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An empirical study of RFID-enabled mobile healthcare

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An Empirical Study of RFID-enabled Mobile Healthcare

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree in any university.

Therefore, I hereby declare that the content of this thesis is the work of me, YE LIU except where indicated in the text and referenced at the end of this document.

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ABSTRACT

In recent years, healthcare organisations have begun to invest in RFID-based systems to control costs and improve efficiency and quality of care. The purpose of this research is to study the influences of technological, organisational and environmental variables on the adoption of RFID in terms of the transformation of healthcare processes, based on the diffusion of innovation theory and the technology-organisation-environment framework. For the purpose of this analysis, 131 cases (including 61 RFID-based applications) from four consulting and solution vendors including RFID Journal, SAP, Oracle and Cerner, have been classified into three categories, namely, asset management, patient management and staff management. A multi-method approach to explore the research questions guiding this study has been adopted. Our findings indicate that RFID capabilities positively affect the adoption of RFID in healthcare settings, whilst the environmental and organisational contexts have significant impacts as well. This research contributes to a growing body of study related to the impact of RFID in the healthcare sector and the enabling role of RFID in enhancing process performance.

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ABBREVIATIONS

Acronym	Description
ADC	Automated Distribution Cabinets
ADD	Automated Dispensing Devices
ADM	Automated dispensing machine
AMC	Academic Medical Centre
CDSS	Clinical Decision Support System
CMMS	Computerized Maintenance Management Software
CPOE	Computerised Physician Order Entry
CT	Computed Tomography
DIO	Diffusion of Innovation
EHRS	Electronic Health Record Systems
EMR	Electronic Medical Records
ERPS	Enterprise Resource Planning System
FDA	Food and Drug Administration
GDP	Gross Domestic Product
GPO	Group Purchasing Organisations
HAS	Health Athletes Software
HF	High-frequency
HIPPA	Health Insurance Portability and Accountability Act
HIS	Hospital Information System
HMO	Healthcare Maintenance Organisations
ICT	Information and Communication Technology
IDN	Integrated Delivery Networks
IOM	Institute of Medicine
IP	Intellectual Property
IR	Infrared
IS	Information System
IT	Information Technology
LBMS	Location-Based Medical Service system
MBS	Mississippi Blood Services

ABBREVIATIONS

MRI	Magnetic Resonance Imaging
MRN	Medical Record Number
MSKCC	Memorial Sloan-Kektter Cancer Center
NVPLLC	New Venture Partner
PACS	Picture Archiving and Communications System
PMS	Practice Management Software
POI	Return-On-Investment
PPACA	Patient Protection and Affordable Care Act
PRIM	Physical Resource Infrastructure Management
QOS	Quality Of Services
RFID	Radio Frequency Identification
RIS	Radiology Information System
RTIS	Real-Time Locating System
TOE	Technology-Organisation-Environment
WHO	World Health Organisation
UBC	Unit-Based Cabinets
UID	Unique Identifying

1 CHAPTER 1: INTRODUCTION AND OVERVIEW

Today, patient safety is one of the most important issues to concern in the World Health Organisation (WHO). It depends on several key resources to effectively deliver health service: motivated staff, equipment, information and finance, and adequate drugs (WHO 2007). Unsafe factors exist in the whole care-giving process, and medical errors have been seen as a leading cause of death and injury in 2000 (Kohn, Corrigan et al. 2000). It cost the federal Medicare program $8.8 billion to cover patient safety incidents, which resulted in the potentially preventable death of 238,337 people from 2004 to 2006, according to *Health Grades*' fifth annual Patient Safety in American Hospitals Study (Health Grades 2008). Evidence from the WHO shows that 23% of European Union citizens have been directly affected by medical errors, of which 18% have experienced serious medical errors in hospital and 11% prescribed the wrong medication (WHO 2007). Reducing medical errors, therefore, is considered as a primary goal to improve patient safety. Achieving high efficiency in healthcare operation is another vital goal for organisational performance evaluation. On the other hand, as it is hard to immediately and correctly track information about a patient's ID, operational time and location, obstacles exist in healthcare system resulting difficulties in real-time decisions-making based on the integration of information flow and object flow.

Mobile health, a sub-segment of electronic health, can help improve the performance of healthcare sector through fewer medical errors, improved quality of services and optimised workflow of management using information technology (IT). Devices such as computers, PDAs, patient monitors are used to deliver health services and gain information. It is commonly used in the practice of public health, supported by mobile devices, such as wireless technologies and tablet computers for positioning and identifying patients, staff or equipment (Cipresso, Serino et al. 2012). With mobile health applications using mobile devices, health data can be collected, real-time information can be delivered, and even health services can be directly provided by mobile telemedicine (Germanakos P. 2005). As a result, data becomes an especially important aspect of mobile health. Mobile technologies and collection devices like mobile phones, computers, or RFID systems are adopted to collect health-related data. RFID technology for automatic data collection can help health sector reduce costs by improving efficiency and decision-making through real-time information delivering,

and enhance healthcare quality by better access to medical and health information (Mechael 2009). Therefore, the mobile health using RFID technology has the great potential to promote health communication and achieve healthy lifestyles. RFID technology as a tool can be leveraged to support existing workflows within the health sector and between the health sector and the general public (Malhotra 2005).

Moreover, consecutive technology innovation enables the optimisation of the healthcare value chain by identifying the most important activities in the delivery of services. For instance, an electronic health record system (EHR) in the form of electronic data for patients' private information can be used to improve efficiency of healthcare delivery and provide evidence-based medicine, thereby increasing patients' safety (El-Kareh, Gandhi et al. 2009). Thus, better service can be provided, which in turn enables healthcare providers to achieve a highly reliable performance in a complex environment. Nowadays, development in radio frequency identification (RFID) has further enhanced the healthcare transformation. RFID offers more capabilities in terms of patient management, drug management, staff management and equipment management. Moreover, it designs and evaluates methods to push integrity and accuracy in supply chain, providing a patient safety medical environment (Kuo and Chen 2008). According to the Food and Drug Administration (FDA), RFID technology for automatic data collection improves communication and cooperation along the healthcare value chain. With the RFID tag on drugs, staff dispensing medicine can match drugs and patients exactly, track and trace their positions and movement precisely. In addition, RFID can also be used as a tool to guard against drug counterfeiting. Conveying the healthcare value chain concept, RFID technologies can also be used at key activities (inbound logistics, operations and outbound logistics). For instance, the integration of surgical-medical products that may locate in several different therapeutic areas, with customer information, could result in more efficient and safer surgical procedures. Thus, the implementation of RFID technology increases the visibility of assets and the availability of information, thereby ensuring the safety of patients. In summary, RFID can help track patients, staff, drugs and equipment anywhere within a firm's value chain, resulting in shorter waiting time, increase in the capacity and utilisation of hospital resources and the optimisation of patient flow (Lee, Fiedler et al. 2008).

The identification of relevant technologies may thus create a competitive advantage for a company or a sector. However, there are few studies on the assessment of the factors affecting adoption of RFID in healthcare sector. This study attempts to bridge this knowledge gap by examining impacts of RFID technology in the medical area. In order to better understand the impact of RFID in healthcare sector, we will use the guiding principles proposed by Saranummi (Saranummi, Demeester et al. 1995), as follows:

1. The development of healthcare as a result of both internal and external drivers;
2. The progress in terms of the implementation of healthcare information systems drawn from IT; and
3. Information systems implemented as a tool to support and optimise functions and interactions.

1.1 Background and research questions

Against current competitive environment, IT plays an important role in almost all aspects of an organisation's operations and collaborative strategies (Lin 2007). IT can increase an organisation's competency, for example, by facilitating the supply chain process to achieve higher efficiency (Wu, Yeniyurt et al. 2006), and provide an organisation with better products or services as an competitive advantage among the peers (Shao and Lin 2001). As healthcare poses strong requirement for correct decisions based on the acquisition of timely and correct information, it has become one of the most suitable sectors for use of IT (Satyanarayanan 2001).

Healthcare is a specific area involving information security and other distinct characteristics. It also shows similarities (common characteristics) with customer-oriented, "profit" conscious markets and other conventional markets (Pitta and Laric 2004). Certain marketing measures or tools such as the value chain model can thus be used in healthcare organisations to achieve competitive advantage by identifying questions concerning healthcare delivery and alternative approaches, and obtaining a greater understanding on how the process of healthcare supply chain works.

In recent years, RFID technology has developed into a new generation with two significant characteristics, an increase in service and a cross-industry research area (Ahn, Hong et al. 2009), in addition to the main promise of this technology, which is

reflected in its ability to automatically and wirelessly collect information from tagged targets (Fosso Wamba, Lefebvre et al. 2008). Therefore, this technology shows its advantages in helping healthcare sector improve patient safety and achieve operational efficiency thereof storing and retrieving information automatically.

In fact, implement an RFID system in healthcare solutions can improve patient safety by timely processing and correct transmission of information among healthcare players during the information management processes. RFID technology as a tool can therefore support the management and processes to accomplish the activities of the value chain. Moreover, the information transfer process within the chain, both in terms of accuracy and efficiency, determines the overall value derived from the value chain (Pitta and Laric 2004). However, there is a shortage of studies on how the value chain model contributes to the understanding of RFID technology applied for effective and efficient transmission of information in the healthcare sector. This study attempts to bridge this knowledge gap by examining the impact of RFID technology through an analysis of the value chain in the medical area, to answer the following research questions:

1. What are the drivers and challenges that affect the development of healthcare?
2. What is the impact of IT in terms of the value chain concept in the healthcare sector?
3. What are RFID capabilities and its role in healthcare processes?
4. How do RFID capabilities improve healthcare processes, which ultimately impact healthcare performance?
5. What are the roles of the environmental and organisational contexts in an RFID-enabled healthcare area?

1.2 Significance

The healthcare sector, as a service industry, is facing many complex challenges in delivering time-efficient, high-quality and accessible healthcare that determines the life and death of individuals. Thus, timely and effective access to patient health information, such as the history of allergies and chronic diseases, is critical in helping practitioners to make correct decisions in emergency cases (Friedewald, Vildjiounaite et al. 2007). Today, IT can be used to provide better solutions for healthcare, for instance,

videoconference and telesensing methods are being used to interview and examine patients who live in remote areas. The clinical decision support system (CDSS) provides expert advice based on a comprehensive analysis of a vast amount of medical information (Kaplan 2001). Therefore, it is crucial to use IT in the healthcare domain.

In this context, through the study of relevant background knowledge, the main drivers and obstacles required to advance the development of RFID in healthcare will be identified. In addition, application areas will also be identified according to their functions by the in-depth analysis of 61 case studies. Adopting RFID technology in hospitals can support the tracking and better management of patients, staff and assets. Furthermore, diffusion of innovation (DIO) theory and technology-organisation-environment framework (TOE) will be introduced for the purpose of understanding the factors affecting the adoption of RFID technology in healthcare sector. The final results of this study were achieved through the analysis of 131 cases from IT-enabled healthcare vendors, including 61 RFID-enabled healthcare cases. We draw a conclusion after discussion and comparison studies on the two categories cases and in-depth analysis of RFID-enabled healthcare applications.

1.3 Limitations

As with all research, there are limitations in this study. The research introduces strong evidence in terms of the analysis of certain variables that potentially affect healthcare processes, thereby improving healthcare performance. However, RFID as a topic in the healthcare and process areas is fairly new. There are not many measurable and tangible results of RFID implantation in the healthcare area that could be accessed in our research. In addition, this research is a cross-sectional empirical study. Data collected are therefore a snapshot of the perceived evaluation from the cases studied.

Finally, there are some unsolved findings concerning organisational resource, relative advantage and complexity. Further investigation is necessary to explore the significance these factors might have if adopted.

1.4 Outline of the thesis

In this context, through the study of relevant background knowledge, the main drivers and obstacles are identified as social, political, sectorial and technological as shown in Chapter 2 to advance the development of RFID in healthcare. Application areas are also identified based on functions technologically; the potential benefits of adopting RFID technology in hospitals support for tracking and better management on patients, staff, and assets. Chapter 2 also offers the contribution on the impact of IT in terms of value chain concept in healthcare sector. In Chapter 3, theories of diffusion of innovation and the TOE framework are introduced for the purpose of examining the factors that affect the adoption of RFID technology, followed by discussion on the research model to better understand how RFID combines with organisational and environmental context to help improve healthcare processes which impact healthcare performance corresponding to the meaning of RFID capabilities, organisational and environmental context raised in research question 2. Next, research methodology is discussed in Chapter 4. Based on the above, Chapter 5 discusses the results from analysis of 131 case studies, including 61 in-depth analysed cases. We make Table 5.4 to clearly show our proposition results. It is evident that RFID technology has played an important role in the development of the healthcare area through improving operational and management processes. In this chapter, research questions 3, 4 and 5 are exactly answered with the in-deep analysis of the case. In the final Chapter, we summarise our research findings regarding all the research questions, and then present contributions and implications, the limitations encountered when we were carrying out this research and outlined future research.

2 CHAPTER 2: CONTEXT OF THE STUDY

This study examines improvements in the development of healthcare through the usage of new IT, in particular, the case of RFID. The development of healthcare shows close relationship with the progress of new IT, which enables the optimisation of the healthcare value chain by identifying the most important activities in the delivery of services. In addition, continuing technology innovation is of great help in the healthcare sector by reducing costs, improving the quality of services and optimising the workflow of management. The identification of relevant technologies may thus create a competitive advantage for a company or a sector. Key drivers and challenges facing the healthcare sector will be presented following description on the healthcare value chain. Finally, the most common RFID functions and their application domains will be identified.

2.1 Definition and evolution of the healthcare sector

The healthcare sector is considered to be a key aspect of the economic burden in many developed countries. In US, expenditure on healthcare as a share of gross domestic product (GDP) has tripled since 1950, from approximately 5% to 15% today (Kotlikoff 2009) and in Australia, expenditure on healthcare totalled $86.9 billion, representing almost 9% of GDP in 2005 compared with 7% of GDP in 1995 (AIHW 2007). In the last decade and a half, significant growth in health expenditure shows that a high proportion of economic resources are allocated through the healthcare system to improve the health and wellbeing of the nation. Moreover, continual demand for medical services is on the rise, due to factors such as a growing population of elderly citizens and the impacts of a wide range of social and economic factors. Thus, improvements in healthcare information management to reduce operating costs, and the transformation of healthcare through IT are considered to be good ways to reduce national financial stress (Raj Reddy 2001).

The healthcare industry is concerned with the provision, distribution and consumption of healthcare services and related products. As we know, the healthcare sector involves hospitals, nursing and residential care facilities, private practices of physicians, offices of dentists, home healthcare services, offices of other health practitioners, ambulatory healthcare services, etc. (Dolbeck 2009 Feb 16). Healthcare as a market has some

similarities (common features) with conventional markets such as customer-oriented and "profit" conscious markets (Pitta and Laric 2004). Therefore, for supporting the analysis of healthcare improvements, certain marketing measures or tools such as the value chain model can be used to form a set of strategic alliances to improve efficiency in the sector.

2.1.1 Definition of the value chain

According to Harvard economist Michael Porter, the value chain describes the whole production chain, from the input of raw materials to the output of final products consumed by the end user, and all the activities conducted within this chain create value and competitive advantage (Porter 1998). In fact, a firm's value chain is part of an overall value system that consists of supplier value chains, firm value chains, channel value chains and end user value chains, as shown in Figure 2.1.1.1 (Porter 1998). In this context, the outputs of suppliers can be seen as the inputs of a firm, then through a set of valuable activities performed within the firm these affect the performance of channels. Finally, the outputs of channels become the inputs of end users (Burns and School 2002).

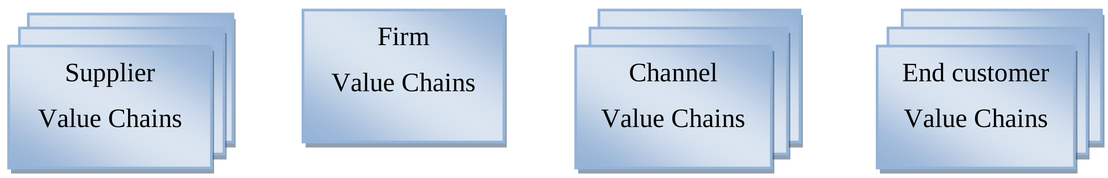


Figure 2.1.1.1 The value system (Porter 1998)

There are five primary activities and four support activities in a firm's value chain, as shown in Figure 2.1.1.2. Primary activities describe the process from the manufacture of products to delivery to the end customer, involving: inbound logistics (including receiving, storing and disseminating goods or services for use), production operations (including overseeing, designing, and redesigning business operations in the production of goods or services), outbound logistics (including storing, transporting and distributing goods or services to customers), marketing and sales (such as advertising and promotion activities), and service (including enhancing and maintaining the value

of the product). Support activities enable the primary activities to support the whole chain by providing infrastructure, human resource, technology, and purchasing sections. The performance of each activity will determine its contribution to end users (Porter 1998).

Figure 2.1.1.2 The value chain (Porter 1998)

2.1.2 Technologies in a firm's value chain

Technology is important as it can influence a firm's competitive advantage as well as the industrial structure. To use technologies in a firm's value chain will greatly impact all its activities (Porter 1998). Setting technologies in different areas help increase the effectiveness and efficiency in information sharing. Typical technologies involved in each category of activity in the chain will be introduced respectively (Porter 1998).

Inbound logistics: consists of transportation technology, material handing technology, storage technology, network technology and information system technology, etc;

Operations: comprises basic process technology, material handing technology, packaging technology, design technology and information system technology, etc;

Outbound logistics: involves transportation technology, material handing technology, network technology and information system technology, etc;

Marketing and sales: includes media technology, network technology and information system technology, etc;

Service: involves diagnostic and testing technology, networking technology and information system technology, etc;

Firm infrastructure: involves administrative technology, finance and accounting technology, network technology, database technology, enterprise planning resource and information system technology, etc;

Human resource management: includes training technology, human resource management technology, database technology and information system technology, etc;

Technology development: includes software development tools, network technology, database technology and information system technology, etc;

Procurement: involves transportation system technology and information system technology, etc.

IT is widely used in the value chain as each value activity creates and uses information. IT can support the management and process of accomplishing activities and provide the resources for integrating related technologies. IT also plays a vital role in linkages between activities from the control of information flow to the coordination and optimisation of each value activity in the chain. For instance, in inbound logistics, IT can be used to control and manage transportation, material inventory and material handling. However, as a borrowed model, there are some differences in deploying these technologies in various areas in industry depending on functional necessity. As a consequence, the information flow, whereby upstream activities interact with downstream activities, is affected by the IT adopted, which contributes to the improvement of performance in business.

2.1.3 Significance of using value chain

Value chain offers a pathway to enhance the operation among different players in the chain and describes the strategies of each business. Thus, the value chain is supposed to be a collaborative partnership between players engaged in business exchange (Burns and School 2002). The value chain can also reconcile discrete activities for better understanding of existing and potential sources of competitive advantage. However, in

accordance with different needs of industries, each category of activities is important to some degree in gaining competitive advantage. Production operation plays the most important role in manufacturing, so as outbound logistics in transportation, operations and outbound logistics in service industry such as the healthcare sector. Thus, all the categories of activities play different roles in various industries in terms of competitive advantage. Furthermore, through analysis of the healthcare value chain we will obtain a greater understanding of the working process of healthcare supply chain to form strategic alliances to increase market shares and competitive advantage.

