Association for Information Systems
AIS Electronic Library (AISeL)

PACIS 2014 Proceedings

Pacific Asia Conference on Information Systems (PACIS)

2014

EVOLUTION OF INFORMATION TECHONOLOGY IN HEALTHCARE

Yang Yang
National University of Singapore, yang12@nus.edu.sg

Atreyi Kankanhalli
National University of Singapore, atreyi@comp.nus.edu.sg

Sarada Chandran
National University of Singapore, sarada.chandran@gmail.com

EVOLUTION OF INFORMATION TECHONOLOGY IN HEALTHCARE

Yang Yang, Department of Information Systems, National University of Singapore, Singapore, yang12@nus.edu.sg

Atreyi Kankanhalli, Department of Information Systems, National University of Singapore, Singapore, atreyi@comp.nus.edu.sg

Sarada Chandran, Department of Information Systems, National University of Singapore, Singapore, sarada.chandran@gmail.com

Abstract

The healthcare sector is growing rapidly and taking up a significant portion of the GDP in developed countries. The healthcare industry faces significant challenges such as ballooning costs, shortage of qualified personnel, rapidly aging population, and increase of chronic and epidemic diseases. Information technology (IT) has been suggested as a mitigator for some of these challenges. Particularly, IT can enable automation, management, and integration of clinical and business operations for greater efficiency and effectiveness. Studying the evolution of IT in healthcare is essential to be able to understand the past trends, address the current situation, move to the nest stage, and make use of IT to advance the future. However, although there is considerable literature on IT evolution, we observe a lack of studies specific to the evolution of healthcare IT. With the unique challenges of this sector, we attempt to address this gap in this paper. This study will start with a literature review on IT evolution and then develop a model for the evolution of healthcare IT based on the Nolan stage model and its subsequent refinements. The model will be developed with an initial focus on healthcare IT in Singapore. The reason for choosing Singapore is because of its advanced IT and medical infrastructure, yet the spending on healthcare is relatively low compared to other developed countries. In future, our model will be extended to other developed countries in the Asia-Pacific region e.g., Australia and New Zealand, as well as the UK and US.

Keywords: Healthcare, Information Technology, Stage model, Evolution.

1 INTRODUCTION

The expenditure on healthcare continues to rise in countries around the world. For United States the total expenditure for healthcare in 2012 hits US$2.8 trillion, accounting for 17.2% of the nation's GDP (CMS.gov 2014). The total health spending in UK in 2011 is £142.8 billion, accounting for 9.4% of its GDP (Payne 2013). For Singapore the government health expenditure in 2012 is S$ 4,802 billion, which accounts for 1.4% of the GDP (MOH 2014). Common challenges are faced by the healthcare sector other than growing costs. These challenges include ageing population, increase of chronic diseases, spread of epidemics, and the shortage of qualified medical practitioners (State of Health 2013).

Information Technology (IT) has a potential to reduce healthcare costs and improve the quality of healthcare (Kolodner et al. 2008). IT can play an important role by facilitating both administrative and clinical processes in healthcare through decision support, electronic communication and connectivity, clinical documentation, results management, and patient support (Chaudhry et al. 2006). Specifically, it brings changes in healthcare delivery process by improving healthcare quality, safety, and patient satisfaction (Shekelle et al. 2006). In addition to the significance of IT in healthcare, the distinctiveness of the healthcare context makes IT use in healthcare different from the use in other domains. The healthcare context is characterized by diverse levels including patients, professional disciplines, health delivery processes, and interests of different stakeholder groups (Fichman et al. 2011). Particularly, in the healthcare setting, medical professionals have substantial control over what kind of health information system will be used (Yi et al. 2006), and different units of healthcare usually have their own specialized IT applications (Lenz &Reichert 2007). The high standard of safety is another requirement of healthcare IT, as they are expected to reduce the likelihood of medical error (Ash et al. 2004). Thus, healthcare IT needs to be studied in its own right.

The IT-enabled transformation of healthcare benefits from the ongoing development of information technology. Studying the evolution of IT becomes critical for our understanding of the past trends of healthcare IT development, as well as how to deployment of healthcare IT to advance the future by addressing the challenges faced. Despite of the value and unique features of IT in healthcare, we observe a lack of studies specific to healthcare IT evolution. Much of the existing research has focused on the evolution of IT in other domains (e.g., Andersen & Henriksen 2006; Röglinger et al. 2012). The progression of IT in organizations had been first examined by Nolan (1973). Nolan's stage model has been applied to investigate business process management (Röglinger et al. 2012), enterprise resource planning system use (Holland & Light 2001), and e-government (Andersen & Henriksen 2006). Although these studies are helpful for enriching our understanding of general IT development in these domains, few studies have been conducted to explore the evolution of IT in healthcare. Thus, it is of academic and practical significance to investigate the evolution of IT in the healthcare domain.

