the global economic slowdown. Hence effective and efficient action was necessary to manage the outbreak. E-

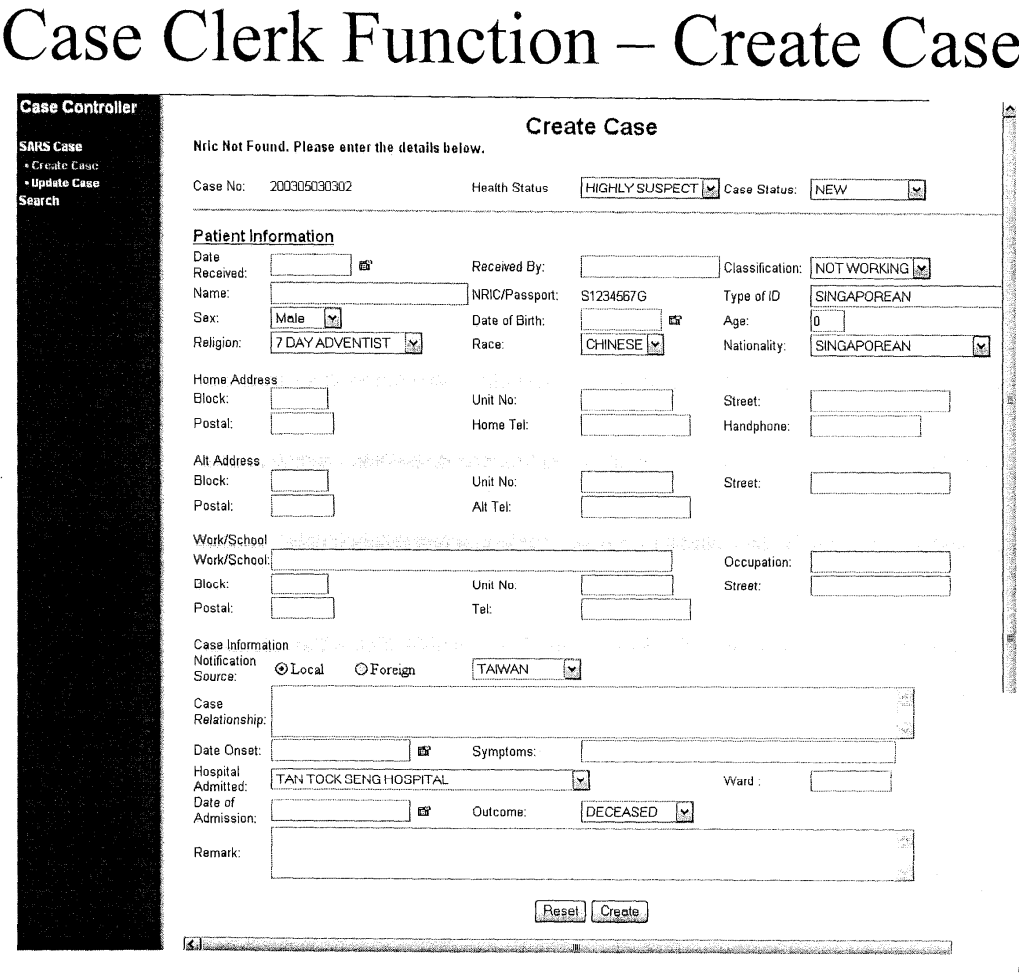

Figure 3: Screen Image of the Creating a Case on Case Management System

government infrastructure was used as a suitable platform, but not as a solution in itself (Nadler and Tushman 1997). It helped coordinate processes across several agencies and manage information. In this section, we discuss the importance of these experiences in the context of leveraging e-government infrastructure. We also explore some important directions for future research.

E-government Infrastructure: Platform for Crisis Management

Governments are adopting information technologies to provide integrated services to citizens (Ho 2002). This is a difficult task considering the bureaucratic nature of governments (Bretschneider 1990). However, increased adoption of technology has forced governments towards accepting a citizen perspective, abandoning their administration friendly approach (Lenk and Traunmuller 2000). This shift has also been due to pressures to leverage existing IT investments and derive greater value (Bannister 2001). Further, advanced e-government programs progress towards more integrated services (Moon 2002; Layne and Lee 2001). Infrastructure and integration are two important aspects of e-government. These two aspects of e-government support tele-cooperation (Wimmer and Traunmuller 2001) to deliver integrated services (Wimmer and Traunmuller 2001; Devadoss, Pan and Huang 2003).

Integration and infrastructure also benefit crisis management in many ways. The

primary objective in any crisis is to give relevant agencies a collaborative system to share knowledge (Turoff 2002), and enable communication and data exchange (Kun and Bray 2002). During the outbreak, the contact tracing operations centre for 110 stations was established within 48 hours and connected to the government network. Government email systems were used to enable instant communication channels between various sources of data and the operations centre.