2.1.4 The healthcare value chain

The concept of the healthcare value chain has been of interest among researchers and scholars since the 1990s. Introduced by Lawton (Burns 2002), the healthcare value chain provides an entire production chain where each link adds value among manufacturers of healthcare products, wholesalers, distributors, group purchasing organisations, hospital customers and users of products. The following is about the players at the various stages in the healthcare value chain (see Figure 2.1.4):

- Payers include governments, employers, individuals and employer coalitions, which pays providers for care delivered to patients.
- Fiscal intermediaries comprise insurers, healthcare maintenance organisations (HMO) and pharmacy benefits managers.
- Providers comprise hospitals, physicians and integrated delivery networks (IDN), which makes decision to select the use of products for treatment.
- Purchasers include wholesalers, mail-order distributors and group purchasing organisations (GPO), which is able to aggregate the buying and distributing of large quantities of products.
- Producers consist of drug manufacturers, device manufacturers, medical-surgical manufacturers and manufacturers of capital equipment and information systems to providers that use their products.

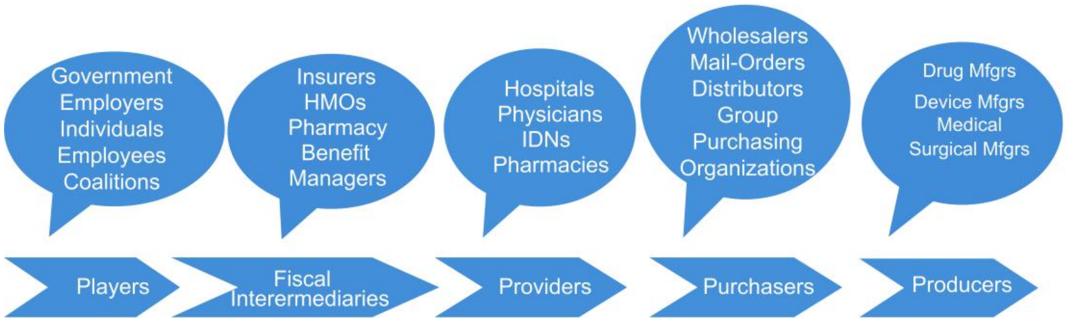


Figure 2.1.4 Healthcare value chain

2.1.4.1 How the healthcare value chain operates

A healthcare value chain typically consists of two-direction flows of money, products and information among various players. Products move downstream from manufacturers to purchasers to providers, whilst information and money move upstream through a back channel to the manufacturers. However, we focus more on the information flow. More specifically, the process is initiated by customers who pull products down from manufacturers. Customers submit product requests to the procurement manager, who makes the decision to select items from a product catalogue. The order is then transmitted to the GPO and distributor for fulfilment. These orders are then transmitted to the various manufacturers for shipment. Overall, product manufacturers provide the products, then GPO or wholesalers purchase and deliver them, and providers consume them in the course of rendering patient care (Burns 2002).

Nevertheless, on the one hand, providers such as hospitals are integrated into the health insurance business, pharmaceutical companies and IDN, which represent integrate downstream toward the patient, contributing to obtain a greater portion of patient flows. On the other hand, every major player in the value chain is horizontally merged. Hospitals have merged with other hospitals; their GPOs have merged with one another; distributors have merged to build warehouses and achieve economies of scale; product manufacturers have merged to obtain market share. There is considerable effort involved in the process, resulting in the need to capture real-time information on product use in other ways.

2.1.4.2 Impact of IT in the healthcare value chain

Through analysis of the healthcare value chain, most activities identified have sought to remove or reduce uncertainty within a supply chain so as to facilitate a more predictable response to the changes in downstream demand (Rachel Mason-Jones 2000). Some hospitals have now invested in integrated information systems, such as electronic health record systems (EHR) and enterprise resource planning systems (ERP) to improve their supply chain operations. The degree of coupling or integration between different information systems of trading parties determines the collaboration extent (White, Daniel et al. 2005).

A fundamental improvement in the healthcare value chain will occur when IT is deployed to capture product information. This will allow upstream players in the value chain to analyse and forecast the entire length of the chain. Providers can link performance to specific product use, such as branded drugs and devices, in a manner that facilitates better product comparison.

Second, IT must be easily integrated into practitioners' work flow, because all these players provide digital data to various storage and retrieval entities and receive information from different sources. For instance, physicians, who play a key role from treatment to prescribing drugs in the healthcare value chain, capture product data and incorporate them into their daily work flow. Using automatic data capture technologies such as RFID technology can be seen as a solution to improve operating safety and efficiency.

2.1.4.3 RFID technology in the healthcare value chain

"RFID technology that automatically and wirelessly collects information from tagged targets (Fosso Wamba, Lefebvre et al. 2008) is becoming widely recognised as a strong tool", said Jamie Hintlian. It designs and evaluates methods to achieve integrity and accuracy in supply chain, and also provides a safe medical environment for patients (Kuo and Chen 2008). RFID is similar to bar codes, but more than bar codes. The comparison between RFID and bar codes is analyzed (see Table 2.1.4.3). According to the Food and Drug Administration (FDA), RFID technology for automatic data

collection improves communication and cooperation along the healthcare value chain involving payers, fiscal intermediaries, healthcare providers, purchasers and producers. In the pharmaceutical industry, if all the pharmaceutical transportations from industry upstream in the supply chain were to paste RFID tags on their products, this would lead to more industrial applications downstream such as in hospitals (Kuo and Chen 2008). With the RFID tag on drugs, medicine dispensing staff can exactly match drugs with patients and precisely track and trace positions and movement. Furthermore, RFID can also be used to guard against drug counterfeiting. Following the traceability principle, original items from the producer to the end user in the supply chain are then verified to prevent counterfeiting (Bouet and Pujolle 2010). There is the special character of the "drug pedigree" in RFID in the pharmaceutical supply chain (Fan Wu 2005). Under the healthcare value chain concept, RFID technologies can also be used in key activities (inbound logistics, operations and outbound logistics). For instance, integrate surgical-medical products that may exist in several different therapeutic areas with customer information can result in more efficient and safer surgical procedures. Implementation of RFID increases visibility of assets and availability of information, thereby ensuring the safety of patients.

In summary, RFID can enable the tracking of patients, staff and equipment anywhere within a firm's value chain, resulting in shorter waiting time, increase in the capacity and utilisation of hospital resources and optimisation of patient flow (Lee, Fiedler et al. 2008).

Table 2.1.4.3 Comparison of Bar Code and RFID technologies

	RFID	Barcode
Line of Sight	Not required	Required
Read Range	Passive RFID up to 40 ft Active RFID up to 300 ft or more	Several inches up to several ft
Read Rate	10s, 100s or 1000s simultaneously	Only one at a time
Read/Write	Read-write RFID tag is rewriteable	Read only
Technology	Radio Frequency (RF)	Optical (Laser)
Interference	Metal, liquids or RF Frequencies	Obstructed barcodes
Automation	Automated	Labor intensive

2.1.5 The evolution of the healthcare sector

The healthcare industry has gone through several major developments over the last six decades. According to Mcdermott (Mcdermott 2002), there are four stages of healthcare evolution as shown in Figure 2.1.5 below:

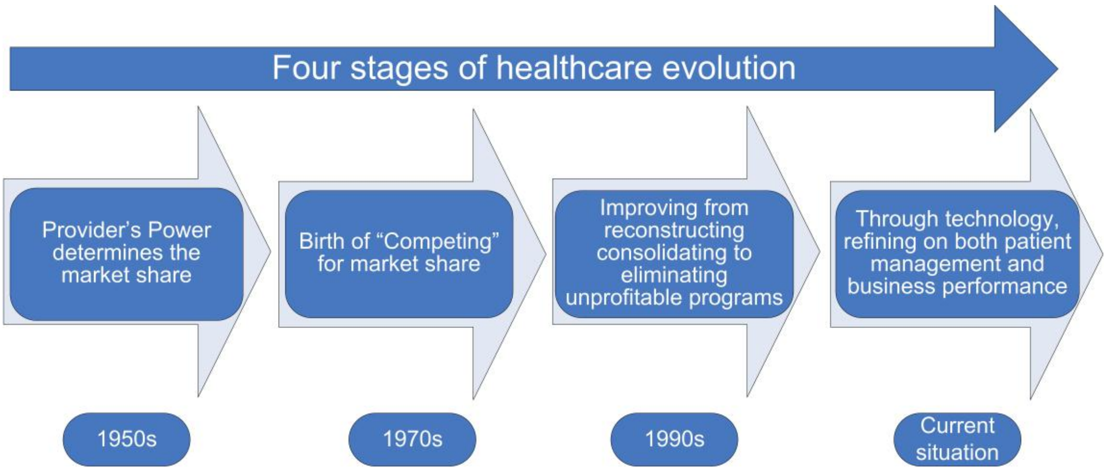


Figure2.1.5 Four stages of healthcare evolution

The first stage occurred in the 1950s, when providers' assets determined their market shares. This meant assets size of a hospital was crucial to the success of business. The government also played a role by assisting construction programs in hospitals.

The second stage began in the 1970s, when balance between supply and need was achieved. The term "competing" was recognised by people when capturing market shares. Thus, t "competitive advantage" was generated in hospitals.

The third stage began in the 1990s, when the main trends were reconstructing, consolidating, downsizing and eliminating unprofitable programs. This meant people began to pay attention on optimising benefits. During this period, "reengineering" appeared and modern information technology such as enterprise resource planning (ERP) was used in redesigning business processes in order to achieve dramatic improvements in performance. In order to better understand this concept, imagine building a new hospital in a city, what will it looks like, and how will the hospital be run to meet patients' needs? The result of this blank sheet of paper method has resulted in the

fundamental re-reengineering of all the activities undertaken in a hospital (Al-Mudimigh, Zairi et al. 2004).

In the final stage, organisations have been experiencing increasing national and international competition, which leads to more and more strategic alliances. Against this backdrop, healthcare information systems focus more on the development of information technologies such as electronic health records (EHR) and telecommunications (Al-Mudimigh, Zairi et al. 2004) to improve the quality of care. Development of the consumerist society is one of the drivers behind. Customers are showing a variety of needs based on own preference, and are demanding more on product or service guarantees as well as technological improvements, which has initiated refinements in patient care and worker performance (Mcdermott 2002).

2.2 Social drivers and obstacles

The health condition of human beings is a parameter of social development in some respect. On the other hand, social development determines the health status of people. The development of healthcare thus has a close relationship with the progress of society. Next, we will discuss detailed aspects of the social impacts on healthcare from various perspectives.

2.2.1 Aging issues

The world's population is getting older, especially in western countries. Based on government projections, 26% of the US population will be aged 65 or older in 2030, compared with 17% today (Bostrom 2005). For example, the Baby Boomers are now reaching their retirement years. Elders require more access to healthcare facilities to for an active and independent life. Moreover, the demand from older people to be able to enjoy high quality, accessible and affordable care causes hospitals to extend, open emergency care services in rural areas, and even open their own continuing care community. Indeed, from a positive perspective, this leads to a steady growth in jobs related to the provision of services to this segment of the population. According to the US Department of Labor's Bureau of Labor Statistics, healthcare will provide 3.2 million new wage and salary jobs between 2008 and 2018, more than any other sector,

largely in response to rapid growth of the elderly population (2010). Consequently, in some ways, aging can be seen as a factor for the growth of medical service industry.

Meanwhile, the advent of IT such as wearable health monitoring technologies, offers caregivers multi-sourced real-time information for elderly people (Raad 2009). The current trend in long-term care is a shift in delivery system away from institutional service to home and community-based service. Thus, IT is expected to create employment. A discussion on healthcare by age researcher Joseph Coughlin suggests that the aging population will spur technological innovation and transform the entire healthcare system.

Obstacles

The biggest challenge lies in satisfying both staff that needs the best resource to serve patients at a facility, and patients who should be cared for. However, due to the continuing struggles in today's slow economy, healthcare facilities are in high demand, especially in the suburbs.

The second challenge is cost. Increase in the aging population demanding for higher service quality, special care, and more nursing staff is bringing more pressure to the society. .

2.2.2 The development of social resource and information

The channels of access to social health resource and information have changed significantly with the diffusion of social networking, developments in telemedicine and improvements in health media coverage. According to data from the Health Information National Trends Survey, approximately 63% of the US adult population in 2003 searched for health information online first (a total of 6369 persons over 18 years or older) (Hesse, Nelson et al. 2005). The results highlight the transition of healthcare from an information sharing perspective, whereby more patients tend to search for information online before talking with their physicians, instead of the conventional way to visit physicians for relevant health and medical information (Hesse, Nelson et al. 2005).

Moreover, people have started to recognise the importance of social media. One in five persons in a recent survey confirmed they used social media to make their healthcare decisions. While consumers think highly of using social media as a source of healthcare information, it is nevertheless not the premier source. 50 % of respondents replied that healthcare provider websites are the preferred source of online healthcare information (Warren 2011).

Therefore, social media provides a wide platform for the development of healthcare. Combined into each link of healthcare value chain, up-to-date resources can be shared among each actor, which ensures the efficiency and consistency of the business operation. Social media also builds a bridge between each link, which develops highly competitive chains and positive outcomes. Transparency on healthcare marketing can continually be maintained through network media, which supplies information to each player and obtains honest feedback directly.

Obstacles

It remains a fact that all these social drivers require time and resources to develop. Most of the results are intangible. Lack of integration on these resources also thwarts the progress of the healthcare industry.

2.3 Political drivers and obstacles

Health policy seeks to understand and improve how societies organise themselves in achieving collective health goals, and how different players interact in the policy and implementation processes to contribute to policy outcomes. It covers a wide range of questions from financing to governance and issues surrounding the implementation of services and delivery of care in both the public and private sectors. For instance, evaluation of a health insurance scheme might use economics to understand the financial consequences and its impact upon demand for services (WHO 2007). The changing of policy has led to a consumerist society where patients and healthcare-givers expect to choose whatever they need to access in healthcare. This is the view offered by Jarrold, who believes that politics with a small "p" enables the world to run: to get things done, to search for support, to build cooperation, to seek harmony (Robert

McSherry 2011). Both a capital “P” and a small “p” should be used for deeper understanding on the political drivers to governance, where, the capital “P” stands for government and policy drivers, and the small “p” points to organisational and individual factors that affect transformation and policy-making (Robert McSherry 2011). In the United States, for example, the Patient Protection and Affordable Care Act (PPACA) is a federal statute that was signed into United States law by President Barack Obama on March 23, 2010. This Act and the Health Care and Education Reconciliation Act of 2010 (signed into law on March 30, 2010) comprised the health care reforms of 2010. The laws focus on reform of the private health insurance market, providing better coverage for those with pre-existing conditions, improving prescription drug coverage in Medicare and extending the life of the Medicare Trust fund by at least 12 years (Sebelius 2010).

Obstacles

The challenges for healthcare is putting policy into practice and keeping up-to-date with changes in healthcare policy. The impact of organisational change is always a barrier in the provision and delivery of healthcare.

2.4 Sectorial drivers and obstacles

We consider this issue in terms of horizontal competition in the healthcare chain, that is, the competition between different manufacturers or between different hospitals, and the competition drive from the same level of each player in the chain. Meanwhile, we divide competition into price and non-price that can have vital benefits for health care. Price competition causes lower prices and results in broad access to healthcare products and services, whereas non-price competition can lead to higher quality products and services and can improve innovation. For example, new drugs that may be generated by competition might have fewer side effects or might be cheaper. Indeed, competition builds winners and losers and can encourage healthcare suppliers to carry out a better job for consumers. Meanwhile, the delivery of high quality, cost-economic healthcare also contributes to protecting competitive advantage.

Obstacles

Competition cannot offer benefits to consumers without real-time information and properly aligned incentives, nor eliminate the inherent uncertainties in health care, or the informational asymmetries among consumers, providers and payers.

2.5 Technological drivers and obstacles

Healthcare faces multiple problems, including high and rising expenditures, imperfect quality of service, and gaps in care and access. Healthcare information technologies such as bar coding and electronic health records (EHRs) have been considered to be possible partial solutions to these problems.

2.5.1 Contribution of IT and emerging concepts in managing healthcare operations

In the rapidly developing healthcare sector, technological improvements have initiated refinements in patient care and worker performance. For example, electronic health record systems are deployed not only to record a patient's medical reports, but transfer information on important symptoms for lab tests digitally to a central repository. This means that little need for paperwork and decreasing errors in recordkeeping. Ggenerally speaking, improvements in technology in the healthcare sector include reducing the risk of error, decreasing costs, improving efficiency and market share and progress in quality of services (QoS). Next, the seven main technologies that are currently used in health institutes will be specifically described.

2.5.1.1 Bar Coding

A bar code is an optical machine-readable code representing a series of data, which can be attached to certain objects and is primarily used by businesses. The trading partners in a supply chain can use bar codes to ensure the unity of objects (2009). An example of a bar code on a patient identification wristband can be seen below:

Picture 2.5.1.1 Photo of LB2-ADULT-L3 Assembled (lbuser 2009).

Benefits for healthcare (Adams 1989)
a) Barcode systems are used in different areas to provide detailed up-to-date information. This means items can be verified quickly and correctly, and records can also be updated synchronously to guarantee consistency in inventory management. b) Using barcode systems to keep historical data that can be used to analyse future predictions. c) Providing sales and inventory tracking, barcodes are very useful in logistics. d) A unique identifying number (UID) can be assigned to an item and a database can link the UID to relevant information about the item, then transmit this information to the final destination, i.e. electronically track the item. e) Barcode scanners are relatively low cost and extremely accurate compared to key entry, with only about one substitution error in 15,000 per 36 trillion characters entered.

2.5.1.2 Enterprise resource planning

Enterprise resource planning (ERP) integrates internal and external management information across an entire organisation, including finance/accounting, manufacturing, sales and service, etc. ERP automates activities with a customised software application and facilitates the flow of information across business functions within the boundaries of an organisation. ERP also manages communication with outside stakeholders (Bidgoli 2004). By the mid-1990s, ERP systems were addressing all core functions of an enterprise (Monk 2009). Companies, governments and non–profit organisations all employ ERP systems to manage their business (Selchert 2004).

Benefits for healthcare
a) Systems vary in the convenience with which the customer can customise these practices; best practice reduces risk by 71% when compared to other software implementations (Monk 2009).
b) To optimise staff work processes and practices; ERP can improve business performance by facilitating work flow and reducing the process of mismatching.
c) To provide a platform for the integration of myriad processes for saving time and money.
d) To protect sensitive data by consolidating multiple security systems into a single structure.
e) To visualise data and non-sensitive information across an organisation.
f) To provide a comprehensive enterprise view; real-time information collected by ERP are given to management anywhere, anytime to make proper decisions.

2.5.1.3 Computerised physician order entry

Computerised physician order entry (CPOE), or computerised prescriber order entry or computerised pharmacist order entry is a process of electronic entry of medical practitioner instructions for the treatment of patients. These orders are communicated over a computer network to the medical staff. Moreover, CPOE allows orders to be entered at a point off-site, and supports error-checking in the domain of pharmacy.

Benefits for healthcare
To ensure patient safety, hand-written notes were traditionally used for communication and cooperation, which caused errors and injuries to patients. A 2006 report by the Institute of Medicine suggested that the medication error rate can be reduced by 80%, and errors that have the potential for serious harm or death for patients can be reduced by 55% through the deployment of CPOE. Furthermore, CPOE increases patient safety by listing instructions for physicians to follow when they prescribe drugs to patients.

2.5.1.4 Electronic health record

Electronic health record (EHR) is a record in the form of electronic data that is uniquely coded and individually searchable from disparate computerised ancillary systems for the accessibility of complete and accurate data, practitioner reminders and relative systems such as clinical decision support systems (Richard S. Dick 1997).

According to a 2003 Institute of Medicine (IOM) report, eight core areas are identified offering various functions:

- Health information and data
- Patient support
- Results management
- Electronic communication and connectivity
- Decision-support management
- Reporting and population health
- Order entry/management
- Administrative processes

Following the development of EHR technology and a given deploying or a particular product, the features and functions have been expanded, thereby forming a comprehensive EHR system. EHR supports hospitals and integrated delivery systems through data integration in its component systems. Users can retrieve data from all connected systems through a common interface (Bleich HL 1992; Vogel and Perreault 2006). The major drawback to this integration is the capability of query across entire

systems, since each component system has its own data model and terms for data element. Thus, a common pool of data with similar standard may become necessary to make all applications to gain access.