The objective of this study is to answer the following research questions: How has IT use evolved over time in healthcare industry? How to utilize the advance in IT to address the future challenges in healthcare industry? To answer these questions, we start with a literature review on IT evolution. We then describe the healthcare infrastructure in Singapore, which is chosen as our initial focus to study the evolution of healthcare IT. Based on Nolan's stage model, we propose a stage model to illustrate the IT evolution in healthcare in Singapore. Through the proposed stage model proposed, we analyse the healthcare IT evolution of Singapore from 1980 to the present through four stages. The challenges faced in each stage and how the healthcare IT alleviate those challenges are elaborated. This study is expected contribute to the literature of evolution of IT in healthcare by analysing its past trend, evaluate current stage of IT use in healthcare, and how to progress further to use advance in IT for future challenges in healthcare industry. This study can also provide insights for healthcare professionals, IT designers, as well as government policy makers.

2 CONCEPTUAL BACKGROUND AND METHOD

In this section, we first introduce the Nolan's stage model as the theoretical background that we employ to explain the healthcare IT evolution in Singapore. We then review the prior studies that had applied Nolan's stage model in different areas. We also provide an overview of the healthcare structure and vision in Singapore. Last, we talk about the method adopted in this study.

2.1 Nolan's Stage Model

A model for the progression of IT in organizations was first proposed by Nolan (1973) to address the need for a descriptive stage perspective to plan, organize, and control IT resources within an organization. The model provides insights for the evolution of information technology and organizational strategies over time (Lyytinen 1991). Nolan's stage model explains how the IT resources within an organization grow in a period of time. It posits that the general pattern of IT use and management within an organization can be approximated by the pattern of the organization's computing budget curve (Nolan 1973). There are four stages in the original Nolan's stage model: initiation, contagion, control, and integration. *Initiation* stage refers to the acquisition of computers in an organization with slow annual increase of budget. *Contagion* stage refers to the period of intense system development and managerial concern and strategies with increasing annual budget. *Control* stage represents that a set of tasks are initiated to control the increasing expenditure for computing resources. *Integration* stage is characterized by a refinement of tasks and elimination of arbitrary tasks to approach maturity. The annual budget for computing resources decreases in this stage.

Nolan's stage model is popular in the IS domain and has been applied in different studies of IS. For example, Holland and Light (2001) developed a maturity model for enterprise resource planning systems use in companies based on the Nolan model. They identified three stages that were illustrated with case data from 24 organizations in U.S. and Europe. Additionally, Röglinger et al. (2012) provided a systematic in-depth review of maturity model in business process management (BPM) context. They found that BPM maturity model offers limited guidance for identifying different maturity levels and for implementing improvement solutions. Further, Nolan's stage model has been applied to study evolution of IT in an industry sector or a country. For example, Andersen and Henriksen (2006) proposed an e-government maturity model to investigate how IT applications facilitate improving the core activities. Lee et al. (1988) developed a stage model of technology development processes for less developed countries from a global perspective. Although these studies have contributed to the understanding of IT evolution in various areas, few studies have been conducted on IT evolution of healthcare. With the lack of an IT evolution model for the healthcare context, we will apply the Nolan's stage model to examine the evolution of healthcare IT. As explained earlier we start with an investigation of the Singapore healthcare context.

2.2 Healthcare Structure and Vision in Singapore

In order to be able to apply the Nolan's stage model in the Singapore healthcare context, it is necessary to have background knowledge about the present healthcare structure in Singapore and the vision of the government. In the mid 1980s the healthcare system in Singapore underwent a major change after the election of a new government. To meet people's rising expectations, the government decided to do a "restructuring" or "corporatization" of the healthcare sector to improve efficiency while reducing state funded healthcare spending. Each hospital would function as an independent entity while still being completely government owned (Okma et al. 2010). These reforms resulted in raised standards of healthcare over the years. As each hospital focused on its own survival, competition increased and cooperation was unlikely to happen among hospitals (Lim 2010). This led the government to group the restructured hospitals into clusters. Currently, there are six regional clusters, i.e., Alexandra Health, Eastern Health Alliance, Jurong Health Services, National Healthcare Group, National University Health System, and SingHealth. Other than the six clusters, there are four

subsidiaries, i.e., Integrated Health Information Systems (IHIS) (the consolidated entity of IT resources for all clusters), Agency for Integrated Care (AIC) (corporate entity formed to look into the integration and enhancement of long term care), Singapore Clinical Research Institute (SCRI) (entity to support clinical research) and Health and Medical Practice Insurance (HMPI) (an insurance entity to self-insure the Ministry of Health Holdings and its subsidiaries) (SingHealth 2013).

