EXPLORING VIRTUAL VALUE CHAIN IN HOSPITALS: A CASE STUDY AT SINGAPORE HOSPITAL

Chang Le, Arun Kumar[*], Sung J. Shim[ж]
School of Mechanical and Aerospace Engineering
Nanyang Technological University
50 Nanyang Avenue, Singapore-639798
Corresponding Author *Email: makumar@ntu.edu.sg

[ж]Stillman School of Business
Seton Hall University
South Orange, New Jersey, USA

ABSTRACT**:** As healthcare costs increase, there is a need for healthcare service providers to look for ways to contain costs and to improve the service level. Due to the limited resources, it is difficult to create value in the physical value chain, so the health care industry should focus on using information system. This paper introduces the virtual value chain evolution in health care industry, the up-to-date virtual value chain functions and how the virtual value chain creates value by using hospital information system and simulation concept.

Keywords: virtual value chain, healthcare, IT.

1. INTRODUCTION

Every facilities management team today is engaged in two worlds: a physical world of resources that managers can see and touch, and virtual world made of information. The latter has given rise to what we call e-commerce. Rayport and Sviokla (1995) describe these worlds as the marketplace and the market space. Facilities management teams must now deal with the creation of value in both of these worlds. However, the process of creating value in the two worlds is fundamentally different. Understanding the interplay of the marketplace and the market space is a prerequisite to leverage commercial advantage.

Virtual value chain has been an important part in the business world. E-commerce and supply chain management (SCM) have caught considerable attention among private and public organizations recently. The idea of achieving higher customer satisfaction and improving operating performance in the digital economy is through an integrated information system. Most of the companies have to prepare to operate in the era of "network competition", where individual businesses no longer compete as solely stand-alone entities, but rather as supply chains. As the virtual value chain is evolving, many nonprofit organizations such as health care industry are developing their virtual value chain to reduce the operating cost.

With increasing use of the hospitals today, the hospital staffs bear bigger pressures from their works due to limited resources of hospitals. These require the hospitals to improve their capacity, but there are only limited resources in a physical chain. So the only way for the hospitals is to expand their capacity in virtual world. This will help in releasing the hospital staffs' pressures, and improving patients' service level.

This paper describes a case study undertaken at the Singapore Hospital where the management considers reengineering the process of delivering medicine to patients. The new process involves using a newly customized hospital information system in reducing the waiting time of patients at the pharmacy and in creating value. Using computer simulation, this study first assesses the efficiency of the new process with respect to waiting time of patients, and then recommends the optimal model for delivering medicine. The results will help those who are considering reengineering and improving patient's service level.

2. LITERATURE REVIEW

2.1 Evolution of Virtual Value Chain in Health Care

The virtual value chain in hospital is realized by the information system in health care industry. Data, information and knowledge are the three key components of health care information system. Table 1 shows the progress in medical computing for each category of application. Within a category, research begins only after the supporting technology is mature enough to support it beyond the conceptual level. After the underlying assumptions are established, prototypes are used to provide operational feedback. Finally, some of the prototypes mature, and new, complementary applications are disseminated.

	1950s	1960s	1970s	1980s to early 1990s	mid-1990s to now
Data application	Research	Prototype	Mature	Refined	Refined
Information applications	Concepts	Research	Prototype	Mature	Refined
Knowledge applications	Concepts	Concepts	Research	Prototype	Matured

Table 1**:** Scope of Medical Computing

It can be seen in this table that, during the period 1950-1975, the history of medical informatics could be characterized as the operational success of the data-oriented applications. For example, artificial intelligence in medical decision making:1975 was a watershed year in the history of medical informatics. After 1975, the information application became mature.

The origins of Hospital Information System may be traced to the Lockheed Missiles and Space Company in Sunnyvale, California in the early 1960s. In 1966, this group was invited under contract to assist the Mayo Clinic in a comprehensive assessment of computer system needs of the clinic and its two associated hospitals. Further, Weed (1969) proposed a new form and flow for the medical record. The goal of this problem-oriented medical record was to interject the same discipline into patient care and training that one used in research. In time this record was converted into an automated form, and the resulting Problem-Oriented Medical Information System (PROMIS) advanced the state of the art in both hospital information systems and personal workstations.

The reliability of early systems left much to be desired. Hardware failures were the norm rather than the exception. Software crashes were commonplace. A lot of hospitals could not afford the expense of hardware. Thus, the virtual value chain provided few values to the patients and hospitals at a very high cost in 1960s.