Benefits for healthcare (Carter 2008)
a) Immediate electronic access to a person's information by authorised users. b) More efficient generation of prescriptions. New prescriptions and refills are generated as a by-product of the documentation process. c) Provision of knowledge and decision support that improves the quality, safety and efficiency of patient care. d) Support for effective and efficient processes for healthcare delivery. e) Promotion of evidence-based medicine; EHR provides access to unprecedented clinical data for research that can accumulate knowledge for effective medical practices.

2.5.1.5 Clinical decision support system

Clinical decision support system (CDSS) uses computer technology to simulate experts' thought processes in diagnosing and curing disease. It is a multi-disciplinary combination of medical and artificial intelligence. The classification of CDSS based on various industries is either a large scale system or a highly centralised system; the former covers many medical areas and the latter focuses on special professional healthcare areas.

Benefits for healthcare
a) To optimise current resource information and turn valuable data into information that supports clinical decision-making. b) To aid doctors to study the situation that they face and accumulate theory and clinical experience for experts. c) To help medical staff to make decisions, and facilitate the adoption of decision.

2.5.1.6 Picture archiving and communications system

Picture archiving and communications system (PACS) provides digital images and paperwork through electronic storage and retrieval of images.

A PACS consists of four major components: the imaging modalities, such as CT and MRI, a private network for the transmission of patient information, workstations for interpreting and reviewing images, and archives for the storage and retrieval of images and reports. Combined with available and emerging web technology, PACS has the ability to deliver timely and efficient access to images, explanation and related data.

Benefits for healthcare
a) To replace hard copy; traditionally, hard copy was used to manage medical images, such as film archives. With the decreasing price of digital storage, the application of PACS provides numerous advantages from the perspectives of time and storage space, in addition to accelerate access to previous images at the same institution (Maani, Camorlinga et al. 2011). b) To provide remote access; PACS expands the potential of conventional systems by being able for off-site viewing and reporting such as distance education or telediagnosis, which means such a system supports practitioners in different physical locations so that they can access the same information simultaneously for telediology. c) To provide a platform for the integration of electronic images; PACS provides an electronic platform for radiology images to interface with other medical automation systems such as Hospital Information System (HIS), Electronic Medical Record (EMR), Practice Management Software (PMS) and Radiology Information System (RIS) (Maani, Camorlinga et al. 2011). d) To facilitate the management of radiology workflow; PACS is used by radiology professionals to manage the workflow of patient examination. e) To provide customised advanced and rewritable software.

2.5.1.7 Automated dispensing machine

Automated dispensing machine (ADM) is a computerised drug storage device or cabinet used in healthcare institutions (Fung, Leung et al. 2009). ADM helps medications to be stored, dispensed and tracked. ADM is also known as unit-based cabinets (UBC), automated dispensing devices (ADD) or automated distribution cabinets (ADCs) (Fung, Leung et al. 2009). Automated dispensing machines can potentially deal with hundreds of medications from different manufacturers, where orders are customised for whatever the cabinet will be specifically used for (Fung, Leung et al. 2009).

The first use of ADM was by members of the pharmacy community in the 1980s since ADCs are continually being refined and improved to meet the changing demands and health standards in the healthcare sector.

Benefits for healthcare
a) To improve patient safety; more specifically, in the pharmacy context, selection errors might occur. For example two different look-alike but similar-looking drug names may be confused, meaning the wrong drug might be given to a patient (Fung, Leung et al. 2009). b) To facilitate the management of inventory; in terms of the process, this facilitates the workflow of controlling a drug, which can improve satisfaction for both staff and patients. Meanwhile, real-time inventory documents are automatically updated, including tracking expired drugs. c) To reduce costs, for instance, reduce the billing paperwork and accelerate staff access to patients' records. d) To synchronise the process between physicians' orders and the pharmacy departments. e) To provide a platform for the integration of drug dispensing; for example, integrate barcode systems, clinical decision support systems, rewritable software and electronic interfaces, etc., to enhance the safety of medication. f) To fulfil medication distribution management, not only in the distribution process but also in the external database system.

2.5.1.8 Electronic materials management

Following the rapid growth, the advantages of using electronic materials systems have dramatically increased in all walks of life. What is the purpose of electronic materials management? Electronic materials management is the management of documents and information records, based on huge amounts of data collected by the system, in order to analyse and solve problems.

Benefits for healthcare
a) To provide a more complete and accurate picture of usage rather than just storing and keeping information. b) To improve effectiveness and efficiency, from the perspectives of sharing information between different departments and retrieving information. c) To optimise daily administrative management, workflow and usage of information resource.

2.5.2 Limitation of these technologies

These technologies bring dramatic benefits to the healthcare sector, but they might also present some shortcomings. For example, customising a system to meet specific needs may damage competitiveness and may cost more than less integrated and/or less comprehensive solutions. Sharing sensitive information between departments could lead to violations of privacy, and the integration of truly independent businesses could create unnecessary dependencies and an imbalance in maintenance and upgrade expenses compared to the solutions that these technologies bring.

2.5.3 Contribution of RFID and emerging concepts in managing healthcare operations

2.5.3.1 The RFID technology

RFID uses radio-frequency electromagnetic fields to transfer data wirelessly for automatically identifying and tracking tags attached to objects (Fosso Wamba, Lefebvre et al. 2008). An RFID system mainly comprises tags, interrogators and a software system. RFID tags may be active or passive. Active RFID tags have their own power source, and the interrogators can send or receive signals in a longer distance. Passive

RFID tags, however, do not require batteries. Interrogators interpret the data with a decoder, send a signal to the tag that has been programmed with information, and read its response. Database system can analyse, store and passes on information to other application systems for further processing. Moreover, such application system comprises such as ERP and EHR, connected to the middleware to retrieve tags information. In healthcare, the RFID system always works with other technologies e.g. personal digital assistant (PDA) or sensors for different purposes.

2.5.3.2 The RFID technology in healthcare

Effective heath service delivery depends on certain key resources, such as appropriate IT solution, professional staff, advanced equipment, effective information and finance support etc. Every point in the care-giving process may comprise a certain degree of unsafety, and inefficient workflows across the process exist due to the difficulty in allocating resources in real time. Five main problems are identified as common phenomena that results in the failures of healthcare delivery, comprising medical mistakes, increase costs, theft loss, drug counterfeiting, and inefficient workflow(Wen, Chao-Hsien et al. 2010). Therefore, reducing such failures is considered as a primary goal to improve patient safety and operating efficiency. RFID technology is able to locate people and equipment in real-time, and offer efficient and accurate access to medical information for staff, thus it has been applied in a variety of healthcare practices. A review of current literature on RFID-enabled application in healthcare sector has been made to gather valuable information on adoption scope and impact of RFID. The literature reviewed includes 78 articles from 2004 to 2010 in different discipline areas and is classified based on functional application areas. This is the period when RFID technology was primarily used in healthcare industry, and attracted more attention from researchers and scholars to conduct theoretical study. Because of the integration between interdisciplinary topics, related articles were presented in different industries like IT, business management and medications. Our review comprised academic journals from different disciplines. Using the descriptors “RFID or “RFID technology”, the articles were searched from three online databases, Scopus, ScienceDirect and IEEE explorer, which provided a systematic bibliography on RFID-enabled healthcare literature. Unrelated articles to RFID-enabled healthcare have been

sorted out of the 278 articles found at first, leaving the articles with full text to be reviewed. The criteria for selection include:

- The core context should relate to the RFID-enabled application in healthcare sector
- Journal articles from 2004 to 2010

The 78 articles were classified into three categories: 1) asset management; 2) patient management; and 3) staff management, in terms of functional application areas, according to the study of Van Oranje. First, asset management introduces the applications from the perspective of asset to be monitored and maintained, such as, asset tracking, inventory management, blood tracking, and medicine-related management proposed to secure drug supply chain and avoid medicine errors (e.g., eliminating wrong patient, wrong medication and wrong procedure surgery and pharmaceutical supply chain management). The second area, patient management, deals with the work related to patients to be monitored and managed, such as, accurate patient identification, monitoring and tracking of patient health or location and eliminating wrong patient wrong procedure surgery, etc. Staff management discusses better staff time utilization, staff monitoring and workflow optimization at hospitals, as shown in Table 2.5.3.2.

Table 2.5.3.2 Distribution of articles by areas of functional application

Functional Application Areas	RFID application type and reference
Asset management	
1. Asset identification blood bags identification hospitals OR to ensure blood type matching	(Aulbach, Brient et al. 2010), (Kebo, Klement et al. 2010), (Li, Chao et al. 2007)
2. Asset tracking	(Sun-Jin, Jung Hae et al. 2008)
3. Asset tracking and tracing to avoid procedure delays	(Qu, Simpson et al. 2011)
4. Ensure proper health service	(Ihmig, Shirley et al. 2006), (Ayoade 2007)
5. Maintenance of medical equipment	(Oztekin, Pajouh et al. 2010)
6. Inventory management	(Rahlfs, Purugganan et al. 2007)
7. Eliminate wrong patient, wrong	(Yao, Chu et al. 2011), (Liu, Chang et al.),

medication and wrong procedure surgery	(Sandlin 2005), (Lahtela and Saranto 2009), (Oehlmann 2010), (Chao, Jen et al. 2007)
8. Pharmaceutical supply chain	(Chen, Hsieh et al. 2007), (Fudala and Johnson 2006), (Jones, Henry et al. 2010), (Huang, Qin et al. 2010)
Patient management	
1. Accurate patient identification	(Chen, Chen et al. 2009), (Yu and Ramani 2005), (Miller, Ferrin et al. 2006)
2. Accurate patient identification for medication safety	(López-Nores, Pazos-Arias et al. 2008)， (Kuo, Fu et al. 2007)， (Ruta, Scioscia et al. 2009), (Lahtela and Hassinen 2009), (Gao, Pang et al. 2010), (Lahtela, Hassinen et al. 2008), (Lahtela and Jantti 2009), (Liao, Liu et al. 2006), (Valenstein and Sirota 2004), (Halamka, Juels et al.)
3. Critical information for the patient	(Perrin and Simpson 2004), (Yang, Prabhu et al. 2009), (Al Nahas and Deogun 2007)
4. Dementia and psychiatric patients tracking and tracing in out patient	(Huang, Chung et al. 2008), (Matic 2009)
5. Implanted RFID carrying medical record	(Huang, Wang et al.)
6. Infant tracking and tracing hospitals for security to forgo theft	(Azevedo and Ferreira 2010),
7. Intelligent medication monitoring for the elderly at home	(Dohr, Modre-Osprian et al. 2010), (Vinjumur, Becker et al. 2010), (Chan, Estève et al. 2008), (Becker, Metsis et al. 2009), (Corchado, Bajo et al. 2008), (Jingwen, Boon-Chong et al. 2009), (Symonds, Parry et al. 2007)
8. Interventions automated care pathways procedures audit management	(Ohashi, Ota et al. 2010)
9. Monitoring tracking of patient health and diet	(Fong, Fong et al. 2007), (Laskowski, Demianyk et al. 2010; Laskowski, Demianyk et al. 2010), (Gu and Wang 2009), (Cavalcanti, Shirinzadeh et al. 2008), (Alemdar and Ersoy 2010)
10. Tracking of patients' locations	(Lee, Cheng et al. 2007), (Wang, Chiang et al. 2007)
11. Patient identification to avoid wrong drug	(Cresswell and Sheikh 2008), (Hu, Celentano et al. 2009), (Fan Wu 2005)

12. Patient tracking and tracing hospitals for monitoring patient flow	(Ching-Huan and Houn-Gee 2008), (Matic, Mehta et al. 2010)
13. Patient tracking to ensure safety access control dementia	(Lin, Lin et al. 2008)
14. Portable current and comprehensive health records	(Jokela, Simons et al. 2008), (Bravo, Hervás et al. 2008), (Chen, Liu et al. 2007), (Cheng, Li et al. 2009), (Britton 2007)
15. RFID ingested or implanted to provide real time information on health indicators and vital signs	(Merrill and Laur 2010), (Sutherland, van den Heuvel et al. 2005)
Staffs management	
1. Better staff time utilization	(Chien, Liao et al. 2006), (Vecchia, Gallo et al. 2011)
2. Improved error prevention	(Mehrjerdi 2010), (Stavroudis, Miller et al. 2008)
3. Improved labor work efficiency	(Chen, Wu et al. 2008), (Ngai, Poon et al. 2009), (Chowdhury, D'Souza et al. 2009)
4. Staff tracking	(Chien, Liao et al. 2006), (Friedman, Halpern et al. 2007)
5. Workflow optimization at hospitals	(Correa, Álvarez Gil et al. 2007)

Adapted from (Battini, Faccio et al. 2009; Van Oranje, Schindler et al. 2009)

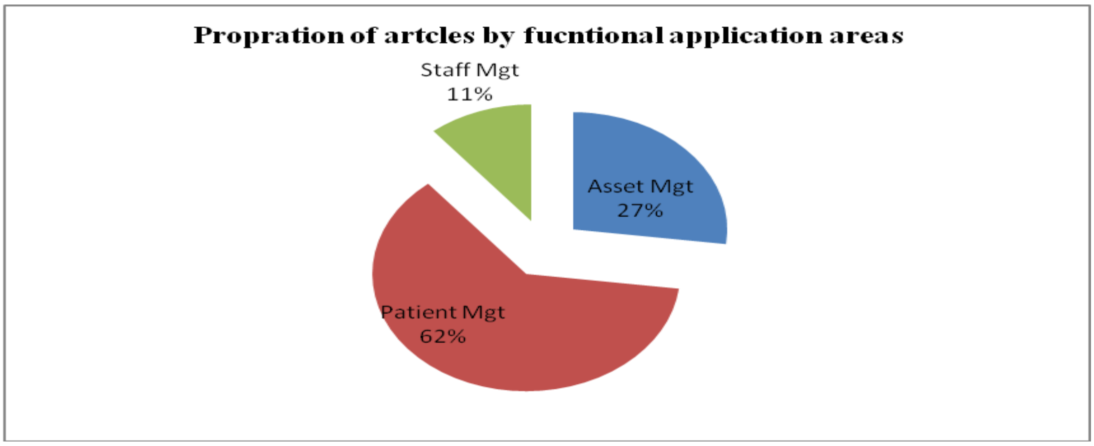


Figure 2.5.3.2 Proportion of articles by functional application areas

The distribution of articles by functional application areas is shown in Figure 2.5.3.2, 48 out of 78 (about 62%) articles belong to patient management category, which means patient management holds the promising potential for setting the RFID system in the healthcare industry. Articles about the applications in asset management occupy approximate 26% of the total (21 out of 78), while staff management category, 9 out of 78 articles are presented to the staff management, almost 11% of the total.

Benefits for healthcare
a) To reduce medical errors thereby increasing patient safety, as described in (López-Nores, Pazos-Arias et al. 2008), (Cresswell and Sheikh 2008) and (Hu, Celentano et al. 2009). b) To provide real-time data access, such as history of patients or real-time information on health indicators and vital signs, as described in (Perrin and Simpson 2004), (Yang, Prabhu et al. 2009) and (Merrill and Laur 2010) . c) To reduce costs, such as theft loss, and improve asset utilization, as described in (Oztekin, Pajouh et al. 2010) and (Sun-Jin, Jung Hae et al. 2008) . d) To facilitate work efficiency and time utilization, as described in (Chen, Wu et al. 2008), (Ngai, Poon et al. 2009) and (Chien, Liao et al. 2006). e) To improve medical process by monitoring patient flow or tracking patients' locations, as described in (Ching-Huan and Houn-Gee 2008), (Lee, Cheng et al. 2007) and (Wang, Chiang et al. 2007). f) To secure drug supply, such as reducing medical errors and guarding against drug counterfeiting, as described in (Huang, Qin et al. 2010) and (Fudala and Johnson 2006).

3 CHAPTER 3: THEORETICAL BACKGROUND

Research on innovation in the healthcare industry always focuses on system design or implementation, certain factors affecting adoption intention or actual adoption of an innovation in an organisation is rarely analyzed. Zaltman et al. proposed that organisations prefer an innovation that is perceived as new and relevant, which enables the organisation to improve its efficiency and effectiveness in the decision-making process. Studies on innovation have shown that success in the healthcare industry relies on the effectiveness and efficiency of IT uses or implementation (Liaw 2002).

In this Chapter, a literature review based on innovation process characteristics will be introduced to explain rates of adoption and impacts. It comprises the following factors: relative advantage, compatibility, complexity, trialability and observability (Porter 1998). Then we will describe the technology-organisation-environment model (TOE) that is used to assist the assessment of RFID adoption in healthcare organisations, followed by discussion of the research model to better understand how RFID combined with organisational and environmental context to help improve healthcare processes and enhance healthcare performance.

3.1 Classical diffusion of innovation

Diffusion of innovations is a theory that seeks to explain the conditions which increase or decrease the probability of new ideas (Rogers 2003). The diffusion of innovation theory provides well-developed concepts and a large amount of empirical researches which are useful for the study of technology evaluation, adoption and implementation (Patrick Schmitt 2007). It provides both qualitative and quantitative tools for assessing the rate of diffusion of a new technology and to identify various factors that facilitate technology adoption and diffusion (Rogers 2003). As well, it plays a vital role in later experiments on expanding the concept of innovation management (Rogers 2003).

3.1.1 Justification of innovation theory and framework

Healthcare organisations have to make decisions in an unpredictable and dynamic environment. They rely on complex interaction with timely and correct descriptions of process and conditions between patients, payers and providers. Thus, how to overcome

these challenges using innovation in healthcare organisation is a major concern. Diffusion of innovation theory and the technology-organisation-environment framework are included here as it.

In terms of the innovation diffusion theory but forward by Rogers (Rogers 2003), IT based solutions offered relative advantages when compared with the old system, especially on the organisational level, such as more visibility in inventory management and more accurate information transmitted along the healthcare value chain. Furthermore, compatibility as a factor determines RFID's fitting suitability, the more compatible, the less uncertain (Rogers 2003). The analysis presented in this paper points out that RFID was a brand new solution which would hardly be replaced by any widely adopted existing technology, and thus it did not challenge any major compatibility issues. Complexity refers to the degree of difficulty perceived to understand and use an innovation (Rogers 2003); therefore, familiarity with a system's control interface can facilitate its adoption.

Meanwhile, taking into account the low adoption level of RFID in healthcare organisation, Rogers' innovation theory provides a link to the perceived lack of uptake of RFID by healthcare organisations. Then we examine the determinants of RFID acceptance at the organisational level. Our research model is based on both Rogers' diffusion theory and the technology-organisation-environment framework (TOE). Tornatzky and Fleischer proposed the TOE framework (Louis G. Tornatzky 1990), which identified that an organisation that adopts and implements technological innovations is affected by the technological context, the organisational context and the environment context (Louis G. Tornatzky 1990). Consequently, it is reasonable that innovation diffusion is used as a basic reference theory and the TOE framework is used for examining on effective and easy uses of RFID technology in the healthcare sector.

3.1.2 Attributes of innovation

According to Rogers' theory, rates of adoption can be affected by the following five characteristics of innovation.

3.1.2.1 Relative advantage

Relative advantage is the degree to which people perceive an innovation to be better than the idea it replaces. It is always expressed as economic profitability, or through indicators including low initial cost, a decrease in discomfort, social prestige, a saving of time and effort and immediacy of reward. What type of relative advantage play an important role is determined by both the nature of the innovation and the characteristics of the potential adopters (Rogers 2003). In addition, a vital point of relative advantage is the fact that the new innovation performs better than existing delivery methods. Scholars point out that relative advantage is one of the most important elements for predicting the adoption of an innovation and for the preservation of these advantages of a new technology. It has a positive effect on final adoption (Rogers 2003).