The goal of the Ministry of Health is to seamlessly integrate the different components of healthcare such as health promotion, primary care, acute care, intermediate, and long term care to provide high-quality, patient-centric care to the public (MOH 2013). The vision of better patient centred care can be realized by developing a Regional Health System (RHS) framework to better integrate all care services under one roof. Under the RHS, restructured hospitals can work in close partnership with other healthcare providers in the region, such as community hospitals (CHs), nursing homes (NHs), General Practitioners (GPs) and home care providers (Muttitt et al 2012). The goal is to anchor each of the six clusters with a regional hospital.

2.3 Method

A qualitative case study method was adopted to understand the evolution of healthcare IT in Singapore. A case study is considered as an appropriate approach for this study as it allows investigations of the issues in contemporary real-life situations using multiple sources of evidence (Yin 2009). Through the utilization of a revelatory case study, we attempt to explore how the healthcare IT evolved, how the challenges were addressed in each stage, and how to progress further to use the advancement in IT for future challenges and healthcare development. Singapore is selected for this study to examine these issues because of its advanced IT and medical infrastructure, and relatively low spending on healthcare compared to other developed countries. To explore these issues, archival data from multiple sources were collected in this study. Related government documents, press releases, yearbook, brochure, and white paper were collected from both government and healthcare organizations. We analysed the data collected by iterating between the empirical data, relevant literature, and the stage model (Eisenhardt 1989).

3 STAGE MODEL OF IT EVOLUTION IN HEALTHCARE

In this section, we will map the healthcare IT systems developed to meet the government's vision, starting from the initiation stage until the integration stage of Nolan's model. By doing so, we can provide insights on how IT in healthcare of Singapore has evolved over time and how each IT in each stage alleviated the challenges faced at that time. The proposed stage model of IT evolution in the context of Singapore healthcare is shown in Figure 1.

3.1 Stage I Initiation (1980-1990)

During initiation, introduction of IT (e.g., acquisition of computing resources) and low expenditure are two main characteristics of this stage. In 1980s, with the development of the economy and improvement of living standards in Singapore, people's need for better healthcare became more urgent. The cost of providing healthcare came from the government budget with a low rate of increase. The national health expenditure remained at 3% of an increasing GDP throughout the 1980s and 1990s (Lim 1998). The National Health Plan initiated in 1983 was the very first attempt at providing modernized healthcare facilities and higher medical standards to citizens (Haseltine 2013). This period also witnessed the adoption of IT in public organization including hospitals with a focus on improving public administration through the Civil Service Computerization Programme (CSCP). This program involved the automation of work functions and data digitisation in public organizations (E-Gov Masterplans 2011).

There were several challenges faced in this stage. As the main focus of this period was the digitisation of paper-based information, each cluster paid attention to the achievement of paperless data and there

was no or little coordination among different health organizations (Lim 2010). Further, in the process of digitising the paper-based data, patient privacy and security became a major issue (Hannan 1996).

To address these issues, Electronic Medical Records (EMR) were introduced within organizations, which are electronic versions of paper-based medical records and represent the electronic record of health-related information on patients. Compared to paper-based medical records, digitised versions can be easily accessed and shared among healthcare professionals. EMR was created, gathered, managed, and consulted by licensed clinicians and staff from a single organization who are involved in patients' health and care (Hannan 1996).