Between 1975 and 1995, the computer technology developed very fast, and the infrastructure of information system became cheaper. But because there were few operational models to follow, knowledge-oriented applications were still in a research setting. Medical informatics began as a tool-driven discipline; the intent was to solve problems that were constrained by the limits of manual processing. Many hospitals decided to have new information systems replacing many older and dysfunctional ones. Some healthcare organizations have moved towards greater use of computerized information systems as their work has grown increasingly complex and introduced a diverse range of systems (Fitter, 1987), from the operational to the managerial, such as Resource Management. The reforms have increased demand for more sophisticated information so that purchasers and providers can manage the demands of the internal market (Culyer et al. 1990). Despite large investment in information systems in some healthcare organizations over the last decade, the perceived benefits of these systems have been slow in coming. Buxton et al. (1991) state that many National Health Service (NHS) information systems have not yet demonstrated substantial enough benefits to justify the investment. The virtual value chain evolved very fast between 1975 and 1995.

Since 1995, the advent of advanced information technology has transformed many aspects of healthcare delivery processes. Information technology in many cases has functioned as an enabler to facilitate significant changes within a healthcare system, especially through the process of reengineering. Consequently, practicing medicine is increasingly relying on the processing, evaluation, synthesis, and transmission of information. There is a continuous need for healthcare practitioners to access, manage, and incorporate new information, new knowledge, and new capabilities into their practices. So the healthcare information system became more and more important.

2.2 Business Process Reengineering in Health Care

Hospitals constitute a particularly appropriate context for the study of reengineering outcomes. Hospitals are strongly influenced by both economic and institutional forces (Scott and Meyer 1991). With stiff competition and difficulties in reducing the costs, hospitals are looking in the direction of logistics to gain an edge over competitors (Gattorna, 1998). Faced with ambiguous technologies and outcomes, hospitals also experience strong influences from institutional pressures (Zhang, 2001) that may encourage adoptions of new programs. As a result of both economic and institutional pressures, hospitals have historically tended to adopt many different organizational changes. Early changes included external alliances, diversification, changed strategic reorientations (Shortell et al. 1990), and corporate restructuring (Arndt et al. 1995). More recently, hospitals also experimented with many other organizational changes, including self-directed work teams, quality circles, matrix management, and total quality programs (Burns, 1989, Kumar, et al, 2003). Reengineering is among these, with 63 percent of all hospitals engaging in reengineering initiatives (Pierson and Williams, 1994). Reengineering perspectives have been widely applied in hospital settings in recent years (Buchanan, 1998). Kumar and Shim (2005) discuss surgical care process reengineering. Jarrett (1998) describes the advantage of reengineering in the healthcare supply chain. Further, Huang (1998) classified materials management systems among Taiwanese hospitals by using a Fuzzy clustering method. Heinbuch (1995), Motwani et al (1996), and Clare et al (2000) highlighted the value of JIT inventory system for materials management in clinical areas of hospitals. In a recent paper, Jansen-Vullers and Reijers (2005) have discussed the business process redesign in healthcare.

Over the past two decades, simulation has proven to be a significant tool in the analysis of a wide variety of healthcare delivery systems. Anderson et al (2002), Levy et al (2002), Rauner (2002), Jacobson and Sewell (2002), Zaric (2002) and Kumar et al (2005) illustrate the use of simulation for various health policy analyses and in improving the design of facilities, reducing patient wait times and operating costs. Montgomery et al (2000) reveal that some healthcare managers use simulation to assist with staffing. Arvy and Morin (1997) use simulation to study the effects of staffing adjustments on patient throughput within a clinic. It is worth noting that many applications of computer simulation to specific healthcare processes assess patient wait times. Lane *et al.* (2003) describe a simulation model to understand patient wait times in accidents and emergency department. Everett (2002) describes a simulation model that provides a means for a central bureau to schedule the flow of elective surgery patients to appropriate hospitals in Australia. Von Merode *et al* (2002) use simulation to determine the optimal production and inventory policies for each combination of patient type and cytostatic drug type to minimize patient wait times and costs. Blake *et al* (1996) describe a simulation model of the emergency room to investigate issues contributing to patient wait time.

3. VIRTUAL VALUE CHAIN IN HEALTH CARE

To enable information and information technology to create value, the value-adding steps must themselves become virtual. Rayport and Sviokla (1994) explain that a sequence of five activities is required to create value within a virtual value chain:

-- Gathering information,
-- Organizing the information,
-- Selecting the information,
-- Synthesizing the information, and
-- Distributing the information.

It is however crucial that the value created through information does not destroy the value created by the other activities, but rather adds to the total.

When implementing virtual value chain in a hospital, there are three stages illustrating the depth of automation:

Visibility: it allows hospitals to "see" physical operations through information, co-ordinate activities, and lay the foundation for a virtual value chain. Moreover, information technology acts as a central nervous system within the hospital that integrates patient management, ancillary services, HR management, material and financial management; it also provides managers with information on suppliers, customers, and competitors.

Mirroring capabilities: in mirroring capability, hospitals substitute virtual activities for physical ones and begin to create a parallel value chain in the management. Once the necessary infrastructure for visibility is established, managers should then try to establish what the hospital is currently doing in the management; what could be done more efficiently and effectively in the patient management; and what value-adding steps currently performed in the physical value chain might be shifted to the mirror world of the virtual value chain?