Potential adopters have to see an advantage in adopting an innovation, for example, business drivers may include customer requirements, decreased costs in terms of the supply chain, reduced inventories or increased competitive advantage.

RFID is used in the healthcare area, as it has the ability to wirelessly collect and transmit real-time information about tagged persons or items (Fosso Wamba, Lefebvre et al. 2008), which could be used to optimise operations and support tracking of patients, staff, assets and other suppliers. A relative advantage to illustrate would be the performance that an RFID system might actually fulfil better than existing delivery methods (e.g. bar codes), such as, line of sight, storage space and the number of items that can be scanned simultaneously and so on (Berezny and Hassanein 2007), as shown in Table 2.1.2.2, thereby contributing to reduced inventories and increased competitive advantages in response to changing environment.

3.1.2.2 Compatibility

Compatibility is the degree to which people perceive an innovation to be compatible with the existing values, past experience and demands of potential adopters (Rogers 2003). To the potential adopter, the degree of compatibility determines the suitability for their situation; the more compatible, the less uncertainty. There are three elements that affect compatibility (Rogers 2003).

- Socio-cultural values and beliefs
- Past introduced ideas, and
- Needs of adopters

In addition, old ideas are the important tools that individuals use to assess new ideas and give them meaning (Rogers 2003) . Individuals always deal with an innovation based on the concept of the familiarity. Previous practice provides a standard against which an innovation can be interpreted, thus decreasing its uncertainty. Compatibility as perceived by individuals or organisations is positively related to rates of adoption (Rogers 2003).

One dimension of compatibility is the degree to which an innovation, such as IT, is perceived as meeting the needs of the clients system. When clients feel their needs are met, a faster rate of adoption usually occurs (Rogers 2003). A case study by Soon and Gutierrez found that early adopters had low satisfaction levels due to unexpected system integration and compatibility issues (Soon 2010).

The bar coding system is more compatible with RFID technology as it has something in common with RFID. Compared to a one-time bar code tag, an RFID tag is compatible, reusable and redesignable. However, an important aspect of compatibility is that the RFID system has to be compatible with other systems (e.g. EHR) or equipment in order to collect and transmit information in real-time. Therefore, the real values are the strengths that RFID technology builds on and how it reengineers business processes to capitalise.

3.1.2.3 Complexity

Complexity refers to the degree of difficulty in understanding and using an innovation. Compared to relative advantage or compatibility, complexity might not be that important; however, it can have an negative impact on rates of adoption (Rogers 2003).

Some innovations, such as IT, require complex knowledge to be implemented, and can be classified in accordance with their degree of complexity. For instance, when the home computer was first introduced, how to get word-processing or software programs

to run were barriers to adopters. They were puzzled by the computer manual; therefore the perceived complexity of home computers was an important negative force in their rate of adoption. Eventually, home computers become more friendly, and their rate of adoption gradually rose to about 50% of all USA households by 2002 (Rogers 2003).

From optical recognition used in the bar code world to radio frequency recognition in the RFID world, what is perceived as complex will be reduced following the development of new technology. Furthermore, familiarity with a system's control interface can facilitate its adoption (Rogers 2003). RFID equipment that is operated with buttons and simple prompts is easier for average users to learn and control as it involves less complexity.

3.1.2.4 Trialability

Trialability refers to the degree to which an innovation may be used experimentally on a small scale, which, as perceived by individuals and organisations, is positively related to its rate of adoption (Rogers 2003). If an innovation can be tried more easily, it will have a more rapid rate of adoption (Rogers 2003). Pre-testing of new applications by targeted users can help facilitate diffusion (Rogers 2003).

Trialability allows the suppliers or distributors to try out RFID in various forms that suit their business processes. As a result, they are able to know specifically where RFID might be useful for them, for instance, Wal-Mart is trialling RFID with a view to full adoption.

3.1.2.5 Observability

Observability is the degree to which the results of an innovation are visible to others (Rogers 2003). For example, picture archiving and communication system (PACS) have higher rate of adoption, as electronic images and reports are transmitted digitally via PACS. Some ideas are easily observed and communicated, whereas other innovations are difficult to observe or describe (Rogers 2003).

Organisation trialling RFID can obtain first-hand information on its use and then make decisions quickly to add business value to their business.

3.1.3 Diffusion of innovation model

The diffusion of innovation model plays an important role to attract more people willing to use and actual adopt the innovation. For example, the technology acceptance model proposes that improving users' attitudes toward technology in an organisation results in an increase in their usage intention (Davis 1989). Moreover, identifying the factors that shape one's intentions will enable organisations to manage these factors and improve acceptance of an innovation, and thus promote its rate of adoption (Holden and Karsh 2010).

3.1.3.1 Technology-Organisation-Environment Framework

Tornatzky and Fleischer proposed the technology-organisation-environment model (TOE) (Louis G. Tornatzky 1990), which identified that an organisation that adopts and implements technological innovations is affected by the technological context, the organisational context and the environment context (Louis G. Tornatzky 1990). Figure 3.1.3.1 below shows this model. The technological context consists of internal and external technologies including equipment and processes (Louis G. Tornatzky 1990). The organisational context refers to the characteristics and resources of the firm, including the firm's size, degree of centralisation, degree of formalisation, managerial structure, human resource, amount of slack resource, and linkages among employees (Louis G. Tornatzky 1990). The environmental context includes the size and structure of the industry, the firm's competitors, the macroeconomic context and the regulatory environment (Louis G. Tornatzky 1990). This theory has been tested by numerous studies on information systems in different areas. Thus, the three elements influence the way an organisation adopts and implements new technology.

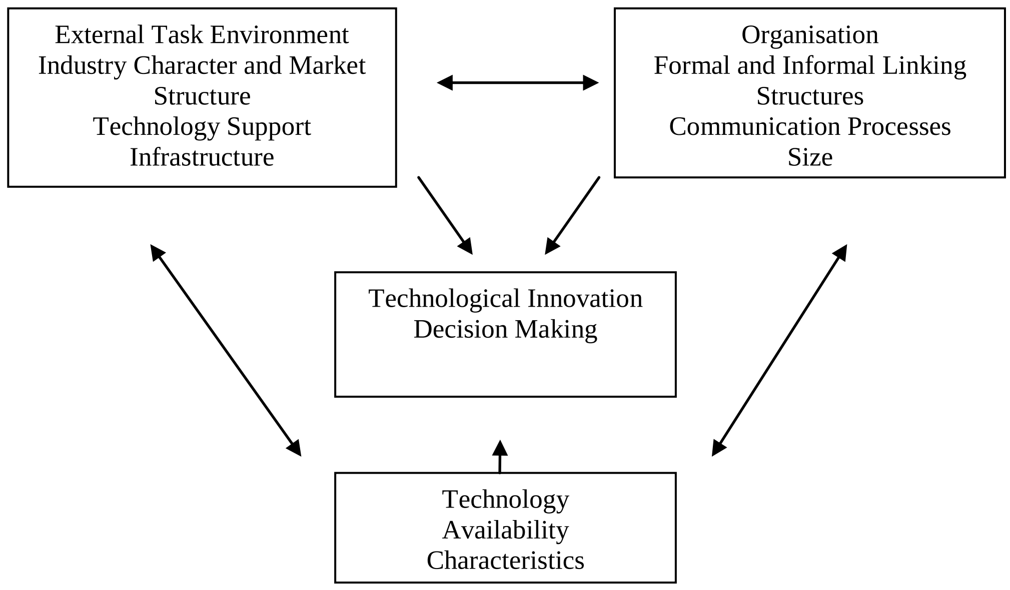


Figure 3.1.3.1 Technology-Organisation-Environment Model (Louis G. Tornatzky 1990)

In our research, IT capability consists of IT management capability, IT personnel expertise and IT infrastructure flexibility; we will thus examine RFID capability from the three dimensions. The environment context refers to outside factors that may support decision-making in a healthcare organisation, comprising the competitive environment and the macro environment (Nigel Melville 2011). The competitive environment consists of industry characteristics and trading partners (Kohli 2003). Industry characteristics include competitiveness, regulation and factors that may be integrated with IT applications to impact business process performance (Kohli 2003). Macro factors (country factors) comprise the level of development, education, culture, government regulation and so on (Sirkka L. Jarvenpaa 1997), forming IT application or IT business value (Nigel Melville 2011).

The organisation context refers to the firm's characteristics and resources, which may influence healthcare processes. According to Barney, the factors in the organisation context can be classified into three categories: physical capital resource, human capital resource and organisational resource (Barney 2000). The factors may lead a healthcare organisation to conceive of and implement a strategy which then will impact on the healthcare firm's strategising processes (Barney 2000).

3.2 Emerging diffusion of innovation theory: The case of open innovation

An innovation can be a new idea, practice or object, and is always used as a synonym for technology (Rogers 2003). It is usually created and used as an enabler of activities to achieve a desired outcome by reducing uncertainty.

Companies that rely on internal resources with a high cost of innovation have found it difficult to adapt to rapid developments in market demand and increasingly fierce competition. Ketan points out that the main difficulty in the process of corporate innovation is resource, which is constrained from monetary budgets and manpower perspectives. Many large companies have begun to significantly reduce internal R&D funding by purchasing external technology or research based on re-innovation, which greatly reduces the chance for innovation. In this context, "open innovation", as an alternative proposed by Chesbrough (Chesbrough 2003), is becoming the dominant paradigm for innovation among enterprises. Open innovation may make a company run faster and more competitive with lower cost, and finally resulting in more income.

3.2.1 Open innovation: an introduction

Open innovation, as a paradigm, assumes that organisations can use external and internal resource, internal and external paths for their marketing, when they are looking to advance their technology (Chesbrough 2003). They might seek external joint ventures, technology licensing, outsourced research, technology partnerships or other suitable business ventures to put innovative ideas into products and profits. For example, CD-R technology is mainly owned by Philips and Sony, but they do not need to personally manufacture optical discs, as CD-ROM manufacturers produce CD-ROMs. It is necessary for them to pay 32-42% in royalties. In 2004, the net profit of Philips was 2.49 billion euro dollars, with 97 million euro dollars of technology transfer fees.

Intel is not as technologically advanced as we thought. It rarely carries out basic research, has processors with the fastest speed or the cheapest price. However, sales of its processors exceed four times over its biggest rival. The reason is that, compared with other processor companies, Intel obtains more technical support from professionals. Intel maintains its technical status mainly by focusing on external academic research activities and other new enterprises for venture capital (i.e., the establishment of

"venture capital funds"). They set up "Lablet" in many universities for original technology research and have spent more than 100 million dollars to fund university research to find "potentially useful" ideas. Intel also actively tries to employ co-innovation, as it announced in November 2006 to establish the "Intel platform application innovation alliance" to cooperate with many software and hardware companies. Intel actively encourages employees to innovate, and only staff who are smart, experimented and innovative can survive and be promoted within the organisation. In fact, its internal technological innovation is based on the availability of external technical resource, rather than competing with or ignoring them. Intel is a "fast follower", and as long as there is benefit of its products, it adopts a strategy of "external technology inside".

To sum up, adopting a paradigm such as open innovation allows an organisation to capitalise on the latent value of innovations, leads to significant growth and enables it to maintain competitive advantage into the future.

3.2.2 Challenges and issues of open innovation

In practice, the integration of internal and external innovation entails the following challenges:

First of all, the open innovation model is likely to raise the requirements for innovation management, because the process of developing technology increases the number and diversity of participants. Implementation of the open innovation model requires careful design and conduct to maintain communication and cooperation with all the participants at the same time. Project management and information technology support also require considerate investment and delegation.

Second, the open innovation model brings the issue of how to deal with patents and intellectual property (IP), such as, who owns the patent? How can firms work to ensure the stream of external innovation is replenished? Why would firms contribute IP that is going to be available to their rivals?

Third, open innovation has a very complex reward system, including service charges, reward success and licence fees. Therefore, if a participant initially invests to promote the project, then, after the success of the project how would fund be allocated?

Finally, although the open innovation model allows the parties involved to share the risks, it is difficult to identify the risks of open innovation in system development programs.

3.3 Research model

This research model, as illustrated in Figure 3.3, demonstrates that RFID capabilities, together with environmental and organisational contexts may improve healthcare processes, which may ultimately impact healthcare performance at the organizational level. Healthcare organisations customise, deploy and maintain technological systems and have to manage both IT and non-IT resources to generate better value (Hitt 2000). Organisations with management and deployment of the right RFID in the right environment to the right healthcare process are expected to have better process performance.

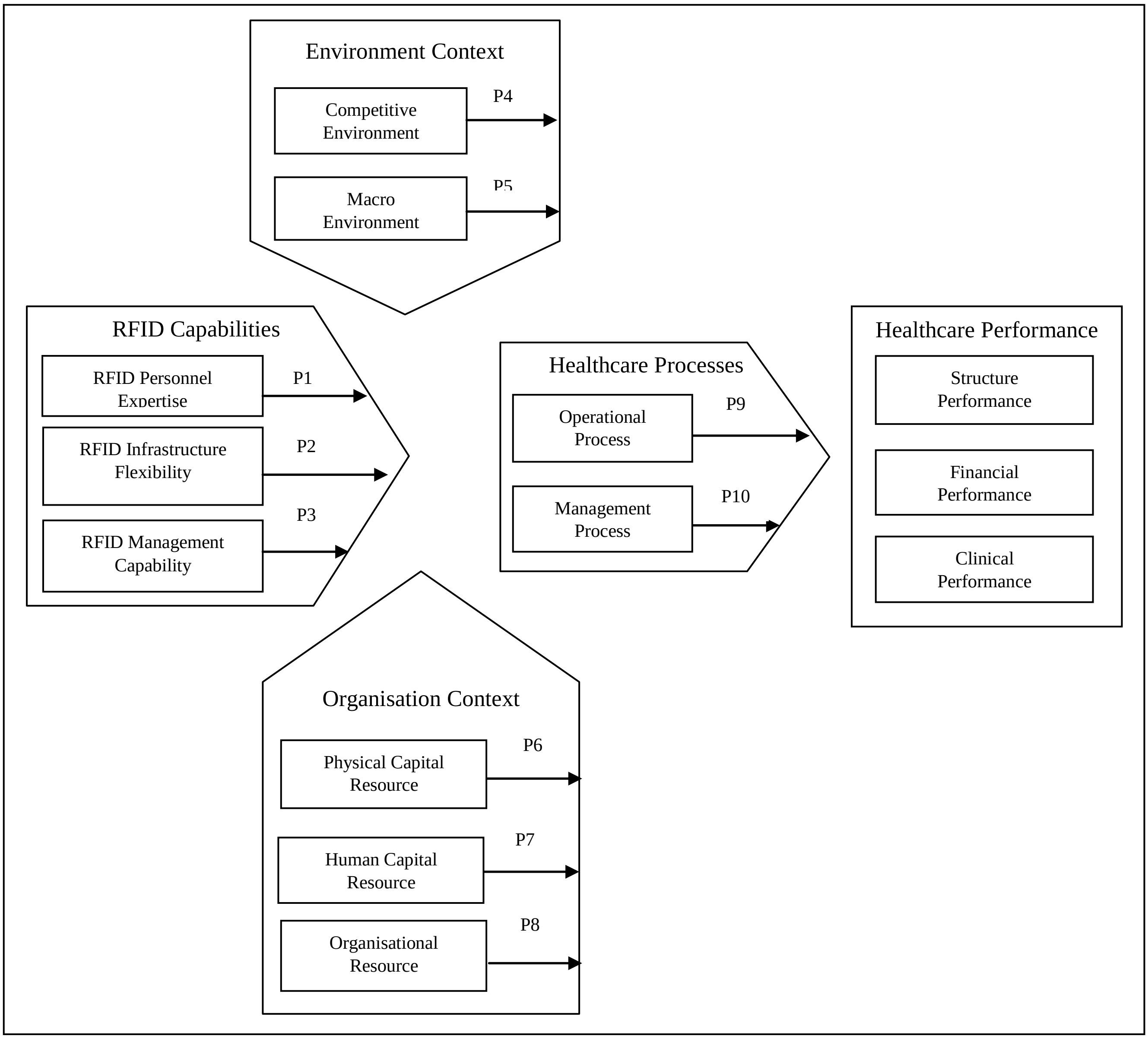


Figure 3.3 Research Model

3.3.1 RFID capabilities

RFID, as a category of IT, has the common characteristics of IT capability. It is able to create routine and standard transactional processes that ultimately impact organisational performance (Nigel Melville 2011). According to Kim (Kim 2010), IT capability consists of IT management capability, IT personnel expertise and IT infrastructure flexibility; thus, we will examine RFID capability from the three dimensions. In the

following section, the categories of RFID capabilities and healthcare process performance will be outlined.

3.3.1.1 RFID personnel expertise

RFID personnel expertise is defined as professional knowledge of technologies relating to the areas necessary for staff to complete their tasks effectively and efficiently (Denis M. S. Lee 1995), such as network technology, databases, and even communication skills with team members. Organisations with capability RFID personnel expertise can meet competitive demands such as developing inventory management systems in the healthcare area and forecasting RFID demands for delivering services better than competitors. Moreover, RFID personnel expertise is able to redesign healthcare processes (consisting of operational and management processes) (Davenport 1993) that are effective and efficient when the environment changes. We therefore propose that:

> *Proposition 1 (P1): RFID personnel expertise has a positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level.*

3.3.1.2 RFID infrastructure flexibility

RFID infrastructure flexibility enables staff to develop and support systems that run quickly and correctly, and can react to a changing environment (Keen 1991). Compatibility can be achieved when flexible RFID infrastructure is connected within an information system (Byrd and Turner 2001). A healthcare organisation with a flexible RFID infrastructure can take better advantage of existing RFID resource to support structural change (Boar 1996). Such capability improves healthcare processes with the development of applications, facilitating information sharing within departments and integrating organisational functions. We therefore propose that:

> *Proposition 2 (P2): RFID infrastructure flexibility has a positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level.*

3.3.1.3 RFID management capability

RFID management capability is defined as a collection of RFID processes in the areas of planning, decision-making, coordination and control, that is centrally controlled distributed RFID function across a firm (GANESH D. BHATT 2005). RFID management capability enables staff to manage resources to gain business value. It is vital to for the healthcare sector to take advantage of RFID coordination to have powerful decision-making mechanisms. We therefore propose that:

> *Proposition 3 (P3): RFID management capability has a positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level.*

3.3.2 Environment context

Environment context refers to outside factors that may support decision-making in an organisation. In this context, it comprises the competitive environment and the macro environment (Nigel Melville 2011).

3.3.2.1 Competitive environment

Competitive environment consists of industry characteristics and trading partners (Kohli 2003). Industry characteristics include competitiveness, regulation and other factors which may be integrated with IT applications to impact business process performance (Kohli 2003). For example, during the decision-making process, it is important for a healthcare organisation to rapidly react to a changing environment (Friedewald, Vildjiounaite et al. 2007). Trading partners may include RFID vendors, payers, producers and providers (Nigel Melville 2011). Porter’s value chain concept has provided a framework for technology in supporting competitive advantage at the process level (Porter 1998). Moreover, the healthcare value chain concept (Burns and School 2002) has been borrowed from the pharmaceutical industry; for example, if all the pharmaceutical transportations from industry upstream in the supply chain were to paste RFID tags on their products, it would lead to more industrial applications downstream such as hospitals (Kuo and Chen 2008). We therefore propose that:

Proposition 4 (P4): Competitive environment has a positive effect on environment context, which is positively associated with the impact of RFID at the process level.