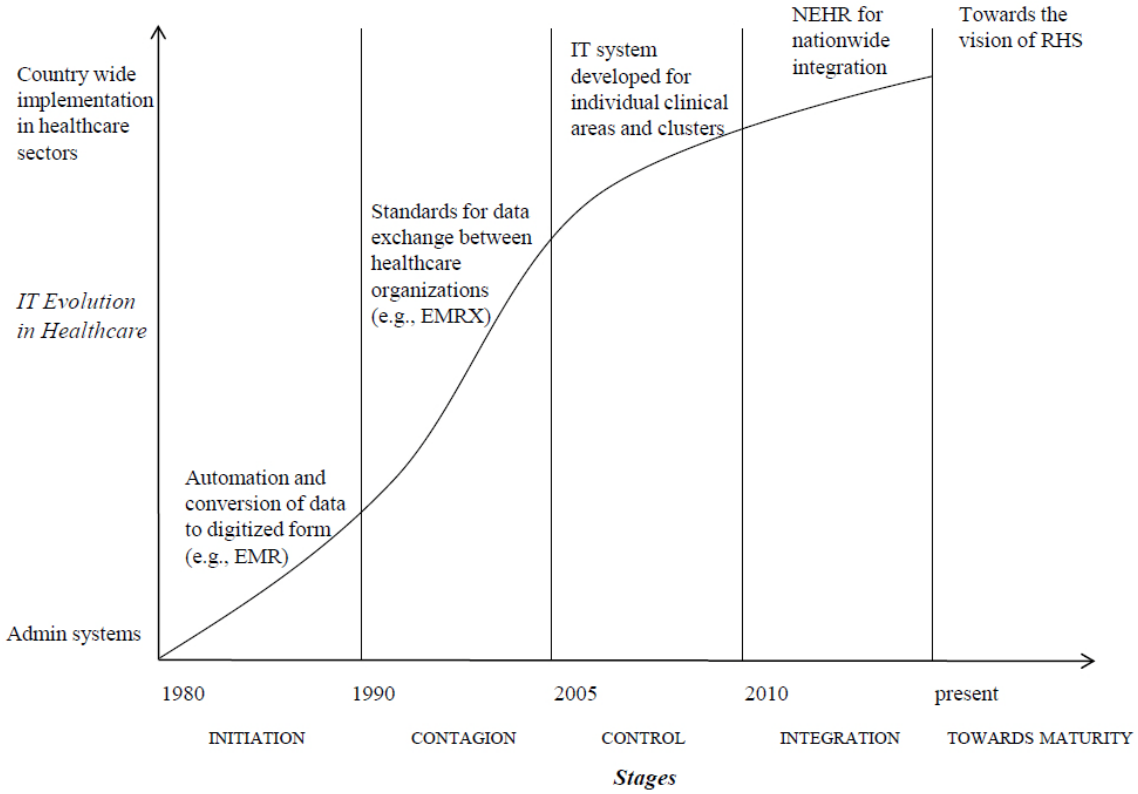

Figure 1. Proposed Stage Model of IT Evolution in Healthcare

3.2 Stage II Contagion (1990-2005)

In contagion stage, due to government's commitment towards computing resource exploitation and people's expectation about the health IT, the use of IT resources in healthcare rapidly increased. The rapid rising cost of healthcare is another feature of this stage. For medical financing, the MediFund scheme that is an endowment fund was set up by government in April 1993. The initial endowment of S$200 million came from government and the fund has increased to S$600 million in 1998 (Tajne et al. 2010). This stage witnessed the transformation of the basic healthcare infrastructure to a "coopetition" system (i.e., cooperation amidst competition), which delivers accessible information and value added e-services to the patients and doctors.

The challenges of this stage arise from the cooperation and coordination among corporatized hospitals. The corporatized hospitals, which were owned and managed by a monolithic government company—the Health Corporation of Singapore, competed with each other for market share of patients. Each hospital developed their own electronic medical records system, including signing separate contracts with the same vendors. The separation and counterproductive competition raised challenges for healthcare sector. The patients would be better served and costs would be reduced if these hospitals

adopted a common platform, shared medical records, and cooperated to take advantage of economies of scale (Lim 2004).

To solve the issues of cooperation among different healthcare organizations, the Electronic Medical Records Exchange (EMRX) architecture was launched in public hospitals and polyclinics to share patient records online in 2004 (iN2015 2006). EMRX was introduced to meet the need for a federated architecture to enable the clusters to implement standardized and interoperable IT systems (IHIS Yearbook 2011). This would facilitate quicker and easier access to patient data and test results in order to aid doctors to make more accurate and timely decisions. EMRX contained hospital inpatient discharge summaries, medical alerts and allergy information and medication information. It enabled hospitals to provide better-coordinated care especially when a patient moves within a cluster (E-gov eGAPII 2011).

3.3 Stage III Control (2005-2010)

The rising cost of healthcare in the previous stage made the government search for controls to contain healthcare costs. The health expenditure as a percentage of GDP decreased to 3.7% in 2007 but kept increasing subsequently to 5.1% in 2009 (Department of Statistics Singapore 2011). Therefore, planning became critical in the control stage to centralize these computing resources and reduce costs. To achieve the centralized state of IT resources, standards used to be established for documentation, processing, storage, accessing, and using of information (King and Kranemer 1984). In this stage, the focus was mainly on the utilization of IT resources for different purposes such as reducing adverse drug effect, preventing chronic diseases, and improving patient management.