New hospitals and patients relationships: finally, hospitals use information to establish new patient relationships. Managers draw on the flow of information in their virtual value chain to deliver value to patients.

3.1 Hospital 2000 Concept Construct Virtual Value Chain in Singapore Hospital (SH):

Around three years ago, Singapore Hospital (SH) chose the famous Enterprise Resource Planning (ERP) system SAP R3 as its information system to format their work. However, due to SAP's main focus being on manufacturing industry, the hospital information module could not meet its need, and SH decided to implement Amalga PACS module from Hospital 2000 system and link this module to SAP R3 system to make up the functions. As one of the most successful concept and hospital information system, Hospital 2000 system is a fully integrated, single-solution information system created and implemented by Global Care Solutions. It not only includes all the function of SAP R3 system that has been implemented at SH, but also provides additional module to make up the SAP R3 functions.

All Hospital 2000 data are stored in a single database providing real time data across applications throughout the hospital. Because all data are stored centrally, they can be viewed simultaneously from multiple terminals giving department access to timely, up-to-date patient information. The use of PC based servers and workstations in combination with advanced RAID 5 hard disks provides mainframe class reliability at a cost that allows most hospitals to replicate their data center, thereby ensuring foolproof data security without user intervention to archive data or perform time consuming backups archiving or time consuming data back-ups.

Because the function modules are compatible, we are introducing the function modules in Hospital 2000, and describe the functions provided by SAP R3 and the additional Hospital 2000 module implemented at SH.

At the core of Hospital 2000 is the Electronic Medical Record (EMR), made possible by the single integrated database design. The EMR integrates a document imaging and delivery system that allows the instantaneous scanning, storage and retrieval of both electronically generated and handwritten material from any terminal in the Hospital 2000 system. Furthermore, Hospital 2000 front office strengths include its Radiology, Laboratory, and Pharmacy, RADT (Registration Admission, Discharge and Transfer) and Clinic and Ward systems. The Hospital 2000 back office is a comprehensive product suite comprised of all the applications necessary to administer a hospital. From a full-featured accounting system including General Ledger, Accounts Receivable, Accounts Payable and Fixed Asset Maintenance modules, to Purchasing and Inventory modules that handle all materials management, the Hospital 2000 system provides fully integrated back office functionality in addition to a full Human Resources Management and Payroll system.

In addition to streamlined computer architecture, innovative designs are built into Hospital 2000 software to optimize hospital workflows. Device support for security technologies such as the i-button, smart cards or iris scanning devices securely identifies users, while support for web cams to acquire patient photos ensures positive patient identification and virtually eliminates insurance fraud. Another advantage of the Hospital

2000 system is that it is extremely user friendly. The Hospital 2000 GUI is designed specifically to lower the employee learning curve and minimize user-training costs.

Multi-language support is available throughout the entire Hospital 2000 system. Virtually all languages are supported, including those with "right to left" text entry requirements. Hospital 2000 is fully Unicode compliant, so it is ready for even the most difficult, multi-lingual environments. The functions available throughout the Hospital 2000 system are created to address the organizational demands of large or growing hospitals. The fully integrated Hospital 2000 system modules provide configurable solutions that cover the full healthcare and financial services spectrum.

3.2 Current Virtual Value Chain based on the information system:

PACS/RIS: Picture and Communication System (PACS) & Radiology Information System (RIS) receives patient demographic, order and appointment information from the Registration, Appointment and ordering components of the Clinic, Ward and Radiology system. Integration ensures data integrity, elimination of transcription errors and duplicates data entry and optimizes patient and report turnaround. Above all, this module provides function of archiving all the medical data into the backup database.

Patient Management: Figure 1 shows the workflow of Patient Management modules, which includes three integral components: *Appointments*, *RADT*, and *EMR*. *Appointments* module receives patient demographic information from the Registration system and is seamlessly launched from the Clinic, Ward, Laboratory, Radiology and other clinical systems. *RADT* module manages the entire patient care workflow, from the registration of patient information in the Patient Master Index (PMI) to bed tracking and discharge. The *EMR* is the central repository for all medical related documentation, combining each patient's medical history into a single medical record. From any terminal in the system the *EMR* provides the necessary tools for physicians to complete all procedures and administrative tasks associated with a patient visit.

Ancillary Services: Figure 2 shows the workflow of Ancillary Services modules, which also includes three major components: *Dietary Management*, *Laboratory*, and *Pharmacy*. The Dietary Management module manages all information regarding patient diets, including menu printing, patients' choices of meals and restrictions set by allergies, and supports the logistics of food preparation and distribution. The *Laboratory* module includes tailored systems designed to effectively meet the needs of every size lab. The third component, *Pharmacy Information System (PhIS)*, assists in the automation of the medication management process throughout Inpatient and Outpatient settings.