3.3.2.2 Macro environment

Macro factors (country factors) comprise the level of development, education, culture, government regulation (Sirkka L. Jarvenpaa 1997), determining IT applications or IT business values (Nigel Melville 2011). For instance, government regulations play an essential role in the acceptance of IT in the healthcare industry, as they affect healthcare organisations' IT choices and resultant impacts on organisational performance. In addition, the level of development may also impact the capability of a healthcare organisation to apply IT successfully, due to the constraints in applying IT in the area of infrastructure (Sirkka L. Jarvenpaa 1997). We therefore propose that:

Proposition 5 (P5): Macro environment has a positive effect on environment context, which is positively associated with the impact of RFID at the process level.

3.3.3 Organisation context

Organisation context refers to a firm's characteristics and resources, which may influence healthcare processes. According to Barney, the factors in the organisation context can be classified into three categories: physical capital resource, human capital resource and organisational resource (Barney 2000). The factors may lead a healthcare organisation to conceive of and implement a strategy that then impacts on the healthcare firm's strategising processes (Barney 2000).

3.3.3.1 Physical capital resource

Physical capital resources consist of the physical technology used in an organisation, such as its equipment, geographic location and access to raw materials (Barney 2000). Nigel points out that certain organisational characteristics may be complementary to IT, such as access to raw materials (Nigel Melville 2011). Managing data can become an incredibly boring task. The Gartner group therefore presents a new concept of physical resource infrastructure management (PRIM) that tracks trends and solutions for data centre management. To do this, integrated management capabilities whereby staff can

control the physical layers of the data centre, such as servers, PCs and other non-computer equipment, may be expected to offer operational efficiency. We therefore propose that:

> *Proposition 6 (P6): Physical capital resource has a positive effect on organisation context, which is positively associated with the impact of RFID at the process level.*

3.3.3.2 Human capital resource

Human capital resource includes the training, experience, judgment, relationships and insight of people in an organisation (Barney 2000). Nigel presents that certain organisational characteristics may be complementary to IT, such as, thinking complementary to the data warehouse (Nigel Melville 2011). Support from the people in an organisation is necessary for the implementation of RFID. We therefore propose that:

> *Proposition 7 (P7): Human capital resource has a positive effect on organisation context, which is positively associated with the impact of RFID at the process level.*

3.3.3.3 Organisational resource

Organisational resource includes organisational structure, policies, workplace practices and so on (Nigel Melville 2011). Nigel in his of quantitative and qualitative empirical research findings shows that organisational resource interacts with IT in the process of value generation (Nigel Melville 2011). We therefore propose that:

> *Proposition 8 (P8): Organisational resource has a positive effect on organisation context, which is positively associated with the impact of RFID at the process level.*

3.3.4 Healthcare process

Davenport defines process as a specific ordering of activities across time and place from inputs to outputs (Davenport 1993) and consisting of two classifications namely operational process and management process (Davenport 1993). Therefore, we classify healthcare processes into healthcare operational process and healthcare management

process. Each process consists of three sub-categories, asset management, patient management and staff management.

First, asset management introduces the applications of asset monitored and maintained. Such as, asset tracking, inventory management, blood tracking and real-time inventory count, location tracking and medicine-related management proposed to secure drug supply chain and avoid medicine errors, (e.g., eliminating wrong patient, wrong medication and wrong procedure surgery and pharmaceutical supply chain management). Second, patient management deals with the work related to patients monitored and managed, such as, accurate patient identification, monitoring and tracking of patient health or location and eliminating wrong patient wrong procedure surgery, etc. Staff management discusses better staff time utilization, staff monitoring and workflow optimization at hospitals.

3.3.4.1 Healthcare operational process

Operational process refers to the execution of tasks related to activities along the organisation's value chain (Davenport 1993). Operational process comprises the inbound logistics process, outbound logistics (customer relationships), production and operation processes, product and service development processes and sales and marketing processes (Porter 1998).

In the healthcare area, more focus is put on the procedure performed, such as patient management, staff management and asset management. An RFID-enabled system may improve operational efficiency and accuracy in order to enhance healthcare performance (consisting of three dimensions: economic performance, structural performance and clinical performance) (Solovy 2003). Economic performance refers to the financial context. Structural performance refers to work-related processes (functioning of various activities) and clinical performance introduces care-related processes into the healthcare context. We therefore propose that:

> *Proposition 9 (P9): Healthcare operational process improvement from RFID will have a positive effect on the performance at the organizational level.*

3.3.4.2 Healthcare management process

Management process refers to the administration, allocation of resource, resource coordination and control in an organisation (Solovy 2003), such as patient management, staff management and asset management. RFID capabilities may improve management processes, which may ultimately impact healthcare performance consisting of three dimensions (economic, structural and clinical performance).

> *Proposition 10 (P10): Healthcare management process improvement from RFID will have a positive effect on the performance at the organizational level.*

4 CHAPTER 4: METHODOLOGY

4.1 Introduction

Research methodology defines how a research activity utilises or is applicable to a model, and thus specifies concepts and related statements (Clarke 2005). It also defines what methods are applied and how progress is measured (Clarke 2005). Different types of research questions need different types of methods (Clarke 2005).

The purpose of this Chapter is to introduce the principle research methodology and other factors that frame the whole research project. The methodologies have been chosen based on specific attributes and perceived benefits in a research area, and are in line with the factors determining the parameters of the research project, such as RFID management capability, RFID infrastructure flexibility and RFID personnel expertise; competitive environment and macro environment; and operational and management process. A combined method (qualitative and quantitative methods) for data collection and analysis is used in this research. This Chapter outlines the justification for the paradigmatic choices and methods, followed by a discussion of the various steps in the research procedures and data collection. Finally, the primary ethical considerations and obligations encountered throughout the research work are outlined.

In this research the following questions will be answered:

1. What are the drivers and challenges that affect the development of healthcare?
2. What is the impact of IT on the value chain concept in the healthcare sector?
3. What are RFID capability and its role in healthcare processes?
4. How do RFID capabilities improve healthcare processes, which ultimately impact healthcare performance?
5. What are the roles of the environmental and organisational contexts in an RFID-enabled healthcare area?

4.2 Research methods and justification

In order to achieve our research objective, it is vital to consider the nature of the research methodologies relating to qualitative and quantitative methods. The qualitative method is defined as describing methods without measurement or statistics (Fischer 2005), while the quantitative method refers to the systematic investigation of social

phenomena through statistical, mathematical or computational techniques (Given 2008). In fact, differences between the two methods are not limited to data collection. Kervin points out the different methods used. Qualitative methods include interviews, observation, case studies, fieldwork and analysis of documents (Kervin 2006), whereas quantitative methods focus on observations using statistical, mathematical or computational techniques (Given 2008). In addition, the various methodologies are used for different kinds of research settings and objectives, and bring different outcomes for hypotheses-testing, theory development and analysis.

Since the 1980s, the qualitative method has gained more attention in the areas of administration sciences, logistical sciences and information systems (Benbasat and Goldstein 1987). It is used in research studies that use non-statistical processes, comprising the analysis of people's lives, emotions, feelings and socio-cultural interactions (Strauss 1990). Qualitative research focuses on process and meaning without quantified measurements, intensity or frequency (Zikmund 2010).

Qualitative research needs a contextual grounding by the researcher using grounded theory (Strauss 1990). Such grounded theory is developed from researched data, which is in turn comprehensively organised and assessed (Strauss 1990). Qualitative methods based on theory and analysis, together with the identification of patterns, processes, causes and frequencies (Babbie and Mouton 2001), comprise an element of qualitative methodology and support the application of qualitative methodology in this research. Furthermore, it is important and relevant to learn theoretical and empirical knowledge in our research; for example, to understand the role of the environmental and organisational contexts in an RFID-enabled healthcare area; and how RFID capabilities improve healthcare processes, which may ultimately impact healthcare performance.

Trumbull points out that a more important element of qualitative research methodologies is the ability of the researcher to engage with the research phenomena in their natural context or setting (Trumbull 2005). It helps the researcher to validate the analysis of the data, as the qualitative method privileges multi-approaches based on interpretation of the subject as experienced in a naturalistic setting (Trumbull 2005). It can also be presented for the development of theory (Trumbull 2005); in particular, a grounded theory is vital for theoretical explanations to be developed following the

research analysis process. In this context, gaining an insight into the healthcare industry is important for better understanding the uses of IT (RFID) throughout this area. In addition, the use of qualitative methods and case study research enable this research to develop analysis based on the experiences and understanding of the healthcare industry toward RFID. Research findings reflecting a contextual knowledge of the research setting and the significance of qualitative methods through the analysis of case study are suitable to the objectives of this research.

Eisenhardt regards case study as a research strategy focusing on the understanding of the dynamic present in a research setting (Eisenhardt 1989). Benbasat regards case study as an enabler for researchers to understand the nature and complexity of the process in natural settings, as well as capture valuable information (Benbasat and Goldstein 1987). Maykut regards case study as an analysis of a system with boundaries, in which researchers can limit the scope of their work, thereby enabling deeper analysis of a specific setting (Pamela S. Maykut 1994). This study restricts the case study's qualitative analysis to the healthcare sector for gaining more valuable insights into the use of RFID and its impacts, thereby developing theory in the healthcare area (Wamba 2011).

Data collection in case study can include methods ranging from interviews, questionnaires and observations to focus groups (Benbasat and Goldstein 1987). Wamba regards the use of case study to enable the development of information regarding both technological and business-based perspectives (Wamba and Chatfield 2009). It can be seen as a shift from technology to an organisational focus in information system research, and a beneficial use of case studies, enabling a deeper contextual analysis in an organisation. Next, two examples are given to introduce the effects of case study used as a research method.

A study conducted by Lewis (Lewis 2009) explored the transition from RFID-enabled transactional systems to RFID-enabled strategic systems in the healthcare area. He used the comparative case study method from a process-oriented perspective to examine the underlying causal mechanisms that form the transition process. The method he used helped ensure differences along important outcome observations and contextual characteristics he predicted and would affect the transition processes over time.

Archival data refers to information that already exists in others' work (Yin 1999). In general, the result of completed activities is not subject to change and is therefore sometimes known as fixed data (Yin 1999). Moreover, evaluation information may be more likely than assessment data to come in the form of study results (Yin 1999). Furthermore, archival data can make it possible for small organisations with limited resource to conduct thorough evaluation studies and identify patterns or relationships that would not otherwise be sought (Yin 1999). Considering how we carried out our research, we have collected and used archival data in order to better understand the context. An evaluation and a longitudinal study in the future will be conducted.

Using qualitative methods nevertheless has some drawbacks. The main advantages and disadvantages of adopting qualitative methods are shown in Table 4.2.

Table 4.2 Advantages and disadvantages of qualitative methods (Eisenhardt 1989;Strauss 1990;Babbie and Mouton 2001;Yin 2003)

Advantages	Disadvantages
◆ natural setting ◆ context-based and process-oriented ◆ more in-depth and comprehensive information ◆ subjective information and participant observation to describe the context ◆ the variables under consideration ◆ the interactions of the different variables in the context	◆ difficulties in establishing the reliability and validity of the approaches and information ◆ difficult to prevent or detect researcher induced bias ◆ limited due to the in-depth, comprehensive data gathering approaches required

Alternatively, quantitative research methodology offers analysis of numerical and statistical data and is based directly on its original path (Kervin 2006). Given points out that quantitative methods refer to the systematic investigation of social phenomena through statistical, mathematical or computational techniques (Given 2008). Zikmund presents quantitative research that focuses on relationships between variables rather than on meanings and processes (Zikmund 2010). In addition, quantitative research methods facilitate the deployment of a deductive model for examining the relationship between

variables. These elements can therefore be very constructive when considering planning issues that occur before data collection and analysis. However, some shortcomings of quantitative methods also have to be considered (Yin 1999; Babbie and Mouton 2001):

- Cannot undertake intensive or in-depth analysis on phenomenon;
- Not useful for studying complex or conceptual issues or emerging topics;
- Responses may be biased by the questions;
- Statistical validity and reliability concerns; and
- Problems occur with low response rates.

Consequently, after comparison between the above-mentioned advantages and disadvantages of qualitative methods, we decided to use case study in the research, as we are attempting to analyse the variables relevant to the research area under study. Moreover, case study is particularly appropriate when examining "how" and "why" questions, in which the nature and complexity of the process can be better understood (Yin 2003). Third, the focus is on the individual case and not all cases, which enables deeper analysis of a specific setting. Eisenhardt points out that the use of case study allows the development of grounded theory (Eisenhardt 1989). Moreover, researchers can increase the validity of the research conducted from powerful evidence-based definitions through the development of cross-case investigation (Eisenhardt 1989). Last but not least, it is essential to consider the validity, legitimacy and reliability of constructs, coupled with internal and external factors before execution of the case study design (Yin 2003).

4.3 Research procedure and justification

This research aims to identity the factors in how the RFID-enabled healthcare process ultimately impacts healthcare performance. The qualitative and quantitative methods are used to analyse the research results brought about by case studies. In addition, the qualitative research method has been used as the principal method to collect data because case study enables us to understand the nature and complexity of the process in its natural setting (Benbasat and Goldstein 1987). Furthermore, this research has adopted the process view approach to evaluate the impact of RFID in healthcare and to develop theoretical and empirical knowledge; for example, the role of the environmental

and organisational contexts in an RFID-enabled healthcare area; and how RFID capabilities improve healthcare processes, which may ultimately impact healthcare performance. Case study techniques like archival data analysis enable exploration of the roles played by RFID at the process level in the healthcare sector and analysis of the benefits of RFID in facilitating healthcare performance. Therefore, we adopted the archival data analysis technique for data collection. To collect data for the proposed research, a series of cases from healthcare organisations that have adopted RFID technology has been collected from the databases of an RFID Journal, one of the vendors and consultants in IT products and solutions. The reason is that all the cases have been endorsed by their client firms, and the cases contain the contact details of the healthcare organisations, their members who were involved in these cases and also some quotes from their interviews. Hence, this greatly enhances the credibility of the data and information provided to support the proposed research model. Further, through archival data analysis, the capabilities of RFID, such as RFID personnel expertise, RFID management capabilities and RFID infrastructure flexibility affecting the process level of the organisation, ultimately affecting the healthcare performance of the research proposition, can be achieved in detail. Thus, this study utilises the qualitative and quantitative research methods to focus on the development of theory as it relates to grounded case study and they will be implemented through archival data analysis for the development of an in-depth analysis of each proposed RFID-enabled healthcare performance.

Finally, the combination of qualitative and quantitative methods allow us to examine the key factors in RFID capabilities in the environmental and organisational contexts in a healthcare organisation, and how deep these factors facilitate healthcare processes ultimately affecting healthcare performance.

4.4 Research design

Research design is defined by Burns as a set of decisions to guide methods and procedures for collecting and analysing the information needed (Joseph Hair 2002; Alvin C. Burns 2003). It is vital to make appropriate research design, as it determines important aspects such as the type of data collected, data collection techniques, sampling methodology, schedule and budget (Joseph Hair 2002). This part of the

research helps to align the planned methodology to the research problems (Gilbert A. Churchill 2004) for identifying the significance of RFID in the environmental and organisational contexts in the healthcare sector. Figure 4.4 presents the sequence of our empirical research methodology.

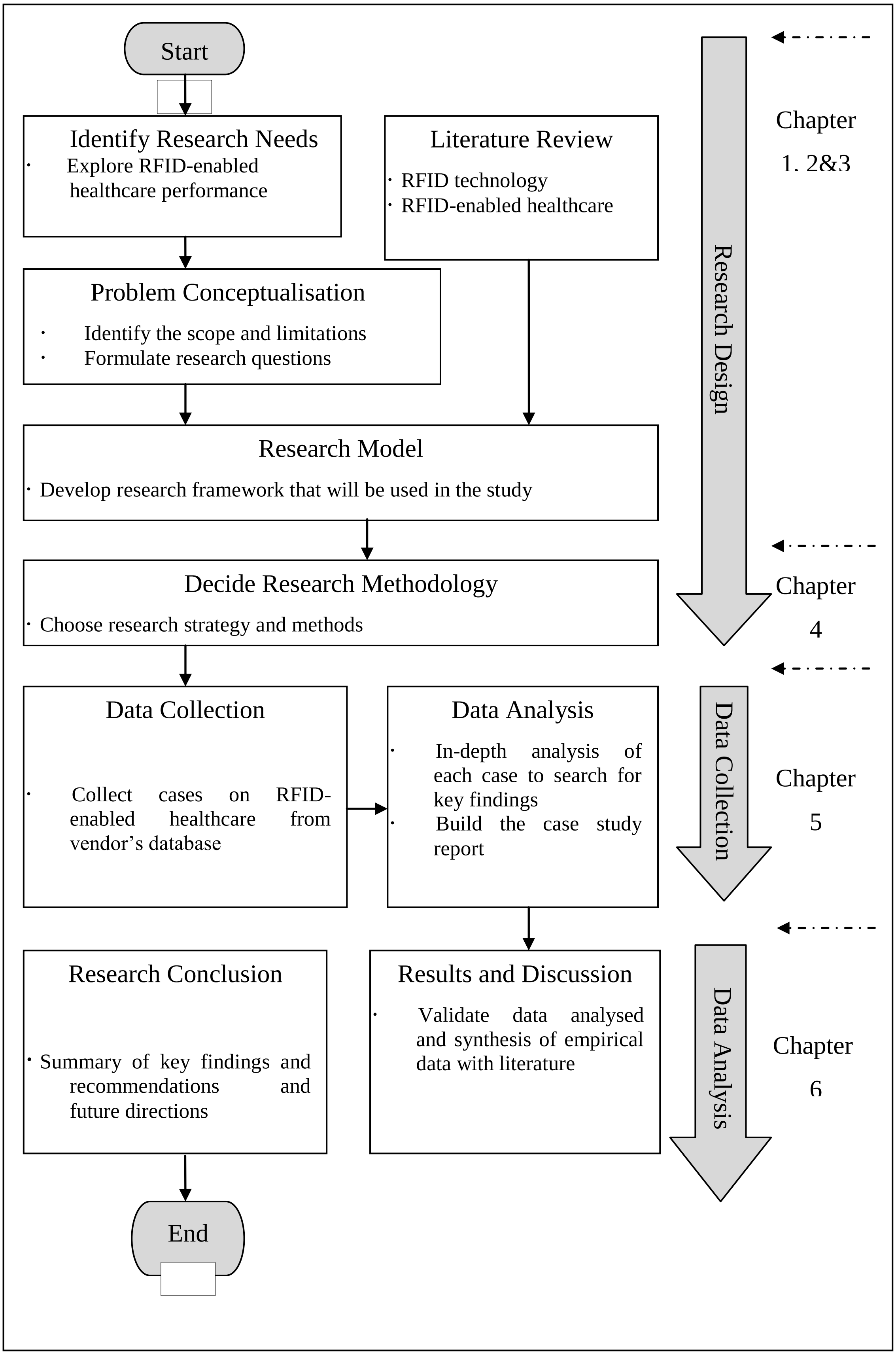


Figure 4.4 Research Design

4.5 Data collection

This research focuses on the examination of key factors in RFID capabilities in the environmental and organisational contexts in a healthcare organisation and how these factors facilitate healthcare processes, ultimately affecting healthcare performance at the organizational level. To explore these factors, the qualitative research method is used as the principal method to collect the data because case study enables us to understand the nature and complexity of the process in its natural setting (Benbasat and Goldstein 1987). Given that our research focuses on processes, meanings and depths, qualitative and quantitative methods will be used for data collection. All the cases have been collected from the professional database of RFID Journal, SAP, Oracle and Cerner, and are related to healthcare areas that have adopted RFID technology in their organisations. Moreover, we will leverage a set of archival data, such as power point presentations from the vendor and hospital perspectives to generate key insights.