The main challenges faced at this stage came from the following aspects. With the rising number of specialization areas in healthcare, there is a need to identify the capabilities of IT that can be applied to certain areas. A set of IT processes and functions were required to meet the needs for seamless healthcare, consumer segmentation, and care continuum (Muttitt et al. 2012). Consumer segmentation classifies the patients into a hierarchy that is composed of individual, family, community, and nation. The care continuum provides healthcare for the different consumer groups through offering health services such as primary care, specialist care, acute care, intermediate care, long term care, and preventive care (Muttitt et al. 2012). To achieve the goal of providing care continuum across all levels of consumers, different healthcare information systems need to be developed.

To address these challenges, different clinical areas such as clinician dashboard, order management, medication management, results management, clinical documentation, and clinical data repository were identified. Accordingly, IT systems were developed in response to the needs of each clinical area. The IT systems for different clinical areas identified from our review are summarized in Table 1. Table 2 describes each IT system and their potential impacts. These systems were first introduced in hospitals and subsequently extended to all the six clusters.

3.4 Stage IV Integration (2010 to present)

The integration stage is characterized by refined control and lower costs of exploiting IT resources. From 2010 to 2012, the expenditure on healthcare ranged from S$3,846 to S$4,802 million. The share of healthcare expenditure in the GDP slightly increased from 1.2 % to 1.4% (MOH 2014). Compared to the costs of healthcare in the previous stage, the costs during this period remained a relatively lower level. In this stage, most of the required IT systems are already in place in each cluster. The focus of current stage is more on integrating these IT systems to be able to implement a more consolidated Regional Health System (RHS) which can be used on a national level to provide quality healthcare to the public. RHS can also help realize patient centric benefits such as care continuity and faster access to a choice of healthcare providers.

Prior studies have suggested that system integration is an important challenge for IT development, especially in healthcare (Liu et al. 2011). For Singapore, the integration of healthcare IT and how to

harness information technology to achieve seamless flow of information across different healthcare establishments is a crucial challenge. In addition, population ageing produces a new set of challenges for national healthcare, especially for the spending on healthcare as seniors consume more healthcare resources than the young (Gill & Low 2013). Further, patient safety and quality of care are still a remaining challenge to overcome.

To improve healthcare quality for all residents, increase patient safety, lower healthcare costs, and develop more effective health policies, the NEHR vision of "one patient, one health record" was developed in 2011 (Accenture 2012). The National Electronic Health Record (NEHR) that is an integrated healthcare record centred on each person aims at serving this purpose for the Singapore population. It extracts and consolidates in one record all clinically relevant information of a patient across all the healthcare clusters (Muttitt et al. 2012). NEHR promises tangible and intangible benefits like better management of chronic diseases, improved access to care, fewer drug events, and reduced wait times (Tan & Seng 2009). By 2011 NEHR was integrated with other systems providing demographic and clinical data (Muttitt et al. 2012).

4 IMPLICATIONS

Healthcare IT seeks to achieve a level of seamless interaction between the provider and patient and among providers through the use of technology. This section will summarize the theoretical and practical implications of the healthcare IT evolution model that we developed and instantiated in the context of the Singapore healthcare industry.

4.1 Theoretical Contributions

In response to the importance of healthcare IT evolution and the lack of understanding of this issue, this study attempts to investigate the evolution of IT in healthcare with an initial focus on healthcare IT in Singapore. Based on Nolan's stage model, we developed a model to illustrate the evolution of healthcare IT in Singapore from 1980 to present. We identified four stages including initiation, contagion, control, and integration based on the characteristics of each period. The challenges of each stage were identified and how healthcare IT helps alleviate those challenges were elaborated.

This study has several potential contributions. It can contribute to the healthcare IT literature by addressing the research gap and investigating the role of IT in healthcare sector from a dynamic view. Not limited to an organization or specific time period, we studied the historical progression of IT use in healthcare on the country level. The study can also contribute to IT evolution literature by enriching our understanding of the evolution of IT in the healthcare context. The unique characteristics of healthcare make the IT use in this context different from the other domains. Further, this study can extend the traditional understanding of Nolan's stage model by applying it to examine the evolution of IT in a country.

4.2 Practical Implications

For healthcare organizations, the evolution of IT has resulted in a shift towards paperless or electronic data that makes storage, retrieval and sharing of data much easier than paper archived format. In the journey starting from small offices or departments such as administrative departments within an organization, IT penetration has made nationwide information system architectures possible. For example, EHR was started in individual organizations and clusters, but IT made it possible to realize the "one patient, one record" in the form of NEHR. In the future, systems such as RHS will help bring healthcare closer to patients thus establishing a patient-centred information processing and healthcare system. For patients, medical websites and mobile apps enable people to get access to health related information, making them more confident while discussing their treatment options with doctors. In addition to patients, doctors also benefit from the IT advancement. The evolution of IT facilitates their clinical process when treating patients, as they are able to access instant and comprehensive

information about patients. For example, EHR brings together different data about the patient such as the demographics, medication history, discharge summary, lab results and drug allergy. The IT systems such as EMR, EMRX, and NEHR that were developed for addressing the challenges in each stage provide insights on how to progress further to utilize the advance in IT to address further challenges in healthcare. This can be helpful for policy makers to get to know the trend of healthcare IT evolution and exploit the benefits of IT to alleviate healthcare challenges faced in future.