A complete information system was developed in 11 days to manage information related to the emergency, three days ahead of the scheduled two weeks. Organizations exchanged data securely, through government email systems, to help contact tracing operations. This was enabled by extensive e-services that possessed updated contact information, helping to quickly contain the spread of the SARS virus. For example, one government agency maintained updated employment contact information for some of their electronic services. Members' contact information was considered accurate due to the nature of their services. This government electronic service database was a big boost to the CMS since it instantly gave accurate contact information to a large number of residents in Singapore. However, such data was not freely available to other government agencies and the government of Singapore specifically approved such a use by CMS under special circumstances.

In summary, the crisis management tools relied on the e-government infrastructure to operate, and used data from e-government services shared by respective agencies. The development of CMS and its circumstances has prompted establishing crisis management tools that can cater to such needs in the future, such as an early warning system monitoring some symptoms at clinics (Straits Times 2004). Particularly in the context of bio-terrorist threats or even the recurrence of SARS or other epidemics, appropriate information infrastructures could serve these dual purposes (Kun and Bray 2002). E-government provides suitable platforms for development of such information infrastructures because of their extensive reach and variety of electronic databases.

Leveraging e-government infrastructures and capabilities however, is not an automatic process as demonstrated in this case. In Singapore, there was no prior experience or procedures and the government had to adapt to evolving conditions. While planning provides for some responses in the event of a crisis, a crisis may also pose entirely new situations that may need new solutions and approaches. In the next section, we discuss how SARS posed new demands and Singapore's response to the same.

Crisis Management: New Demands from SARS Experiences

Advanced applications of technology within e-governments have also centred on vertical and horizontal integration in order to provide more integrated services to citizens (Moon 2002). A significant benefit of information technologies is the ability to implement changes through windows of opportunities (Tyre and Orlikowski 1994). This is particularly true during a crisis, since every crisis is unique and presents an opportunity to prepare for new eventualities in the future. In this context, a common infrastructure would be necessary to manage a variety of crises such as bio-terrorism or natural disasters for example (Arens and Rosenbloom 2003). Thus, leveraging IT capabilities, identifying, creating and responding to changes quickly become relevant to e-governments in this respect. Problems in data accuracy, collation of data from a variety of sources, effective sharing of such data and management of crisis data for better analysis are important new issues that the system had to cater to from Singapore experiences. Further, these important issues were addressed with an eye on the long-term feasibility of their solutions.

In managing SARS, the primary lesson is the realization of a need to exchange accurate information quickly and efficiently across several agencies. CMS was deployed for this purpose. Channels of communication were immediately opened with several sources of data, such as hospitals, MOH, NEA and CISCO, who were actively involved in collection and using the data related to the SARS outbreak. During the early days of SARS in Singapore, data inconsistency, variety of formats in exchanging data,

inaccuracies and even lack of data caused a significant slowdown in the contact tracing operations. The deployment of CMS was aimed at addressing such issues in data management.

However, the CMS was insufficient to detect a possible outbreak of the symptoms of the disease in Singapore. CMS was not sensing data from the sources that could enable such functionality. This was addressed through an early warning system (Straits Times 2004) that is now being tried in a few clinics to capture and analyze the outbreak of some key symptoms in regions across the country. The need for an operations room was another outcome of the experiences of SARS management. An equipped operations centre is now on standby, ready to swing into action within a couple of hours. Hospitals and organizations dealing with large gatherings are also preparing standard operating procedures to deal with crisis situations. In addition, Singapore also experimented with RFID (Radio Frequency Identification) to tag patients at emergency wards to improve the accuracy of its data during contact tracing. Also, several government agencies contributed data to the development of an effective system in managing the SARS crisis. The availability of a variety of data sources was an advantage in the effectiveness of the CMS in Singapore. Such an ability to identify and gather relevant data from a variety of sources was enabled through an effective use of the e-government infrastructure. Further, DSTA took great care in ensuring secure access and availability of such data during management of the crisis.

Singapore's experiences in focussing on ensuring accurate data collection and communication across agencies, relying on other services for initial data requirements and deploying its capabilities to deliver such functionality holds interesting implications for crisis management in general. With increasing investment in e-government infrastructures around the world, the development of such experiences and systems as capabilities which can be leveraged for new demands is an important lesson. Their information management capabilities provide governments the opportunity to efficiently collate accurate data on the crisis, which is an important part of managing the crisis.

Systems Users: Adapting to Structured Data Exchange

As is often during a crisis, users work long shifts trying to ease the situation, and have little time to learn new systems (Turoff 2002). Hence, the choice of an appropriate interface is important. However, the quality of data gathered and entered into the system is also important. The web browser is often the preferred interface due to its popularity, familiarity, and simplicity (Milford 2000). Managing SARS provided useful insights into user behaviour towards data handling at times of crisis.

Singapore's high technology adoption was visible with several distributed users relying on spreadsheets and charting software to represent and exchange data during the crisis. However, such applications were unstructured data sharing mechanisms, and users had a strong preference towards unstructured data entry. Users familiar with spreadsheets queried if they could see all the data at once instead of a case-by-case view as designed in the CMS. "They wanted to see all the data at once as in the spreadsheet, and did not want to click here and there for different views." reported the CIO.