Human Resource (HR) Management: Human Resource Management modules include four important components: *HR*, *Rostering*, *Training* and *Payroll*. The *HR* system manages the full employment lifecycle specializing in the needs for both medical and non-medical personnel. *Rostering* module provides managers with a powerful tool for scheduling staff and tracking employee attendance and department productivity. *Rostering* captures the labor hours of the entire organization. The third component, *Training* module manages hospital education and training processes and employee development activities. The fourth component, *Payroll* is a fully integrated part of the HR suite of applications and processes all recurring and non-recurring payments and deductions for employees. Global payroll requirements are also supported.

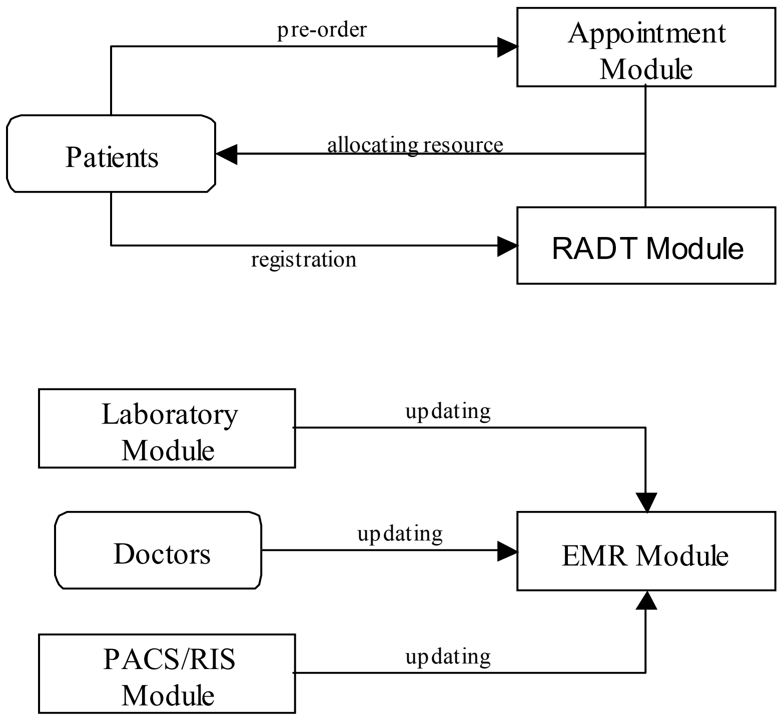

Figure 1: Workflow of Patient Management Modules

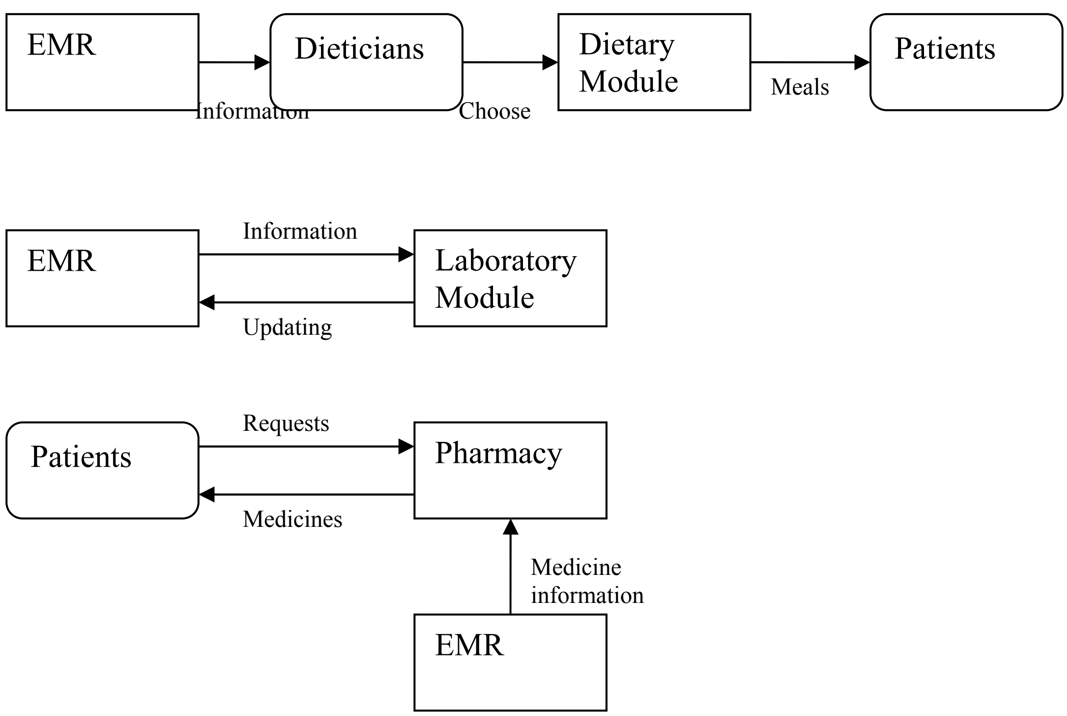

Figure 2: Workflow of Ancillary Service Modules

Financial Management: this includes five modules: *Patient Accounting*, *Accounts payable, Accounts Receivable, General ledger*, and *Fixed Assets.* The Hospital 2000 *Patient Accounting* system is the financial interface between the Hospital 2000 front and back office systems. It represents the main integration point for business processes, concentrating financial transactions generated during a patient visit into financial data that can be posted to the *General Ledger* via the *Accounts Receivable* gateway. The Hospital 2000 Financial suite is comprised of *Accounts Payable*, *Accounts Receivable* and *General Ledger* and seamlessly integrates with the entire Hospital 2000 system.