In addition, the development of mini case studies was assisted with the adoption of archival data analysis for examining the impact of RFID technology on the healthcare industry, thereby answering research questions and creating a knowledge base. Wamba presents that the use of case study enables the development of information regarding both technological and business-based perspectives (Wamba and Chatfield 2009). It can be seen as a shift from technology to an organisational focus in information system research, thereby enabling a deeper contextual analysis. The cases have been collected from the databases of RFID Journal, SAP, Oracle and Cerner. Consulting these databases was because they represent leading market resources, consultants in IT or RFID products and solutions and publication source. Furthermore, the cases studied were published upon approval by various organisations from different sectors. Particularly, RFID Journal is the world's first independent media company devoted solely to RFID and its business applications. Cerner is a leader in the health informatics sector with 30% of the market share (Placide 2012). In addition, these cases include the contact details of the healthcare organisations and the members who participated in the cases, which increases the credibility of the information that is offered as data supporting the proposed research model and to further an in-depth analysis for each proposition. Thereafter, we performed web searches with the following keywords: "IT" and "healthcare" in the above-mentioned database. Altogether, we randomly identified

more than 200 cases from SAP, Oracle and Cerner, and then qualified them as applying to the healthcare sector with potential directions similar to those we planned to classify in accordance with the functional application areas. After that, the same method was used on RFID Journal. We finally identified 131 cases, 70 of which were qualifying as healthcare sector implementations by IT vendors, as shown in Figure 4.5.1, and 61 qualifying as RFID vendors, as shown in Figure 4.5.2. In IT category, the majority of cases were collected from Oracle (37) and SAP (24); whilst in the RFID category, almost 80% were collected from RFID Journal (52). RFID-based cases came from countries on the five continents, with the majority from the North America (USA) (36) and Europe (10), including five from the United Kingdom with, and one Germany.

All the case studies in this chapter are available in the link provided in Appendices.

Figure 4.5.1 Number of IT implementations in healthcare

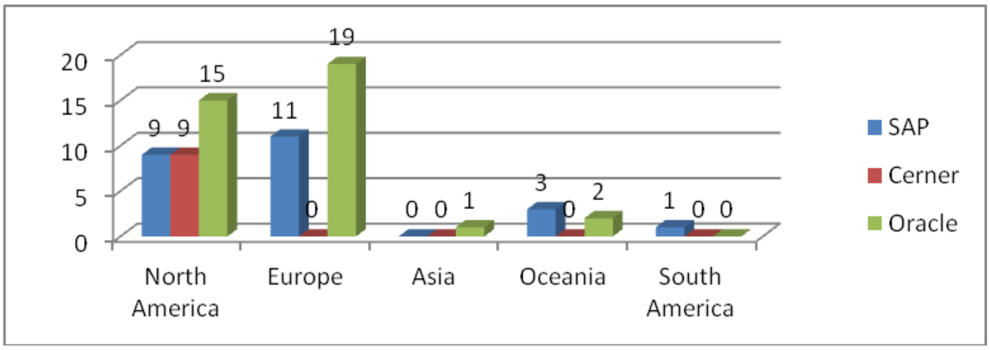
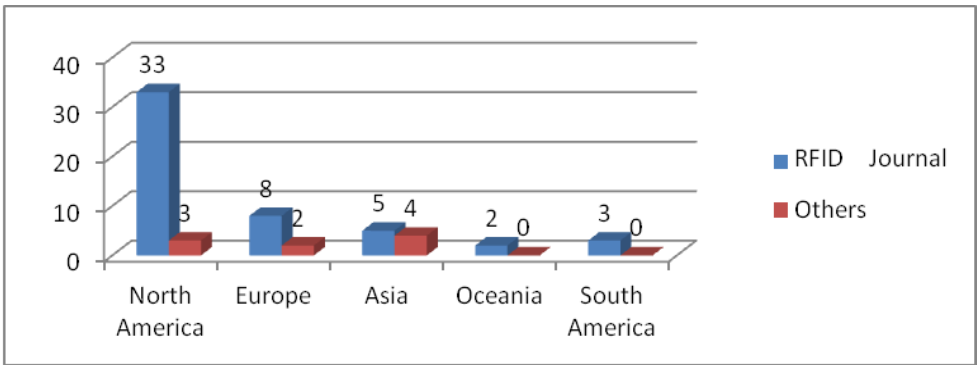


Figure 4.5.2 Number of RFID implementations in healthcare



Furthermore, to collect the story data, two main categories are presented: case attributes and drivers of RFID adoption. The case attributes refer to RFID vendor and functional

coverage of RFID system, including asset management, patient management and staff management, as shown in Table 4.5.1.

Table 4.5.1 Breakdown of healthcare modules and cases

	Oracle Freq. (%)	SAP Freq. (%)	Cerner Freq. (%)	RFID Journal (RFID-based cases) Freq. (%)	Others (RFID-based cases) Freq. (%)
Patient Mgt (33)	4 (12)	6 (18)	6 (18)	13 (39)	4 (12)
Asset Mgt (49)	7 (14)	6 (12)	1 (2)	30 (61)	5 (10)
Staff Mgt (49)	26 (53)	12 (24)	2 (4)	9 (18)	0 (0)
Total (131)	37 (28)	24 (18)	9 (7)	52 (40)	9 (7)

Drivers of RFID adoption refer to organization attributes, environment attributes and RFID technology attributes. The organization attributes considered here include physical capital resource affiliation, human capital resource affiliation and organizational resource affiliation. The environment attributes include competitive environment consisting of industry characters affiliation and supply chain context affiliation, as well as macro environment affiliation. RFID technology attributes include RFID management capability affiliation, RFID infrastructure flexibility affiliation and RFID personnel expertise affiliation.

Meanwhile, a survey using all the 61 RFID-based cases was done to assess the extent of statistical association between the dependent and independent variables of the proposition. A 4-point scale (0-3) was designed to measure the strength of evidence of the variables of the model. The scoring rules were as follows:

Table 4.5.2 Scoring rules

Score Rules	
Score	Meaning
0	No evidence (no mentioned of any statements related to the construct)
1	Limited evidence (vague mentioned or indication)
2	Significant evidence (good indication from the background)
3	Extensive evidence (clearly mentioned as excepted)

For each of the 61 RFID-based cases, a score from 0 to 3, as shown in Table 4.5.2, was assigned to each of the factors steaming from research model, which provided a dataset as shown in Table 4.5.3 as the base for quantitative analysis to test the model.

Table 4.5.3 Sample extract of the dataset

Case	OP	MP	RM	RP	RI	IC	TP	ME	PR	HR	OR
1	3	1	3	1	3	1	0	3	3	3	1
2	3	2	3	3	3	0	3	0	2	3	0
3	2	1	2	1	2	0	0	0	2	2	0
4	3	3	3	1	2	2	3	0	0	3	0
5	3	2	3	2	2	0	2	0	2	0	0
6	1	1	1	3	3	0	2	0	2	1	0
7	3	1	3	1	3	3	3	3	0	2	0
	OP=Operational Process; MP=Management Process; RM=RFID management capability; RP=RFID personnel expertise; RI= infrastructure flexibility; IC= Industry Characters; TP= Trading Partners Context; ME=Macro environment; PR=Physical Resource; HR=Human Capital Resource; OR=Organizational Resource.										

4.6 Conclusion

This Chapter outlines the key research methodologies and procedures followed throughout this research process. In this research work, the qualitative and quantitative methods are used for data collection and data analysis based on the research focus. The research is conducted according to the research policies of the University of Wollongong, Australia.

5 CHAPTER 5: DATA ANALYSIS AND RESULTS

5.1 Introduction

This Chapter data analysis methods adopted in the research will be introduced. Data was collected from mini case studies, centred on the various experiences described in each mini case. Finally, results will be drawn through an in-depth analysis of these mini case studies.

5.2 Qualitative and quantitative data analysis

In this study, the cases under consideration are reviewed and analysed in detail. Analysis is based on various experiences described in each mini case rather than on the conclusion of each author. An in-depth analysis will be conducted on how RFID capabilities are combined with environmental and organizational contexts to improve healthcare processes, which ultimately impact healthcare performance at the organizational level. Next, through a comparison between IT-enabled healthcare and RFID-enabled healthcare, we will draw out the key differences from the perspective of healthcare processes and performance.

5.2.1 Case study 1: Pantai Hospital Ipoh

Pantai Hospital is located at Ipoh in Malaysia. Due to the growth of local population and a shortage of chronic skilled labour, they deployed RFID-enabled administrators to provide better patient care.

‘What we've basically done over the last two years is to reexamine the whole business model, and then introduce change management into the hospital.’

Dilshaad Abas Ali, M.D.,CEO, Pantai Hospital

Pantai was facing the difficulty to provide high-quality patient care due to shortage of the nursing staff. Pantai’s administrators wanted to take and record patients’ temperature as efficiently as possible. After studying the situation in collaboration with a Singapore firm Cadi Scientific specializing in hospital-based wireless technologies, the administrators decided to focus on patient temperature monitoring and location tracking, impressed by the RFID system. The hospital thus deployed an RFID system to

automate administrative-oriented tasks, thereby relieving nurses' hands for care-related work. Temperatures were automatically uploaded to a central Electronic Medical Records (EMR) to eliminate manual processes and human transcribing errors. Moreover, patient tracking could eliminate paper-based tasks, such as manually records updating when a patient moved across different departments, thereby ensuring patients' safety. Thus, RFID environment improved both staff performance and patient care.

'We looked at the whole architecture, streamlining the work flows and the infrastructure that had to be put in.'

Dilshaad Abas Ali, M.D., CEO, Pantai Hospital

'So far, the nurses who have used the wireless temperature-monitoring system have been very pleased with the amount of workload that the system has helped reduce.'

Goh Zenton, CEO, Cadi Scientific

Through the deployment of RFID system, Pantai Hospital eliminates the manual processes, providing caregivers more time for care-related work. In other words, through improving healthcare operational processes, RFID management capability, RFID infrastructure flexibility and RFID personnel expertise ultimately enhance healthcare structure and clinical performance. In addition, during the implementation of this project, competitive environment, physical capital resource and human capital resource have been taken into account. We can therefore support our P1, P2, P3, P4, P5, P6, P7 and P9 of the research proposition.

5.2.2 Case study 2: Memorial Sloan-Kektter Cancer Centre

Memorial Sloan-Kektter Cancer Centre (MSKCC) is a pioneer in cancer care and RFID in the healthcare sector. Before deploying RFID, MSKCC used manual processes and a bar-code system for inventory management, which required human power and line of sight. Therefore, a project based on RFID solution was created to solve these two challenges by a multi-disciplinary term.

'The primary driver for looking at RFID was the intuitive understanding that this technology could drive the inventory and supply-chain management and finances.'

Paul Frisch, MSKCC's chief of biomedical physics and engineering

'Establishing the unique relationship and association between patients, staff, equipment, pharmaceuticals and supplies can be used to support processes such as device assignment, connectivity solutions, medication administration and sample collection.'

Paul Frisch, MSKCC's chief of biomedical physics and engineering

After the implementation of an RFID-based asset tracking solution, MSKCC reaped from optimising staff time and equipment utilisation. MSKCC eliminates the manual processes and overcomes the limitation of line of site application on inventory management by applying RFID technology. In other words, RFID management capability, RFID infrastructure flexibility and RFID personnel expertise ultimately enhance healthcare financial and structure performance through improvement on inventory management and operational processes. In addition, during the implementation of this project, healthcare partners, organisational resource, physical resource and human capital resource have been taken into account, which can therefore support our P1, P2, P3, P4, P6, P7, P9 and P10 of the research proposition.

5.2.3 Case study 3: Jacobi Medical Centre

Jacobi medical centre, located in New York City, serves more than one million residents. They already possessed a computerized physician order-entry system for electronic management, including nearly 95% of the healthcare records.

'I thought, "If I can just wave the PC over the patient's wrist and bring up the problem list, medications, allergies and other critical information, it will simplify patient identification and save clinical-staff keystrokes.'

Daniel Morreale, CTO, North Bronx Healthcare Network

However, manual processes were still being used in some areas. They therefore deployed a pilot system in which RFID-enabled plastic wristbands were used to change the interaction between caregivers and patients at their bedside by automatically identifying each patient.

During that initial trial, RFID readers were installed in portable PCs to read the unique ID number encoded on an RFID tag embedded in the patient's wristband, helping the patient's records to be reviewed and updated, thereby enabling operational processes to

be more efficient. After two months' trial, the reaction from the staff proved the further deployment of this technology.

'Staff refused to give back the equipment, and other departments had started to say they wanted it too.'

Daniel Morreale, CTO, North Bronx Healthcare Network

Designed, deployed and managed by Siemens Business Service, the pilot RFID system replaced a heavy manual system. In addition, the bar code system was included to enable staff to read medical record numbers (MRN). However, bar code system required a line of sight between the wristband and the staff member, whereas RFID chips could be scanned through bedcovers. Thus, it proves the compatibility and relative advantage of RFID from Rogers' diffusion theory.

All in all, we summarise that Jacobi Medical Centre deployed a RFID-enabled system to improve patient care and increase operational efficiency by eliminating manual paper-based procedures. In other words, RFID management capability and RFID infrastructure flexibility with physical resource and human resource, improve healthcare operational processes, and enhance the structure and clinical performance. We can therefore prove our P2, P3, P6, P7 and P9 of the research proposition.

5.2.4 Case study 4: Integris Health

Integris Health as the largest healthcare provider in Oklahoma had been facing the challenges of inventory and expiration dates of hernia mesh tracked manually. Thus they employed RFID technology in accurate care facility in Southwest Medical Centre to track hernia meshes, thereby reducing the likelihood of expired and missing products. Furthermore, Integris planned for the long-team deployment, and got management supports.

'We had to show management RFID works and it is cost-effective rather than roll it up into just the OR, we are frog-leaping the process throughout the enterprise.'

Jerome R. Gardner, VP of special projects and consulting services

A cross-functional team was created to deploy RFID aiming to improve the process of identifying the status of mesh. During this trial, hospital staff performed daily system

reconciliations to ensure the visibility of expiration date and status of products. Gardner pointed out that big extrapolated ROI comes from the results of process management-lost revenue-$614,600. This technology enabled continuous monitoring of stock, as well as the ability for order replacements in real time.

We then summarise that Integris Health deployed an RFID-enabled system in Southwest Medical Centre to eliminate waste in process. In other words, RFID management capability and RFID infrastructure flexibility, combined with the consideration of trading partners and human resource, enable healthcare operational and management processes, thereby enhancing the structure, financial and clinical performance. It can therefore support our P2, P3, P4, P7, P9 and P10 of the research proposition.

5.2.5 Case Study 5: Paul L.Foster School of Medicine

Paul L.Foster School of Medicine located in El Paso, was facing the inefficiency issues caused by manual processes in equipment tracking processes before employing a technology-solution. Therefore, they implemented a RFID-based solution to improve its inventory-management process, thereby reducing the time needed to locate asset.

This system worked with Enterprise Software System, providing significant process improvement when it came to track more than 1,500 assets in the school. In addition, this system reduced the reliance on paperwork, provided continuous monitoring and created matching reports, thereby improving operational efficiency and effectiveness and reducing cost.

All in all, we summarise that Paul L.Foster School of Medicine deployed a RFID-enabled system through improving inventory management process to enhance operational efficiency and reduce cost. In other words, RFID management capability, RFID personnel expertise and RFID infrastructure flexibility combined with the consideration of trading partner and physical resource, enable inventory operational process efficiency, thereby enhancing structure and financial performance. It therefore supports our P1, P2, P3, P4, P6 and P9 of the research proposition.

5.2.6 Case Study 6: Lahey Clinic Medical Centre

The Lahey Clinic Medical Centre is one of the top medical facilities in Boston area. Lots of time was spent on searching for medical devices, thus they developed a real-time locating system (RTLS) based on RFID technology to track equipment and ensure regularly scheduled maintenance. This system indicates the location of the equipment, and hospital can benefit from better asset utilization and more efficient maintenance.

Through the deploying of RTLS based on RFID technology, Lahey Clinic Medical Centre eliminates the manual processes to give caregivers more time for care-related work. In other words, through improving healthcare operational processes, RFID management capability, RFID infrastructure flexibility and RFID personnel expertise ultimately enhance healthcare structure performance. In addition, during the implementation of this project, trading partner and physical resource have been taken into account, which can therefore support our P1, P2, P3, P4, P6 and P9 of the research proposition.

5.2.7 Case Study 7: Netherlands Hospital

To reduce costs and improve patient safety and service, University of Amsterdam's Academic Medical Centre (AMC) worked with a group of partners to test three RFID applications simultaneously.

'We strongly believe that, especially in health care, the investment in RFID infrastructure will only pay out when you are able to combine different RFID applications on one and the same infrastructure.'

Patrick Jansen, Consultant of the health-care practice at Capgemini's Utrecht office

The trial was rolled out in three phases, the patient and staff tracking pilot, the medical equipment tracking and the blood tracking. Hospital could use RFID data to optimise schedules by tracking patients and staff. The combination of medical equipment and patient tracking provides operational processes efficiency and accuracy. However, AMC has not yet reached any conclusion on the tracking of blood products trail. It needs to be considered here whether RFID could be a viable alternative to bar codes to meet European Union blood-safety guidelines.

From this case, RFID management capability and RFID infrastructure flexibility are adopted to optimise schedule and to reduce supply-related cost through more refined operational processes. Meanwhile, industry characters, trading partner, human resource and macro environment affect healthcare processes when tracking medical equipment and blood-related products considering interference between medical equipment and RFID system. We can therefore prove our P2, P3, P4, P5, P7 and P9 of the research proposition.

5.2.8 Case Study 8: Lucile Packard Children's Hospital

Lucile Packard Children's Hospital used RFID system to track the location of its newest patient, prevent their records from being removed without permission and avoid to be changed with others' by mistake. This system was also used to track other patients, staff and medical equipments under the same infrastructure, but controlled by a different system.

From this case, RFID management capability and RFID infrastructure flexibility with physical resource enhance work-related and clinical performance by improving operational processes. We can therefore support our P2, P3, P6 and P9 of the research proposition.

5.2.9 Case Study 9: Commonwealth Newburyport Cancer Centre

Commonwealth Newburyport Cancer Centre uses an RFID-base system to track patients and their charts to ensure that they receive proper treatments. This system integrated RFID into an oncology-specific electronic medical record to improve patient safety and prevent dangerous treatment errors by automating the patient check-in processes, treatment chart access and verification of treatment delivery. The RFID system ensures the centre to deliver correct treatment to correct patient.

We summarise that Commonwealth Newburyport Cancer deployed an RFID-enabled system to improve automatic delivery of processes to enhance operational efficiency and accuracy. In other words, RFID management capability, RFID infrastructure flexibility and RFID personnel expertise, combined with physical resource, enable

healthcare operational processes, thereby enhancing structure and clinical performance. We can therefore support our P1, P2, P3, P6 and P9 in the research proposition.

5.2.10 Case Study 10: Nice University Hospital

Nice University Hospital relied on a manual, paper-based traceability process that involved attaching paper documentation to all samples, leading to time-consuming and error-prone processes. Thus, they collaborated with the international Secure Communication Solutions organisation to create an RFID-based system which provides traceability and security of samples in the hospital's biobank.

This system worked with IS department of the hospital and its vendor partners to integrate RFID hardware with existing IT components, and contributed to a more than 50% time-saving.

'The traceability of information, both clinical and pathological data, will be excellent with this system.'

Paul Hofman The hospital's biobank manager

Considering the perspective of relative advantages, this system was more efficient, accurate and secure to identify specimens within biobank, thereby improving patient care by reducing the risk of errors, including the lack of a line-of-sight requirement and tags' ability to harsh environment.

Therefore, we summarise that Nice University Hospital deployed an RFID-enabled system to enhance operational efficiency and accuracy by improving tracking processes. In other words, RFID management capability, RFID infrastructure flexibility and RFID personnel expertise enable healthcare operational and management processes, thereby enhancing structure and clinical performance. In addition, during the implementation of this project, corporative vendors, macro environment, human and physical resource have been taken into account. We can therefore support our P1, P2, P3, P4, P5, P6 P7, P9 and P10 of the research proposition.