Their preference for unstructured data could be attributed to the uncertainty as to the relevance and need for information gathered and any data was considered better during the early days of the crisis. This notion was challenged with the arrival of CMS, and users had to learn to structure their data input and obtain more meaningful inputs to systematically track case data. "Some of the early data was just 'Uncle One' or 'Aunty One' making it impossible to do anything useful with it" added another manager.

Further, unique identity numbers of the residents of Singapore was often unavailable or incomplete. To tackle this, CMS included a unique indexing system for its case management. Data repetition was checked through a matching of name and identity numbers where available. Thus data cleaning was done mostly prior to data entry into the system.

Another impact of the system change was in training the users. CMS was a web-based system, designed to simplify data

presentation and provide a familiar interface to users. Older users were not comfortable with the interface and preferred a spreadsheet layout that could be scrolled to input any information at any point. Training was necessary to help older users adapt to the new systems, where information was in one window and navigated through links. The younger army recruits, who also manned a portion of the operations room, reported the interface "familiar and easy to use".

These experiences highlight the variety of expectations from users. The use of a web based system simplifies familiarity problems with most users, due to the popularity of the internet. However, some users may still need more training in using such systems. Further, processing data prior to entry to the system is necessary due to the wide variety of sources that provide data for the system. This could be simplified in the continuing development of the system to enable decentralized data entry into the shared system. Also, in handling data from a number of sources, the common problem is the variety of formats that users tend to use, particularly in the absence of a common input standard. This problem is compounded by the use of spreadsheet systems which allow users excessive freedom in formatting their data. The short term solution in this case was to clean the data prior to data entry, and the long term solution is to decentralize data entry into the system at the source of the data itself.

FUTURE RESEARCH

In our case study, we discussed the possibilities of leveraging extensively available IT infrastructure for crisis management. Crisis management can benefit from such systems through rapid deployment of systems, and wider reach through access to data from a variety of sources. All such issues contribute towards an effective management of a crisis. To gain further insights into such issues, it would be of interest to study the data exchange formats across several systems and the possibilities of capturing some data routinely, as part of crisis management planning. With increased availability and use of ubiquitous technologies such as RFID, it would be of interest to explore the role of data integration on the fly and the resulting security and privacy issues during crisis management.

Singapore has now developed an early warning system, connected to data related to some polyclinics. The role of such early warning systems, which attempt to identify appearance of potential infections, is another area of interest in preventing large scale spread of new diseases. Future research should focus on the ability to gather and synthesize such data into meaning indicators of potential threats through existing information infrastructures. Through our research, we have attempted to contribute towards further development of these important research areas. Knowledge of such issues is important in the context of potential threats that the world faces today.

CONCLUSION

E-governments are growing towards greater vertical and horizontal integration of services (Moon 2002). By studying the management of the SARS viral outbreak in Singapore, we illustrate the use of e-government infrastructures towards developing crisis management tools. Crisis management needs many applications to cater to information needs (Kun and Bray 2002), and Singapore's experiences suggest that e-government provides a suitable platform for deploying these systems. E-government infrastructure's reach into governments can provide the common infrastructures that crisis management needs (Arens and Rosenbloom 2003).

A closer examination of the case reveals two interesting aspects of user behaviour and system functionality. Though e-governments can deliver new functionality for any crisis through their IT infrastructure and capabilities, the SARS crisis highlighted the need for development of contact databases and systematic management of individual cases leading to accurate nationwide data. The focus was to get data input as accurate as possible and share it effectively across multiple organizations. Users' interaction with the system revealed the advantage of simple browser interfaces, and the need for training despite its popularity. Crisis managers need to train users despite the time constraints during a crisis (Turoff 2002).

WHO has warned that the SARS virus is possibly only the first of several health scares. It is thus essential that governments focus on managing such health crises and develop an infrastructure to manage similar threats such as bio-terrorism (Kun and Bray 2002; Turoff 2002; Arens and Rosenbloom 2003). Through a discussion of Singapore's experiences we highlight some directions for crisis managers in the form leveraging e-government infrastructures, managing new functionalities and user interactions. While the discussions are grounded in Singapore's experiences, these lessons are also useful in developing our knowledge in effectively managing crises. Singapore has now institutionalised these systems and hopes to be fully ready to tackle a recurrence of SARS within 2 hours, as well as use these experiences as baseline for new crises.

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APPENDIX A – LIST OF ABBREVIATIONS

CISCO - A statutory board specializing in security services in Singapore

CIO – Chief Information Officer

CMS – Case Management System

DSTA – Defence Science and Technology Agency

HQO – Home Quarantine Order

ICA – Immigration and Checkpoint Authority

MINDEF – Ministry of Defence

MOE – Ministry of Education

MOH – Ministry of Health

NEA – National Environment Agency

NRIC – National Registration Identity Card

SARS – Severe Acute Respiratory Syndrome

TCM – Traditional Chinese Medicine

WHO – World Health Organization

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