5 FUTURE PLAN

This paper highlighted the challenges faced by healthcare sector and how the evolution of IT has helped to manage these. It proposed a model of healthcare IT evolution based on the Singapore healthcare context to understand the effectiveness of IT and how challenges have been met or will be faced in future. This research to start with focuses on the evolution of IT in Singapore. In future we aim to study the healthcare structures in developed countries such Australia and New Zealand, as well as the UK and US. Applying proposed model for the evolution of IT in these countries we will be able to perform a comparative study between these countries. Such a comparative study would allow us to assess where each country stands, what are the best practices, and what is the scope of improvement when compared with other developed countries.

Appendix

Application Category	**Purpose**	**System Name**	**Implementation**	**Source**
Clinician Dashboard	Patient management	CPSS (Computerized Patient Support System)	JurongHealth, NHG[1], NUHS[2]	IDA 2005
		SCM (Sunrise Clinical Manager) - Clinician Desktop	AHS[3], EHA[4], SingHealth	IHIS Yearbook 2011
Order Management	Outpatient prescription	CPSS (Computerized Patient Support System)	JurongHealth, NHG, NUHS	IDA 2005
		SCM (Sunrise Clinical Manager)	AHS, EHA, SingHealth	IHIS Yearbook 2011
	Managing lab and radiology orders	CCOE (Computerized Clinician Order Entry)/ CPOE (Computerized physician order entry) - part of CLMM	JurongHealth, NHG, NUHS	IDA 2005
		SCM (Sunrise Clinical Manager)	AHS, EHA, SingHealth	IHIS Yearbook 2011
	In patient medication	eIMR/eMARS (Electronic Inpatient Medical records system/Electronic Medical Administration	JurongHealth, NHG, NUHS	IHIS Yearbook 2011

[1]National Healthcare Group
[2]National University Health System
[3] Alexandra Health
[4]Eastern Health Alliance

		Recording System) CPOE (Computerized physician order entry) – *part of CLMM*		
		SCM (Sunrise Clinical Manager)	eMAR in AHS, EHA, SingHealth CPOE in SGH, NDC[5], SingHealth	IHIS Yearbook 2011
Medication Management	Managing prescription and dosage	CLMM (Closed Loop Medical management system)	KKH[6], CGH[7], SGH[8], NUH[9] and TTSH[10]	IHIS Yearbook 2011
Results Management	Managing lab results, histology reports and radiology reports	RM (Results management)	JurongHealth, NHG, NUHS	IHIS Yearbook 2011
		SCM (Sunrise Clinical Manager RM)	AHS, EHA, SingHealth	IHIS Yearbook 2011
Clinical Documentation	In patient discharge summary	eHIDS (Electronic Hospital Inpatient discharge summary)	JurongHealth, NHG, NUHS	IHIS Yearbook 2011
	For electronic clinical notes taking	DDS (Digital Documentation system) , eNotes (Electronic Clinical Documentation)	JurongHealth, NHG, NUHS	IHIS Yearbook 2011
		SCM (Sunrise Clinical Manager- cDOC (Clinical Documentation System)	AHS, EHA, SingHealth	IHIS Yearbook 2011
Clinical Data Repository	For storage of all patient medical records such as demographics, visit events history, medication history, lab results and discharge summary	CCDR (Central Clinical Data Repository)	JurongHealth, NHG, NUHS	Muttitt et al. 2012

Table 1. Information systems applied in different clinical areas

[5]National Dental Care
[6]Khoo Teck Puat Hospital
[7]Changi General Hospital
[8] Singapore General Hospital
[9]National University Hospital
[10]Tan Tock Seng Hospital