Material Management: This includes the following modules: Inventory and Purchasing. The *Inventory* module, coupled with the *Purchasing* module, provides a complete Materials Management Solution for hospitals. *Purchasing* module provides comprehensive purchasing functionality, including recognition of existing contracts and agreements, receipt control, and integration to invoice creation in Accounts Payable.

4. CASE STUDY

As mentioned above, the way the virtual value chain provides new value to user is by using hospital information system to reengineer the traditional process. A case study conducted at Singapore Hospital to reengineer the process of delivering medicine to patients illustrates how the virtual value chain provides value.

4.1 Singapore General Hospital (SH):

The modern history of Singapore Hospital began in March 1926, with the opening of 800 beds in the Bowyer, Stanley and Norris Blocks. In 1981, the Hospital was rebuilt, with its current 8-block complex. In March 2000, SH came under the management of SingHealth Group. Figure 3 is the SAP system customized by SH based on the concept of Hospital 2000 system. It can be seen that by using information system a lot of processes have been reengineered compared to traditional hospital processes. The appointment system enables the patient's option of making an appointment with the doctor instead of waiting too long in the clinic. This greatly helps the busy or weak patients in saving waiting time in clinics. EMR system leads to recording of the patient's information accurately and also provides the doctor complete information. This study explores an optimized process benefiting from the information system.

4.2 The Queuing System Problems in the Hospital

This case study focuses on optimizing the process of patients buying medicine after the consultation by using virtual value chain in a hospital. Figure 4 is the flowchart of patients buying their medicines. In the whole process, there are 4 queues. After arriving at the hospital pharmacy, patients enter the queue and get a queue number ticket for the medicine collection. The pharmacy counters are in charge of collecting patients' prescription information and then forward the information to the pharmacists. The pharmacists fill up the prescription order for the patients as per the prescription from ticket counters. Subsequently, pharmacists inform the patients to collect their medicine at the collection counter. At the counters, pharmacists also explain the dose instructions to patients and answer their queries. Patients pay the bills and leave the system. The whole process is composed by four queues, which are in a hierarchical structure. Each delay in upper stream queues might cause the other delay in downstream queues. Multi-queue and hierarchical structure makes the system working in a busy and low efficiency condition.