5.2.11 Case Study 11: Special Olympics

Special Olympics, as an international organisation, serves people with intellectual disabilities. They employed a RFID-based system to reduce reliance on a paper-based system Health Athletes Software (HAS).

This system automated registration process and implementation that coordinates and manages various partners involved in the Healthy Athletes program, thereby improving information management in the department of medical services.

Therefore, we summarise that Special Olympics deployed an RFID-enabled system to enhance operational efficiency and accuracy by improving operational and management processes. In other words, by improving operational process, RFID management capability and RFID personnel expertise enhance structure performance. In addition, corporative partners, macro environment and physical resource have been taken into account during the implementation of this project. We can therefore support our P1, P3, P4, P5, P6 and P9 of the research proposition.

5.2.12 Case Study 12: Intermountain Healthcare

Intermountain Healthcare implemented an RFID-based system to increase speed and accuracy of laboratory testing. This system automated the tracking of laboratory samples to increase efficiency and decrease variation in the process and staff requirements to deal with staff shortages.

We then summarise that Intermountain Healthcare deployed an RFID-enabled system, to improve operational process and enhance operational efficiency and accuracy. RFID management capability, RFID infrastructure flexibility and RFID personnel expertise, combined with industry character, trading partner, macro environment, human and physical resources, ultimately enhance structure performance through improving operational process. We can therefore support our P1, P2, P3, P4, P5, P6, P7 and P9 of the research proposition.

5.2.13 Case Study 13: Intermountain's Mckay-Dee Hospital Centre

Intermountain's Mckay-Dee Hospital Centre has been employing RTLS for tracking of asset to improve facility and resource utilization more efficiently. This system uses a combination of infra and RF tags for a seamless tracking, which enables more powerful operational process.

In this case, Intermountain's Mckay-Dee Hospital Centre deployed RFID-enabled system, through improving tracking processes to enhance operational efficiency. In other words, RFID management capability and RFID infrastructure flexibility enhance structure performance through improving operational process. We can therefore support our P2, P3 and P9 of the research proposition.

5.2.14 Case Study 14: St. Vincernt's Hospital

St. Vincernt's Hospital deployed a patient tracing and real-time clinical information system to improve the quality of care, thereby increasing revenues. This system, combing RFID technology with hospital's various health-information programs, enables the hospital to improve management capability and to enhance the quality of care, by improving patient visibility and eliminating waiting time for care. A key measure of operational efficiency for the hospital climbed from 20% to almost 40%, and an increase of $2.58 million in net revenue during the pilot phase. In addition, they pointed out that nurses readily accepted the patient-location system as it is easy-to-use, since better process and training could determine the impacts of this technology implementation.

In this case, St. Vincernt's Hospital deployed an RFID-enabled system to enhance efficiency, quality of care and related-revenue by improving operational and management processes. In other words, RFID management capability and RFID infrastructure flexibility, combined with human and physical resource, improve operational processes, thereby enhancing structure, clinical and financial performance. We can therefore support our P2, P3, P6, P7, P9 and P10 of the research proposition.

5.2.15 Case Study 15: University of Texas South western Medical Centre

The University of Texas South western Medical Centre deployed an RFID-based solution to overcome the issue of paper-based purchase forms on clipboards attached to a storage cabinet or freezer.

This system provides life-science material vendors a better inventory management solution in research facilities with real-time tracking of on-site products, and eliminates the need for material suppliers to visit the sites, take inventory and refill freezers and cabinets. They have kept its prices low because of the deployment of the RFID system.

In this case, the University of Texas South western Medical Centre deployed an RFID-enabled system to enhance operational efficiency and related-revenue by improving inventory management process. Industry supply chain characters, physical and human resources enhance structure and financial performance through improving management process. We can therefore support our P4, P6, P7 and P10 of the research proposition.

5.2.16 Case Study 16: Providence Saint Joseph Medical Centre

Providence Saint Joseph Medical Centre has deployed a patient-tracking system to integrate patient records from multiple resources with other systems at the Disney Family Cancer Centre.

This system improved patient experience by personalizing each visit, and enabled staff to prepare for each patient. In addition, during the implementation, they pointed out that people needed extensive communication to keep all disparate players focusing on the same objectives.

We therefore summarise that Providence Saint Joseph Medical Centre deployed an RFID-enabled system to enhance service quality and operational efficiency through improving patient-tracking operational and management processes. In other words, RFID management capability and RFID infrastructure flexibility, combined with human capital resource, enhance structure and clinic performance through improving operational and management processes. We can therefore support our P2, P3, P7, P9 and P10 of the research proposition.

5.2.17 Case Study 17: Mississippi Blood Service

Mississippi Blood Services (MBS), a non-profit organisation, collects more than 60,000 units of blood from more than 35,000 donors annually. MBS holds up to 2,500 units of blood products on hand at any given moment, and has to be ready to ship special blood types and products. Some blood products may expire during transportation. Thus, they completed an RFID pilot for future deployment across the entire organisation.

RFID system provides real time information about the location of blood, enables the organisation to better anticipate shortages and distribution problems, so as to improve the efficiency of the overall inventory process, and simplifies the management of blood within the cooler.

In this case, we summarise that MBS deployed an RFID-enabled system to provide real time information to solve blood products expiration problem and improve efficiency in inventory process. RFID management capability, RFID infrastructure flexibility and RFID personnel expertise ultimately enhance healthcare clinical and structure performance through improving inventory management process. In addition, industry characters, trading partner, macro environment human and physical resource have been taken into account during the implementation of this project. We can therefore support our P1, P2, P3, P4, P5, P6, P7 and P9 of the research proposition.

5.2.18 Case Study 18: Memorial Hospital Miramar

Memorial Hospital Miramar deployed an RFID-based real-time locating system to improve patient care, manage room turnover, trace and monitor medical equipment and automate workflow processes.

This system is integrated with other healthcare information system through identifying patient’s location to improve communication, predict discharge and transfer rates, contributing to less patient waiting time and staff searching time. In addition, this system automates workflow process to improve the efficiency and accuracy for passing information. The system also helps medical supply management, ensuring medication use before expiring.

We therefore summarise that Memorial Hospital Miramar deployed a RFID-enabled system to enhance quality of service and operational efficiency through improving patient-tracking, equipment-tracking and workflow operational and management processes. In other words, RFID management capability and RFID infrastructure flexibility, combined with supply management context, human and physical resource, enhance structure and clinic performance through improving operational and management processes. We can therefore support our P2, P3, P4, P6, P7, P9 and P10 of the research proposition.

5.2.19 Case Study 19: Taipei Medical University Hospital (Tzeng, Chen et al. 2008)

Taipei Medical University Hospital deployed a location-based medical service system (LBMS) to track and identify patients. The purpose of implementing an RFID-based system combined with GPRS was to monitor physiological signals and track the paths of infection sources. Later on, RFID-based blood bag circulation system was integrated into previous LBMS system to take care of patient safety under the healthcare industry experiments. Thus, RFID-based platform was established to meet the operational requirement.

We therefore summarise that Taipei Medical University Hospital deployed an RFID-enabled system to improve patient-tracking and blood management processes, which enhances the quality of services. In other words, RFID management capability and RFID infrastructure flexibility, combined with industry character, improve operational processes therefore enhancing clinic performance. We can therefore support our P2, P3, P4, P5 and P9 of the research proposition.

5.2.20 Case Study 20: Taipei Minicipai WanFang Hospital (Tzeng, Chen et al. 2008)

Taipei Minicipai WanFang Hospital was the first build-operate-transfer municipal hospital in Taipei. It deployed a RFID-enabled system in the emergency room to improve treatment quality and patient satisfaction, by reducing incorrect treatment and diagnosis, and delays in treatment. Then it developed an RFID-based medical auditing system and emergency medical system integrated with previous system for the connection of intra and extra hospital systems.

In this case, Taipei Minicipai WanFang Hospital deployed an RFID-enabled system to reduce incorrect operational process, which improves treatment quality and patient satisfaction. RFID management capability and RFID infrastructure flexibility with industry character and physical resource enable the enhancement of healthcare operational process, thereby improving clinical performance. We can therefore support our P2, P3, P4, P6 and P9 of the research proposition.

5.2.21 Case Study 21: Show Chawn Memorial Hospital (Tzeng, Chen et al. 2008)

Due to SARS outbreak, Show Chawn Memorial Hospital began to seek a long distance medical care models. It cooperated with the Ministry of Economic Affairs' technology specialization to create an RFID-based project. The purpose was to monitor patient temperature for potentially infectious patients, access control of staff and track the movement of hospital waste in transport. In addition, this system was integrated with Changhua Senior Citizen Home. Here RFID was employed for transmitting real-time information between these two institutions.

In this case, Show Chawn Memorial Hospital deployed an RFID-enabled system to improve care quality and isolate infection sources through implementing of a long distance temperature monitoring process. RFID management capability and RFID infrastructure flexibility, combined with industry character, trading partner and physical resource, enhance healthcare operational process, thereby improving clinical and structure performance. We can therefore support our P2, P3, P4, P6 and P9 of the research proposition.

5.2.22 Case Study 22: Koo Foundation Sun Yat-Sen Cancer Centre (Tzeng, Chen et al. 2008)

Koo Foundation Sun Yat-Sen Cancer Centre, a not-for-profit charity healthcare organisation, employed a RFID-based system improving their capability to control infectious diseases. Koo Foundation Sun Yat-Sen Cancer Centre collaborated with the Ministry of Economic Affairs' demonstration to develop the RFID application enabling improvement of the hospital's management capability. This system focused on tracking

the spread of infection and preventing its outbreak by providing access control and ensuring a safer medical environment.

In this case, Koo Foundation Sun Yat-Sen Cancer Centre deployed an RFID-enabled system to track and verify patients, thereby improving care quality. Trading partner, macro environment control and physical resource can enhance healthcare management process, thereby improving clinical performance. We can therefore support our P4, P5, P6 and P10 of the research proposition.

5.2.23 Case Study 23: Birmingham Heartland Hospital

Birmingham Heartland Hospital deployed a safe surgery system based on RFID technology, which consists of a digital list enabled by automated patient recognition. This pre-process management and identification system using printed RFID wristbands and digital photo identification are linked to an electronic operative checklist. This system is deployed to improve the operational process efficiency and patient safety.

In this case, Birmingham Heartland Hospital deployed an RFID-enabled system to improve surgery operational process so as to guarantee treatment quality. RFID management capability, combined with industry character and human resource, enables the enhancement of healthcare operational and management processes, thereby improving structure and clinical performance. We can therefore support our P3, P4, P6, P9 and P10 of the research proposition.

5.2.24 Case Study 24: Jena University Hospital

Jena University Hospital deployed an RFID system to track medication and medical assets, thereby optimising patient care. Combined with SAP solution, this system was used to identify, track and match medication accurately. The hospital’s pharmacy to intensive care and individual patient and medication was matched digitally to patients in real time. Moreover, staff can obtain real time information on patients, thereby reducing the risk of any dispensing errors.

‘We have selected SAP technology to expand our existing SAP NetWeaver environment and to enable the innovative use of RFID. This technology will enhance the security of our drug supply chain and reduce potential adverse drug effects.’

Dr. Michael Hartmann, director of the pharmacy at Jena University Hospital and member of the Council of Europe Committee of Experts on pharmaceutical

In this case, Jena University Hospital deployed an RFID-enabled system through the implementation of identifying, tracking and matching medication processes to improve care quality and efficiency. In other words, RFID management capability, RFID infrastructure flexibility and RFID personnel expertise, combined with industry character, supply chain management capability, macro environment and human resource, enables the enhancement of healthcare operational process, thereby improving clinical and structure performance. We can therefore support our P1, P2, P3, P4, P5, P7 and P9 of the research proposition.

5.2.25 Case Study 25: Royal Wolverhampton Hospitals

Royal Wolverhampton Hospitals is employing RTLS provided by Awarepoint for tracking the location of patients, staff and assets to ensure hand-hygiene compliance. This system utilizes Cen Trak's RFLS hardware, including Gen 2IR RFID-infrared tags. This system could track patients and staff as well, then the facility could better direct staff members to the services each patient requires, thereby providing greater visibility into the services the patients were receiving. Meanwhile, the hospital is preparing to install an asset management solution based on current platform.

Awarepoint announced that this system is commercially available for hospitals globally in terms of tracking the location and temperature of assets and suppliers, managing the sterilization of instruments and facilitating workflow.

In this case, Royal Wolverhampton Hospitals deployed an RFID-enabled system to track patients, staff and assets, thereby improving care quality and workflow efficiency. In other words, RFID management capability and RFID infrastructure flexibility, combined with supply chain context, human and physical resource, enable the improvement of healthcare operational process, thereby improving structure performance. We can therefore support our P2, P3, P4, P6, P7 and P9 of the research proposition.

5.2.26 Case Study 26: Curves International

Curves International introduced an automated personal-training system that provides fitness companies a competitive advantage. This system was developed by MyTrak Health System which specializes in automated health-management solutions for fitness and rehabilitation centre. Their members believe that the system keeps them accountable to their goals. This system has become a key motivational tool within clubs.

In this case, Curves International deployed an RFID-enabled system through the implementation of automated health-management processes to improve customer satisfaction. In other words, RFID management capability, combined with industry character, human and physical capital resource, enhances the operational process, thereby improving customer satisfaction and competitive advantages. We can therefore support our P3, P4, P6, P7 and P9 of the research proposition.

5.2.27 Case Study 27: El Camino Hospital in Mountain View (Mehrjerdi 2011)

El Camino Hospital used RFID-based system to uniformly track medication. This system provides one of the lowest error rates in the nation due to the drug inventory management capability. The hospital has automated their pharmacy system leading to rapid prescription verification process. Pharmacist has 25% of the chance to intervene in drug-ordering process to prevent errors.

We then summarise that, El Camino Hospital deployed an RFID-enabled system to improve inventory management processes so as to enhance operational accuracy.

5.2.28 Case Study 28: Vanderbilt Children’s Hospitals (Mehrjerdi 2011)

Vanderbilt Children’s Hospitals deployed a RFID system for real-time tracking of assets’ location and monitoring the utilization throughout the hospital. This system prevented the loss of equipment. Also, according to Jim Shmerling, the CEO of hospital, the trail was really successful. He hoped to implement this system in both Children’s Hospital and Vanderbit University Hospital.

In this case, we summarise that Vanderbilt Children's Hospitals deployed an RFID-enabled system to improve asset tracking process, thereby preventing the loss of equipment and reducing medical error rate.

5.2.29 Case Study 29: Purdue Pharma

Purdue Pharma was one of the first companies to implement large-scale item level tagging to place RFID tags on bottles of painkillers. The RFID system was implemented by a third-party to accommodate item and case level RFID tagging, which enables the company to tackle potential counterfeiting and diversion.

In this case, Purdue Pharma deployed an RFID-enabled system to enable item-level tracking products process so as to secure the drug supply. In other words, RFID management capability ultimately enhances healthcare structure performance by improving item-level tracking process. In addition, supply chain context and physical resource have been taken into account during the implementation. We can therefore support our P3, P4, P6 and P9 of the research proposition.

5.2.30 Case Study 30: Children's Hospital Colorado

Children's Hospital Colorado deployed RFID sensors in temperature-monitoring system provided by TrmpSys for monitoring the temperatures of refrigerators, blood coolers, blanket warmers and other heating or cooling appliances. The hospital used the technology combined with existing antenna system to manage wireless data and transmission, thereby diagnosing and reducing temperature fluctuation within coolers and heaters. In addition, the implementation of such system has ensured a safer product for children by identifying and solving problem products, which paid it by reducing manual labour cost.

In this case, with the deployment of RFID-enabled system, Children's Hospital Colorado improved the temperature monitoring process to secure blood or medical management. In other words, RFID management capability ultimately enhances healthcare structure financial and clinical performance through improving monitoring process. We can therefore support our P3 and P10 of the research proposition.

5.2.31 Case Study 31: Sacred Heart Medical Centre

The facility employs RFID and infrared technologies to help evaluate pump usage throughout the facility. The technologies are used to determine the number of pumps required for each unit. Moreover, the location data is available to the staff in real time. Buchsteiner's return-on-investment (ROI) study has found that the hospital saved $600,000 almost immediately.

'The RTLS solution my biggest surprise has been the accuracy of the system.'

Christian Buchsteiner, the hospital's health-care improvement engineer

In this case, Sacred Heart Medical Centre deployed an RFID-enabled system to improve tracking process and the workflow. In other words, RFID management capability ultimately enhances healthcare structure and financial performance through improving tracking process. In addition, human resource has been taken into account during the implementation. We can therefore support our P3 and P7 of the research proposition.

5.2.32 Case Study 32: North Carolina Hospital

North Carolina Hospital will soon market the RFID-based technology to other medical centres to track blood coolers' locations and length of time they are outside a blood centre, being unrefrigerated.

This system allows staff to track how long a blood cooler is outside the blood bank. By using the system for its 35 coolers, the hospital has been able to track the coolers in order not to get lost. Staff members receive updates using the system when the products are scheduled to be returned to the blood bank to ensure they meet Food and Drug Administration (FDA) temperature requirements for storage.

'There have been no more misplaced coolers, since the system started in August, we haven't lost a single cooler, which is remarkable.'

Mary Rose Jones, blood bank/bone marrow transplant processing manager

In this case, North Carolina Hospital deployed an RFID-enabled system to secure blood products by tracking them. In other words, RFID infrastructure flexibility can enhance healthcare structure performance, combined with the impact of industry characters and

macro environment. We can therefore support our P2, P4, and P5 of the research proposition.

5.2.33 Case Study 33: Medical Marijuana Companies

RFID-based tracking system is used to help producers meet state requirements, track the condition of each plant, and receive alerts if any plant's health declines.

Two Colorado suppliers of medical marijuana are employing a RFID system to provide visibility for the health of plants as they grow, as well as to meet the state's stringent requirements for tracking the drug, from seed to user. The system, which is also being piloted by several other marijuana growers and manufacturers, allows a window into the life and health of each marijuana plant, while also tracks that plant's harvest yield, as well as its transition to a consumable product purchased by a patient.

In this case, these two suppliers implemented a tracking system to secure the drug supply by deploying an RFID-enabled system. In other words, RFID management capability ultimately enhances healthcare structure performance through improving operational process. In addition, industry character, supply chain context and macro environment have been taken into account during the implementation. We can therefore support our P3, P4, P5 and P9 of the research proposition.

5.2.34 Case Study 34: The UC San Diego Moores Cancer Centre

The UC San Diego Moores Cancer Centre is using RFID system to track the amount of time that each patient awaits radiation treatment, and the movement of patient and staff inside and outside the waiting and examination rooms. In addition, this system verifies if the correct equipment is being employed.

‘The system is designed to ensure that the proper equipment is used on each patient.’

Geoffrey Dalbow, CIVCO's chief technology officer

In this case, The UC San Diego Moores Cancer Centre deployed an RFID-enabled system to improve tracking process so as to improve efficiency and accuracy. RFID personnel expertise ultimately enhances healthcare structure and clinic performance

through improving tracking process. We can therefore support our P1 of the research proposition.

5.2.35 Case Study 35: Saint Luke's Hospital

Saint Luke's Hospital deployed an RFID-based system for material management to reduce inventory, improve billing and earn big discounts. This system enables the hospital to better manage its assets. Through improved tracking and controlling over these items, the facility has managed to reduce the size of its coronary device inventory by half a million dollars, and associate more accurately each piece of equipment with the particular patient on whom it is used, thereby reducing patient billing costs. The RFID system has also helped St. Luke's to save hundreds of thousands dollars annually, enabling staff to buy more items in bulk and earning bigger discounts.

'We recently checked in a $900,000 order of pacemakers and defibrillators. By buying in bulk, we saved 12 percent, or $127,000, on that order alone.'