System Name	Description	Evaluation
CPSS (2005)	It is a client-server based, one-point ordering and information access portal for doctors that has widespread adoption for drug prescription at outpatient and discharge medication usage areas	Allows medical practitioners quick access to patient's medical records from all departments in a hospital and facilitates prescription
SCM (2010)	A patient-centric electronic system that enables effective communication between authorized care providers. This also includes access to documentation, medication ordering and clinical decision support system	Enables care providers to share information securely.
CCOE(2010)	Main feature is e-prescription which checks for drug allergies and dosage. Another feature is e-ordering where doctors can order electronically medication, x-ray and laboratory tests for patients	Improves safety by replacing handwritten prescriptions which may be hard to decipher
CPOE (2010)	A system that allows direct entry of medical orders and instructions for the treatment of patients by a medical practitioner	CPOE can decrease delay in order completion, reduce errors related to handwriting or transcriptions, allow order entry at point-of-care or offsite, and provide error checking for duplicate or incorrect doses or tests.
EIMR/eMARS (2010)	Uses bar coding technology to submit and fill prescriptions with hand help scanners and transmit information like Medication dosages, number of refills Medication types, Medication classifications, Patient refill history to pharmacy and nursing stations.	eMars speeds up the prescribing process for patients and physicians. Electronic prescription forms such as eMars can improve quality care for countless patients. They also require less manual data-entry and eliminate the need for paper prescriptions, thus reducing costs
eHIDS (2011)	Electronic record of each episode of patient visit in any hospital.	This data is available for the doctor's access across clusters if need arises.
cDOC/eNotes (2010)	Allows doctors and nurses to enter electronic patient consultation notes	Helps in implementing paperless records
CCDR (2010)	Common data repository containing data from NHS, NUHS and JurongHealth clusters as of now.	The system provides a single source of information for patient medical records.
CLMM (2010)	A system to ensure correct medical administration to pateints. It helps staff to pick up right medication by scanning the barcode on patient's wristband using eMARS. Sensors on these intelligent cabinets track the dosage	Eliminates the need to decipher doctor's handwriting and reduces adverse drug events

Table 2. Description of IT systems and their impacts

References

Accenture (2012). Singapore's Journey to build a National Electronic Health Record System, accessed on Feb 19, 2014 from http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Singapore-Journey-to-Build-National-Electronic-Health-Record-System.pdf#zoom = 50

Andersen, K.V. and Henriksen, H. Z. (2006). E-government maturity models: Extension of the Layne and Lee model. Government Information Quarterly, 23(2), 236-248.

Ash, J. S., Berg, M., Coiera, E. (2004). Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. Journal of the American Medical Informatics Association, 11(2),104-112.

Centers for Medicare & Medicaid Services. (2014). Historical Data of National Helath Expenditure. Accessed on Feb. 22, 2014 from http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and Reports/NationalHealthExpendData/NationalHealthAccountsHistorical.html

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., Morton, S. C., Shekelle, P. G. (2006). Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Annals of Internal Medicine, 144(10), 742-752.

Department of Statistics Singapore. (2011). Yearbook of Statistics Singapore 2011. Department of Statistics Singapore.

Eisenhardt, K.M. (1989). Building theories from case study research. Academy of Management Review, 14(4), 532-550.

E-Gov Masterplans (2011). Vision and Strategic thrusts. Accessed on Feb 15, 2014 from http://www.egov.gov.sg/egov-masterplans/cscp/vision-strategic-plan

E-gov eGAPII (2011). Vision and Strategic thrusts, E-Government Action Plan II, accessed on Feb 21, 2014 from http://www.egov.gov.sg/egov-masterplans/egap-ii/vision-strategic-plan

Fichman, R. G., Kohli, R, Krishnan, R. (2011). The role of information systems in healthcare: current research and future trends. Information Systems Research, 22(3), 419-428.

Gill, A. and Low, D. (2013). Healthcare Financing: How should Singapore's Ministry of Health shift costs from private pockets to the public purse? Lee Kuan Yew School of Public Policy. Accessed on Feb 20, 2014 from http://lkyspp.nus.edu.sg/wp-content/uploads/2013/07/csu_healthcare-financing-final_2207.pdf

Hannan, T. J. (1996). Electronic Medical Records. Health Informatics: An Overview,133-148.

Haseltine, W. A. (2013). Affordable Excellence: The Singapore Health System. Brookings Institution Press.

Holland, C. and Light, B. (2001). A stage maturity model for enterprise resource planning systems use. The Database for Advances in Information Systems, 32(2), 34-45.

IHIS Yearbook (2011). Transforming Healthcare with IT innovation. Accessed on Feb 21, 2014 from https://www.ihis.com.sg/MediaCentre/publications/Documents/IHiS_Yearbook.pdf

iN2015 (2006). Integrating Healthcare Empowering Patients, Report by the iN2015 Healthcare and Biomedical Sciences Sub-Committee. Accessed on Feb 21, 2014 from http://www.ida.gov.sg/~/media/Files/Archive/Collaboration%20Opportunities/Collaboration%20Opportunities_Level2/iN2015Healthcare.pdf

King, J. L. and Kraemer, K. L. (1984). Evolution and organizational information systems: An assessment of Nolan's stage model. Communications of the ACM, 27(5), 466-475.