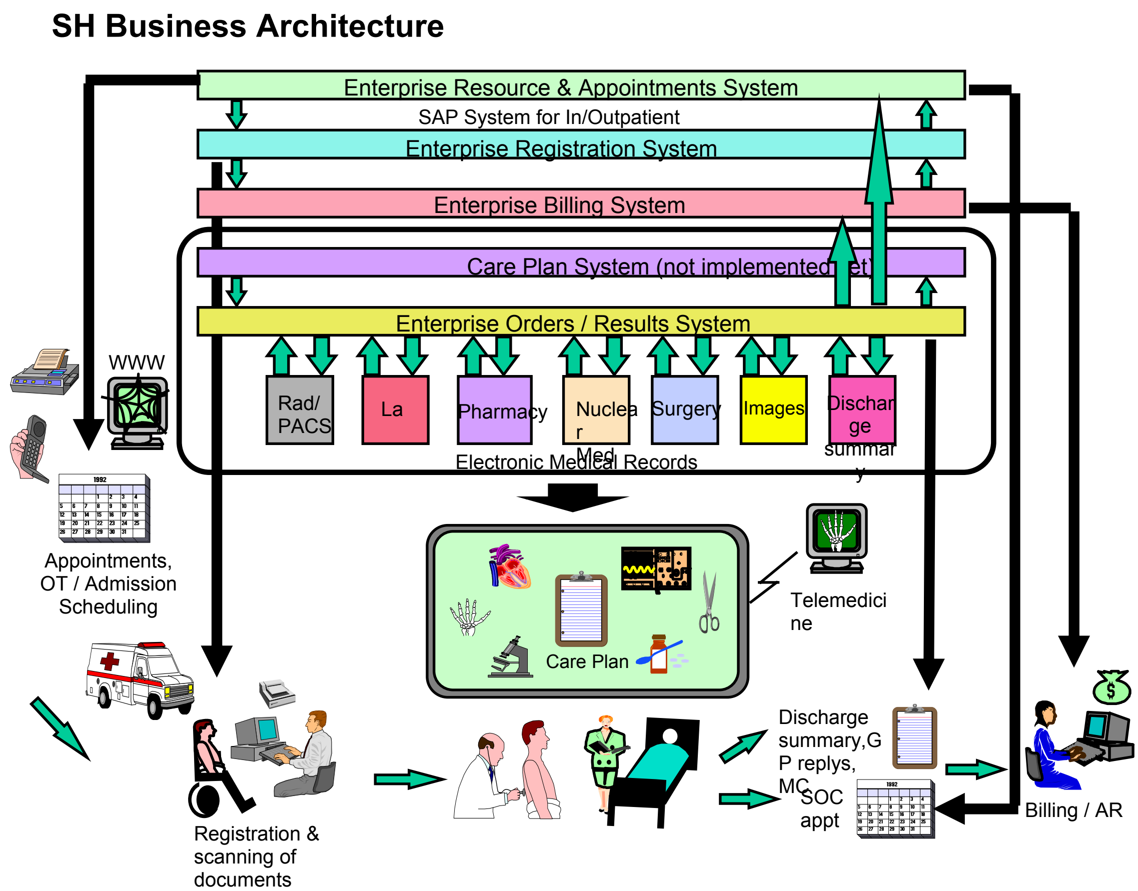

Figure 3: SAP System Customized by SH based on Hospital 2000 Concept

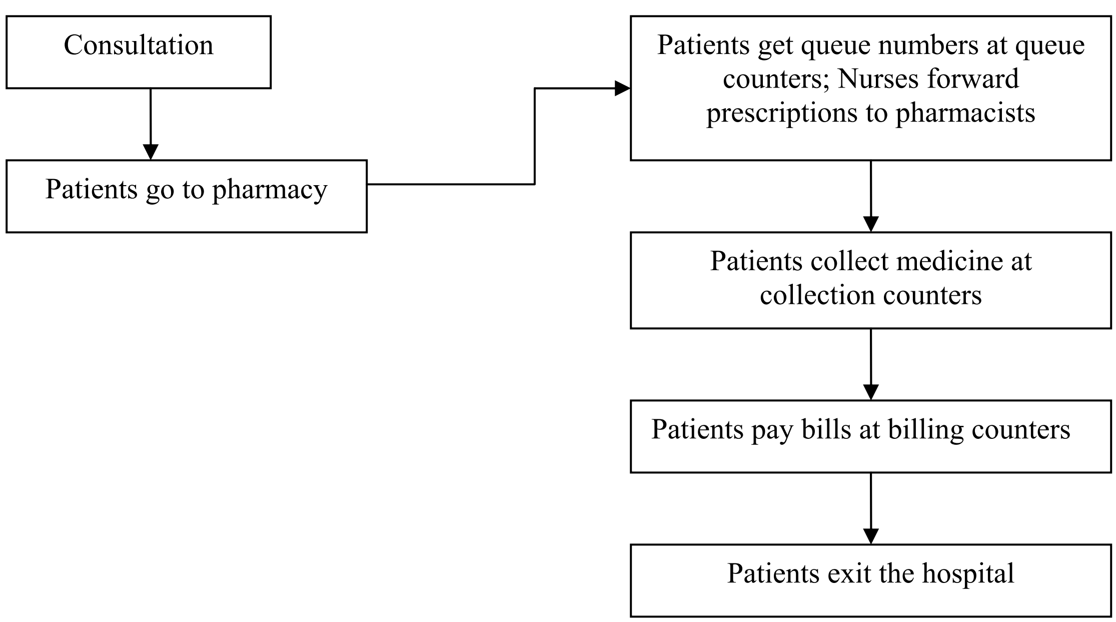

Figure 4: The Flow Chart of Patients Buying Medicine

4.3 Virtual Value Chain Reengineering the Procedure

EMR as mentioned in Hospital 2000 concept earlier is the core in customized SAP system. This module enables the doctors to prescribe the medicine online. After writing the prescription, the doctor asks the patients if they would like to buy medicine from hospital's pharmacy. If the answer is yes, ERP system will generate a ticket number of the patient's medicine marked with medicine list and price and the information will be sent to pharmacists. While exiting the clinic, the patients pay at doctor's lobby and proceed to pharmacy. In the mean time, the pharmacists prepare the medicine for the incoming patients. When the patients enter the pharmacy room, they show the bill and ticket number to the service counter. The pharmacists at service counters match the ticket number with the medicine bag, give the bag to the patient and provide proper consultation concerning doses. Figure 5 is the optimized pharmacy process supported by hospital information system:

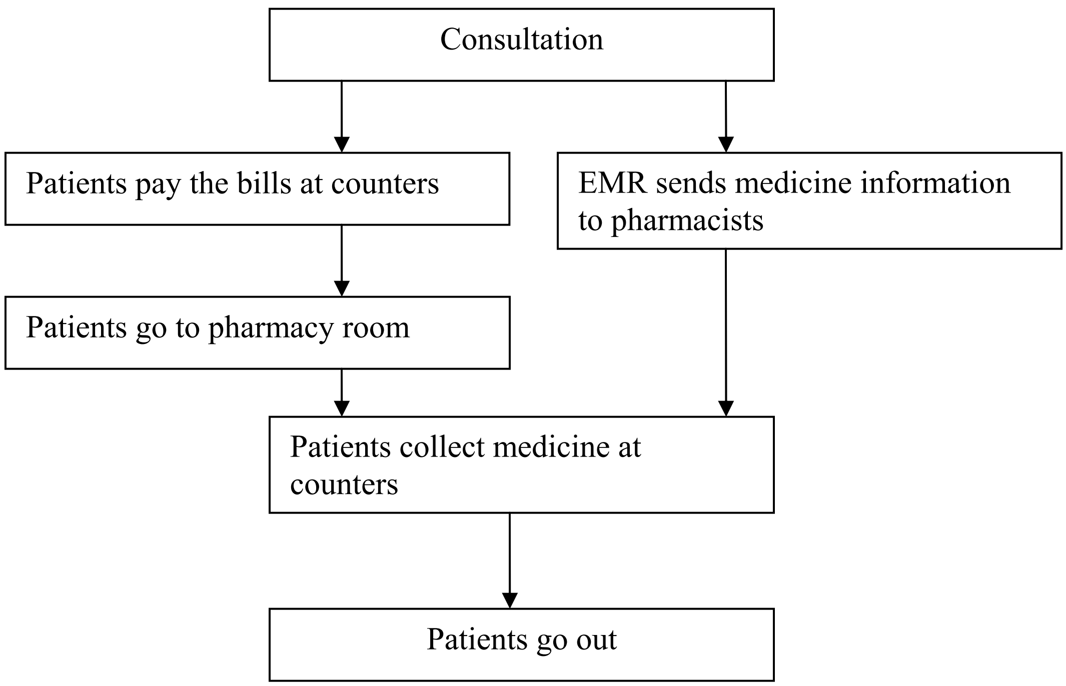

Figure 5: Flowchart of Optimized Process

As shown in the figure, this procedure changes some original hierarchical process into parallel process. In the original process, the information handling and the patients moving alternatively affect the process, but in the optimized process the information handling and patients moving become two parallel channels. The two channels do not interfere with each other. In the new process, the information system also eliminates a ticket collection queue present in the original process.

Figure 6 shows the map of pharmacy and clinics studied at SH. In this case, there are five clinics H, J, K, L and M that share a common pharmacy. The patients from the 5 clinics go to the pharmacy room. In every clinic there are 4 to 5 counters, one of these counters is for billing. After the patients finish their consultation, they go to pharmacy room. It takes a while before they reach the pharmacy. In the pharmacy room there are two registration counters, six prescription fill-up counters and two payment counters, but all of these counters open during peak hours, from 10:30am to 2:00pm. There are five counters behind the medicine collection counter used for medicine preparation, and the full operation is also during the peak hours.

4.3.1 The Simulation Modeling

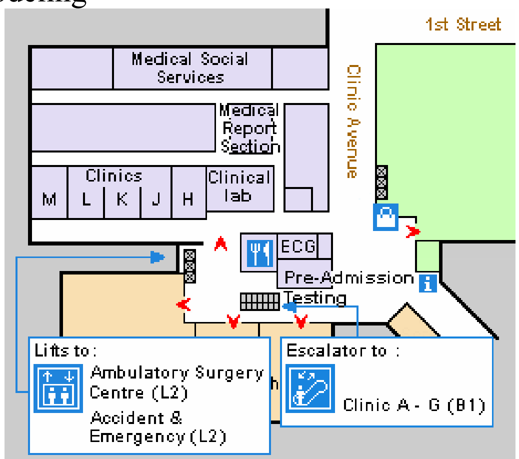

Figure 6: The Map of Hospital

For simulation study, numerous observational data were collected. To investigate the most severe queuing problem in the morning, data were collected from 10:00am to 2:00pm over a 15 days period at each service facility. Most of the data such as the service time of different servers in different counters were defined in the simulation resource and tested patient by patient for a minimum sample size of 30. Other data such as workflow of patients entering pharmacy room were collected according to the patients' registration ticket numbers on an hourly basis. After collecting these data, they were entered into Data Analysis software provided by **Arena 7.0** simulation software. With analysis of the data, the critical values output were collected and used to define the simulation.

In order to simulate the original and the optimized systems, the following values were defined:

- The flow rate of the patient entering the pharmacy room
- The time patients spend on the way to pharmacy
- The time patients spend near the ticket collection counters in pharmacy
- The time spent by the pharmacists filling-up prescription orders for patients
- The time patients spend at medicine pick-up counters in pharmacy
- The time patients spend at the billing counter in pharmacy.

Table 2 shows the data and setting in the models.