Kolodner, R. M., Cohn, S.P., Friedman, C.P. (2008). Health information technology: Strategic initiatives, real progress. Health Affairs, 27(5), 391-395.

Lee, J., Bae, Z., Choi, D. (1988). Technology development processes: A model for a developing country with a global perspective. R&D Management, 18(3), 235-250.

Lenz, R. and Reichert, M. (2007). IT support for healthcare processes–premises, challenges, perspectives. Data & Knowledge Engineering, 61(1), 39-58.

Lim, M. (1998). Health care systems in transaction II. Singapore, Part I. An overview of health care systems in Singapore. Journal of Public Health Medicine, 16-22.

Lim, M.-k. (2004). Shared Electronic Medical Records. Health Policy Monitor. Accessed on Feb. 12, 2014 from http://www.hpm.org/survey/sg/a4/3

Lim, M.-k. (2010). Health Care Reforms in Singapore. In Six countries, six reform models: the healthcare reform: experience of Israel, the Netherlands, New Zealand, Singapore, Switzerland and Taiwan-Healthcare reforms under the radar screen, P111-136. World Scientific.

Liu, C. F., Hwang, H. G., Chang, H. C. (2011). E-healthcare maturity in Taiwan.Telemedicine Journal and e-Health, 17(7), 569–573.

Lyytinen, K. (1991). Penetration of information technology in organizations. Scandinavian Journal of Information Systems, 3, 87-109.

Ministry of Health (MOH) Singapore. (2014). Government health expenditure and healthcare financing. Accessed on Feb. 12, 2014 from https://www.moh.gov.sg/content/moh_web/home/statistics/Health_Facts_Singapore/Healthcare_Financing.html

Ministry of Health (MOH). (2013). State of Health, Report of the Director of Medical Services 2003-2012. Accessed on Feb 15, 2014 from http://www.moh.gov.sg/content/moh_web/home/Publications/Reports/2013/state-of-health-report-2013.html

Muttitt, S, McKinnon S, Rainey S (2012). Singapore's National Electronic Health Record (NEHR) The Journey to 2012 and Beyond, HIMSS12, MOH Holdings. Accessed on Feb 16, 2014 from http://69.59.162.218/HIMSS2012/Venetian%20Sands%20Expo%20Center/2.22.12_Wed/Marcello%204502/Wed_0945/95-21_Sarah_Muttitt_Marcello%204502/95Muttitt.pdf

Nolan, R. L. (1973). Managing the computer resource: a stage hypothesis. Communications of the ACM, 16(7), 399-405.

Okma, K. G., Cheng, T., Chinitz, D., Crivelli, L., Lim, M., Maarse, H., Labra, M.E. (2010). Six Countries, Six Health Reform Models? Health Care Reform in Chile, Israel, Singapore, Switzerland, Taiwan and The Netherlands. Journal of comparative policy analysis, 12(1-2), 75-113.

Payne, C. S. (2013). Expenditure on healthcare in the UK: 2011. Office for National Statistics.

Röglinger, M., Pöppelbuß, J. & Becker, J. (2012). Maturity Models in Business Process Management. Business Process Management Journal, 18(2), Preprint.

Shekelle, P.G., Morton, S.C., Keeler, E.B. (2006). Costs and Benefits of Health Information Technology. Evidence Report/Technology Assessment No. 132. AHRQ Publication No. 06-E006. Rockville, MD: Agency for Healthcare Research and Quality.

SingHealth (2013), Wikipedia, accessed on Feb 15, 2014 from http://en.wikipedia.org/wiki/SingHealth

Tajne, S., Shelar, G., Nair, R., Gaddam, S. (2010). Singapore Health System. Accessed on Feb 19, 2014 from http://www.slideshare.net/drsatishtajne/singapore-health-system

Tan, P. and Seng, O.L. (2009), Singapore's National Electronic Health Record Architecture, Ministry of Health Holdings (MOHH), Integrated Health Information Systems (IHIS). Accessed on Feb 15, 2014 from http://www.omg.org/news/meetings/workshops/SOA-HC/presentations-09/04-03_Tan-Seng.pdf

Yi, M. Y., Jackson, J.D., Park, J.S., Probst, J.C. (2006). Understanding information technology acceptance by individual professionals: Toward an integrative view. Information & Management, 43(3), 350-363.

Yin, R.K. (2009). Case study research: design and methods. Sage Publications, California.