	Number of sources	Distribution		
		DT	Mean	Variance
Clinics	5	Uniform	2(min)	4(max)
Payment counters	2	Normal	1.2	0.3
Medicine collection counter	6	Normal	4.3	2.5
Registration counters	2	Normal	1.1	0.4
Medicine preparation counters	5	Normal	3.3	1.3

Table 2: Operation Character of the Model

The model can be defined by the data above, but still it is based on the assumption that the five clinics have same distribution type and equally share the patient flow to pharmacy room. All the counters serve the customers based on first in first out discipline.

4.3.2 Results and Discussion

The two models ("As Is" and "To Be") are compared in Table 3 below.

	Average waiting time	Average transition time	Average service time	Average total time
Original model "As Is"	22.7	2.6	9.8	35.1
Optimized model "To Be"	18.8	2.6	5.3	26.8
Saving in time	3.9	0	4.5	8.3

Table 3: the Comparisons of Two Models Output

Figure 8 shows the comparison of two models.

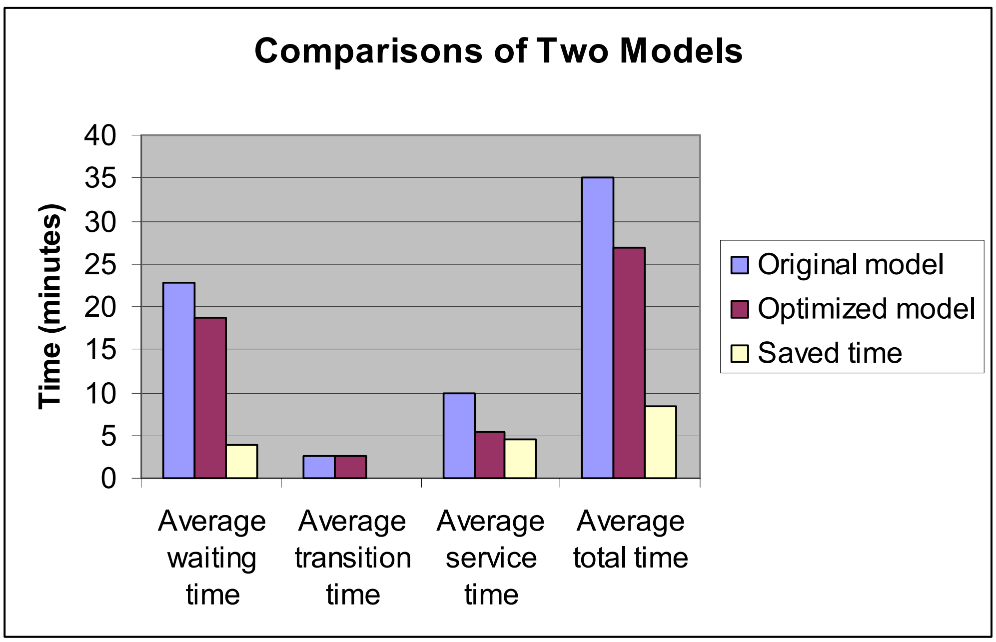

Figure 8: Comparison of the Two Models Diagram

Based on the results presented above, the most efficient model is the second model ("To Be"). It is found that using the optimized procedure, the average waiting time is shortened by 3.9 minutes, the average service time is reduced by 4.5 minutes, and the total time is reduced by 8.3 minutes. But there is no difference between the two models' transition times. This arrangement improves the current service level for the patients buying medicine at the hospital, and less number of patients will be balking due to long waiting time in the system.

The main reason behind the improvement of service level is transforming the hierarchy business structure into parallel business structure, based on the good communication infrastructure. This means that with the EMR system, the optimized process results into the pharmacists preparing the incoming patients' medicine during the time elapsed between the patients paying the bill and going to the pharmacy room. Besides the improved service level, the optimized process also cuts the two billing and two registration counters in the pharmacy room. It also helps the hospital in reducing some of labor cost and improving the utilization level.

5. CONCLUSIONS

This study has introduced the meaning and evolution of virtual value chain in health care industry, and the different kinds of value provided by the latest concept Hospital 2000. It explains the method of virtual value chain providing added value to the users by reengineering the traditional management activities. This also provides a lot of value to the users that physical value chain cannot provide. Both hospital staff and patients have favored the value provided by virtual value chain.

Hospital 2000 provides power functions to the users, but there is still some room for improvement. With the business competition becoming fierce, a lot of new business management concepts have been established and applied in the real business activities such as JIT and VMI. These business concepts represent more economic opportunities in the business operations. Most of them are dependent on good information technology. That means virtual value chain can create more value by using these concepts in health care industry.

Using the JIT concept, the case study reengineered a patient management process. The common approach to develop virtual value chain is by using the information system to reengineer the traditional process. It can also be a good example for the future researcher to use new business concept on the hospital management to study how much value the virtual value chain can provide to hospital. However, despite good IT infrastructure, virtual value chain in healthcare industry still lags behind other highly competitive business industry. New studies are suggested to observe other business processes in health care industry to check if the new concepts can be implemented to reengineer other processes.

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