David Strelow, the hospital's director of CV lab services

In this case, Saint Luke's Hospital deployed an RFID-enabled system for tracking operational process to manage inventory. In other words, by improving operational process, RFID management capability ultimately enhances healthcare structure and financial performance. In addition, macro environment and human resource have been taken into account during the implementation. We can therefore support our P3, P5, P7 and P9 of the research proposition.

5.2.36 Case Study 36: Nyack Hospital

Nyack Hospital deployed an RFID automated solution system to solve problems using a mobile phone with an RFID interrogator, tags attached to medication bottles and a web-based server that remotely manages an individual's prescription regimen. This system, provided by Leap of Faith Technologies, helps the facility monitors patients' medication compliance by following discharge from the heart unit. The solution for the systems' innovation is eMedonline. They were able to put the existing and emerging technologies together in an innovative way.

In this case, Nyack Hospital deployed an RFID-enabled system to track medication-taken process to deliver quality care. In other words, through improving operational and management processes, RFID management capability, combined with macro environment, physical and human resource, ultimately enhances healthcare clinic performance. We can therefore support our P3, P5, P6, P7, P9 and P10 of the research proposition.

5.2.37 Case Study 37: Geisinger Medical Centre

Geisinger Medical Centre is using an RFID system to help robots deliver medicine to patient-care units and provide a real-time identification of the person that sent and received each item.

The RFID-enabled robots travel facility delivers medications and equipment to departments throughout several buildings, which could save labour and improve working efficiency, but is of no help in delivering controlled medications, since regulations and the drugs' high value require greater oversight and thorough records regarding the person who sent and received them.

'Since the RFID system was installed, the hospital calculates that it is now 40 to 50 % more cost-effective than with human labour.'

Deb Templeton, Geisinger's VP of supply chain services

In this case, Geisinger Medical Centre deployed an RFID-enabled system by using RFID-enabled robot delivering system to securely transport drugs.

5.2.38 Case Study 38: Argentine pharmaceutical distribution company

Argentine pharmaceutical distribution company deployed an RFID system to track the buying and selling price of its medicines and expiration dates, ensuring that the drugs are properly billed, and no expired products are shipped to customers. Their reports showed a 40 % rise in its profit margins since it began using RFID technology.

RFID has helped them cope with this rapid expansion by enabling the tracking of each medicine container from the time it arrives at the warehouse until the drug is sold and shipped to a customer.

'While the profit margin improvement is significant, even more important is the increase in the safety of its products resulting from the greater visibility RFID affords.'

Federico van Gelderen, Axxa Pharma's executive director

In this case, Argentine pharmaceutical distribution company deployed an RFID-enabled system to track products to secure the drug supply. In other words, by improving tracking management process, RFID management capability ultimately enhances healthcare structure and clinic performance. In addition, supply chain context has been taken into account during the implementation. We can therefore support our P3, P4 and P10 of the research proposition.

5.2.39 Case Study 39: University of Pittsburgh team

University of Pittsburgh team has developed a system, in which an RFID tag would be affixed to an orthopedic implant, thereby enabling sensors to be built into the tag to track the device's health and use within a patient's body. Not only would the system track conditions inside the body surrounding the implant, but it could also identify the device itself in the event of a recall. Moreover, it could help verify that the implants were authentic, and not counterfeit. In addition, this system could be used to track the frequency of the implanted joint's movement, thereby enabling physicians to determine how well the patient was using that joint.

In this case, University of Pittsburgh team deployed an RFID-enabled system for tracking and monitoring process to secure the orthopedic implant.

5.2.40 Case Study 40: WellSpan Health's York Hospital

WellSpan Health's York Hospital has expanded its use of Wi-Fi RFID tags and computerized maintenance management software (CMMS) with real-time location system (RTLS) for tracking mobile assets. Identification and its associated location data are collected, processed and displayed in order to reduce the amount of time that the staff spent tracking assets, thereby saving time and allowing staff to perform their jobs more effectively.

In this case, WellSpan Health's York Hospital deployed an RFID-enabled system to improve the tracking process of assets. In other words, through improving tracking operational processes, RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure performance. In addition, during the implementation of this project, trading partner and human resource have been taken into account. We can therefore support our P2, P3, P4, P7 and P9 of the research proposition.

5.2.41 Case Study 41: Wholesaler Max Pharma

Wholesaler Max Pharma has deployed an RFID system to track medicines internally and the company reports, encouraging it to move to the rollout phase, which further encouraged more suppliers and pharmacies to take advantage of the technology as well.

The visibility of products within its facilities has been improved to store data regarding products and their shipping time and dates. In addition, RFID-based track-and-trace solution could also monitor temperatures and other sensor data. Therefore, the benefit of employing RFID system is guaranteed for customers since their products' transportation is visible and monitored along the supply chain.

In this case, Wholesaler Max Pharma deployed an RFID-enabled system to improve products tracking process in order to secure the drug supply. In other words, through improving tracking operational and management processes, RFID management capability and RFID infrastructure flexibility, combined with industry character, trading partner, macro environment, human and physical resource, ultimately enhance healthcare structure performance. We can therefore support our P2, P3, P4, P5, P6, P7, P9 and P10 of the research proposition.

5.2.42 Case Study 42: Tift Regional Medical Centre

Tift Regional Medical Centre is employing a Wi-Fi-based system to track the locations of documents, crash carts and other assets, as well as the temperatures of refrigerators. The system leads to fewer nurses, which previously had to manually write down temperatures of refrigerators throughout each day.

In this case, Tift Regional Medical Centre deploys an RFID-enabled system in tracking process to improve workflow.

5.2.43 Case Study 43: Oregon Clinic

Oregon Clinic is using an RFID system for automatic access to electronic records as they approach to a computer to save time and increase the security of files.

It is calculated that the process consumes many hours every year, involving input passwords before each task, wait for them to be accepted and then sign out again when finished. This system not only maximizes the workflow, but also helps the clinic comply with the government's Health Insurance Portability and Accountability Act (HIPAA), by not leaving files open, which could result in security breaches.

In this case, Oregon Clinic deployed an RFID-enabled system for automatic medical record access processes, to secure medical records. In other words, by improving automatic access to operational and management processes with the RFID system, RFID management capability and RFID infrastructure flexibility enhance healthcare structure performance. In addition, industry character, macro environment human, organisational and physical resources have been taken into account during the implementation. We can therefore support our P2, P3, P4, P5, P6, P7, P8, P9 and P10 of the research proposition.

5.2.44 Case Study 44: Gador Laboratories

Gador Laboratories is using an RFID solution at one of its factories to track individual pharmaceutical products, and the pallets on which the products are transported. Besides, it also protects against counterfeiters in the supply chain between its facility and retailers. It proves that RFID system could provide Gador with accurate and timely data regarding the shipped products.

In this case, Gador Laboratories deployed an RFID-enabled system for tracking products process to secure drug supply. In other words, by improving tracking process, RFID management capability and RFID infrastructure flexibility, combined with supply

chain context and human resource, ultimately enhance healthcare structure performance. We can therefore support our P2, P3, P4, P7 and P9 of the research proposition.

5.2.45 Case Study 45: Frisbie Memorial Hospital

Frisbie Memorial Hospital is using an RFID system to track equipment and the temperature of medicine that emergency medical technicians take with whenever an ambulance is dispatched. In addition, the hospital uses GPS technology to track vehicle's location and speed in real time to determine if a piece of equipment is left behind by a vehicle's crew and the temperature inside a medicine bag.

Within several months after the automated system was installed, the system has already provided a return on investment by ensuring that equipment does not get lost, and that medication is returned to cold storage before it is spoiled.

In this case, Frisbie Memorial Hospital applied an RFID-enabled system for tracking processes to improve workflow and secure the drug. In other words, by improving tracking processes, RFID management capability enhances healthcare structure and financial performance. In addition, physical resource has been taken into account during the implementation. We can therefore support our P3, P6 and P10 of the research proposition.

5.2.46 Case Study 46: Mission Hospital

Mission Hospital is using a hybrid infrared (IR) and RFID-based real-time location system to help manage equipment. After the system's installation, utility of equipment for tagged items rose 7 %, whilst the rate of lost or stolen devices dropped from 13.8 % to zero. In addition, nurses show greater work satisfaction as equipment and tools needed to treat patients are kept more readily and can be easily accessed. With material-management solutions and services, staff is released from tracking the location and condition of its medical equipment.

In this case, Mission Hospital deployed an RFID-enabled system for tracking assets process to improve efficiency. In other words, through improving item-level tracking process, RFID management capability and RFID infrastructure flexibility enhance

healthcare structure performance. In addition, trading partner, human and physical resource have been taken into account during the implementation. We can therefore support our P2, P3, P4, P6, P7, P9 and P10 of the research proposition.

5.2.47 Case Study 47: Innsbruck University Hospital

Innsbruck University Hospital has used two RFID-based alarm systems to track workers and respond to alarms. One system is used by emergency-room staff, while the other is intended for attendants at the psychiatric ward. Both deployments rely on Wi-Fi enabled RFID tags and real-time location system (RTLS) software.

The emergency-room systems, which are identical, run on the hospital's existing infrastructure and RTLS, are designed to enhance the security and quality of clinical workflows. Hospitals can also utilize the platform to track expensive medical equipment and reduce wait time for patients.

'Due to severe legal restrictions and challenging reservations regarding privacy of employees in Austria, the device is not assigned to an individual person.'

Andreas Gereke, the head of innovation and research solutions

In this case, Innsbruck University Hospital deploys an RFID-enabled system by tracking process to enhance workflow. In other words, through improving tracking process, RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure performance. In addition, industry character, human and physical resource had been taken into account during the implementation. We can therefore support our P2, P3, P4, P6, P7, P9 and P10 of the research proposition.

5.2.48 Case Study 48: Apollo Hospital

Apollo Hospital is deploying a RFID-based RTLS that enables staff to redirect patients through diagnostic procedures, thereby improving workflow of patients through the process. Moreover, this system offers data to adjust the future schedule for the facility to improve traffic flow. Meanwhile, since Apollo implemented this system, other Indian health-care companies have been offering similar programs as well.

In this case, Apollo Hospital deployed an RFID-enabled RTLS system to improve workflow by tracking process. In other words, through improving tracking process, RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure performance. In addition, competitive environment and physical resource had been taken into account during the implementation. We can therefore support our P2, P3, P4, P6, P9 and P10 of the research proposition.

5.2.49 Case Study 49: Hartford Medical Group

Hartford Medical Group is using a RFID/infrared technology to track the efficiency of medical visits and staff. The system was installed in a matter of hours, and could be uninstalled even more quickly. In fact, as the company reports, mobility is the whole point.

This system provided Hartford with a baseline of analytic data regarding an overall understanding on its operations in respect to each centre's efficiencies before and after it installs a new electronic medical record system. The data showed that, on average, 40 % of a doctor's time is spent in examination rooms. Two questions exist here, how the remaining 60% is allocated, and whether there is a way to improve efficiency by increasing the percentage of time spent with patients.

In this case, Hartford Medical Group deployed an RFID-enabled system to identify efficiency by tracking process. In other words, RFID management capability ultimately affects healthcare structure performance through tracking processes. We can therefore support our P3, P6, P7 and P9 of the research proposition.

5.2.50 Case Study 50: South Carolina hospital

South Carolina hospital has deployed a RFID-based solution by GE Healthcare and RF Code for locating equipment and identifying the availability of beds.

This system could track assets and manage beds to prevent delays caused by a lack of information about bed availability. Since the asset system was in place, it only took 5 minutes for every nurse to seek equipment per shift, compared to the 21 minutes in the past. In addition, by using the system the hospital was able to calculate the utilization

rate of existing equipments, the time spent for finding equipments, the distribution of biomedical devices and the process for rental management.

In this case, South Carolina hospital deployed an RFID-enabled system to improve efficiency by tracking process. In other words, through improving locating process, RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure performance. In addition, physical resource had been taken into account during the implementation. We can therefore support our P2, P3, P6, P9 and P10 of the research proposition.

5.2.51 Case Study 51: St. Gallen Canton Hospital

St. Gallen Canton Hospital has found that wristbands with 13.56 MHz passive RFID tags do not significantly interfere with the functionality of imaging devices, nor pose a risk to scanned patients wearing such wristbands.

The quality of the magnetic resonance imaging (MRI) was minimally affected by the RFID tag's presence, and was limited to the area of the skin on which it was attached. Furthermore, the tag had no effect on a computed tomography (CT) scan's image quality. Thus, RFID wristbands can safely remain on a patient as he or she undergoes diagnostic procedures.

In this case, St. Gallen Canton Hospital tested RFID tags to enable RFID system implementation. RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure and clinical performance. In addition, physical resource had been taken into account. We can therefore support our P2, P3 and P6 of the research proposition.

5.2.52 Case Study 52: Grady Hospital

To improve surgical department efficiency, Grady Hospital has employed a real-time location system. Combined with other software, this system has raised the utilization rate of the facility's 16 operating rooms by 23%.

This system provided services that track patients' status as proceeds through surgical procedures and update the patient's status to staff, thereby improving hospital’s own processes in the surgery department.

In this case, Grady Hospital deployed an RFID-enabled system in patient tracking process to improve efficiency. In other words, through improving tracking process, RFID management capability ultimately enhances healthcare structure performance. In addition, human resource had been taken into account during the implementation. We can therefore support our P3, P7 and P9 of the research proposition.

5.2.53 Case Study 53: Union Hospital

Union Hospital is using a hybrid infrared (IR)/RFID hybrid system to enable Indiana hospital to pinpoint the location of its assets quickly. This system has reduced the time for the searching of equipment, eliminated the staff's tendency to hoard equipment and reduced the amount of rental equipment it required.

In this case, Union Hospital deploys an RFID-enabled system to improve efficiency by tracking asset process. Meanwhile, physical resource has been taken into account. We can therefore support our P6 of the research proposition.

5.2.54 Case Study 54: Ospedale Treviglio-Caravaggio

Ospedale Treviglio-Caravaggio has deployed an RFID system, combined with the existing Compuware Uniface platform to track patients’ locations. Meanwhile, staff could use this system to identify delays and document services received.

With the RFID system provided by Softwork, hospital personnel can immediately locate a patient. It also provides the hospital with a better understanding on patient flow in various departments, which can then be used to anticipate backups in specific areas.

‘RFID added value in terms of emergency patient management.’

Paola Visentin, Softwork's marketing and communication manager

In this case, Ospedale Treviglio-Caravaggio deployed an RFID-enabled system to track patient, thereby improving efficiency. In other words, by improving tracking processes,

RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure performance. In addition, human and physical resource had been taken into account during the implementation. We can therefore support our P2, P3, P6, P7, P9 and P10 of the research proposition.

5.2.55 Case Study 55: Blood Centre of Wisconsin

Blood Centre of Wisconsin and its partners will create a prototype RFID system for blood banks and hospitals based on the results of an earlier study. This project is supported by a $1.4 million government grant.

After the first phase of the study, they found out that high-frequency (HF) RFID technology would bring blood band with safe-to-use and financial benefits. It showed that as fewer blood products expire before they could be located and used, there were less manual tracking of the movement of blood products and wastage resulting to saving. Next, this latest phase will be run by the same organisations and used as models of different sizes and methods for managing blood products and transfusion.

In this case, Blood Centre of Wisconsin deployed an RFID-enabled system in the tracking and monitoring processes to enhance efficiency and financial benefit. In other words, by enhancing operational and management processes, RFID management capability and RFID infrastructure flexibility ultimately enhance healthcare structure and financial performance. In addition, physical resource, human resource, industry characters, trading partner and macro environment had been taken into account during the implementation. We can therefore support our P2, P3, P4, P5, P6, P8, P9 and P10 of the research proposition.

5.2.56 Case Study 56: Virginia Mason Clinic

Virginia Mason Clinic is using a hybrid RF-IR system provided by Versus Technology to quickly track the locations of patient and staff. This system helps the clinic pinpoint the room in which a physician examines patients, associate the physician with patients, and indicate how long they are in the examining room together, which helps the clinic analyze doctors' time spent with patients, and determine spare rooms for the improvement in efficiency.

Howard Memorial Hospital deploys a hybrid RF-IR system for tracking and locating patients and staffs to enhance operational efficiency. In other words, by improving healthcare operational processes, RFID management capability and RFID personnel expertise ultimately enhance healthcare structure performance. In addition, human and physical capital resource had been taken into account during the implementation. We can therefore support our P1, P3, P6, P7 and P9 of the research proposition.

5.2.57 Case Study 57: Howard Memorial Hospital

Howard Memorial has employed a ZigBee-based RFID system to monitor the location and condition of pricey equipment throughout its campus. This system enables to track where items are located, when they require repair, cleaning, or removal from the buildings. In other words, RFID management capability ultimately enhances healthcare structure performance by improving healthcare management process. In addition, human and physical capital resource had been taken into account during the implementation. We can therefore support our P3, P6, P7 and P10 of the research proposition.

5.2.58 Case Study 58: New York Medical Centre

New York Medical Centre has employed a Wi-Fi based RFID solution to track the location of its emergency equipment, as well as the temperatures of drugs and tissue samples in 100 refrigerators. This system enables to locate items quickly and improve asset visibility, thereby providing greater productivity, equipment utilization and OR throughput.

‘We are saving a little bit of time for a lot of people, and we know that the staff now has more time to focus on other areas of their jobs, such as direct patient care.’

Mark Zeman, SUNY Upstate's associate administrator of integrated materials and technical support

In this case, New York Medical Centre deployed a Wi-Fi based RFID system to enhance operational effectiveness by tracking and monitoring emergency equipment and temperatures of drugs and tissue. In other words, by improving operational and management processes, RFID management capability, RFID personnel expertise and

infrastructure flexibility, combined with human, organisational and physical capital resource, ultimately enhance the structure performance. We can therefore support our P1, P2, P3, P6, P7, P8, P9 and P10 of the research proposition.

5.2.59 Case Study 59: Georgia Hospital

Georgia Hospital in southeast Georgia expends less than $400,000 per year to deploy a RFID-based RTLS to track its own assets, instead of paying a contractor to do it. This system could track the location and utilization of mobile hospital equipment, managing asset more effectively and at a lower cost. In addition, Hardy and other members of the asset management team play an important role during the implementation of this system.

In this case, Georgia Hospital deployed an RFID-enabled RTLS in management process to enhance operational efficiency. In addition, human capital resource has been taken into account. We can therefore support our P7 and P10 of the research proposition.

5.2.60 Case Study 60: Shady Palms assisted-living facility

Shady Palms assisted-living facility has deployed an RFID-based tracking system to alert staff members if a resident suffering from dementia attempts to leave the facility. In the process, they tested a wide range of tag types to avoid the situation in which people with dementia did not know why they are wearing a tag.

Bennett is enthusiastic about the RFID system, because through the implementation of RFID-based system, facility no longer has to be confined to a secured area with a lower cost.

'This RFID system makes sense because the costs of the system are easily covered.'

Robert Bennett, the facility's administrator

In this case, Shady Palms assisted-living facility deployed an RFID-enabled tracking system in management process to enhance operational effectiveness by tracking and monitoring resident. In other words, by improving operational and management processes, RFID management capability, RFID personnel expertise and infrastructure

flexibility, combined with organisational and human capital resource, ultimately enhance the structure and financial performance. We can therefore support our P1, P2, P3, P7, P8, P9 and P10 of the research proposition.

5.2.61 Case Study 61: Medicarte

Medicarte deployed an RFID-based system for identifying and tracking expensive drugs dispenses to customers in order to ensure that the empty packages cannot be reused by bogus pharmaceuticals.

This system was integrated with Medicarte's ERP software to confirm the patient's identity and determine whether the package matches the one that was originally issued to patient. In addition, this system also helped company to manage expiration dates and reduce both the manual mistakes involved and the potential for human errors.

'We closing the loop and ensuring that the empty package cannot be refilled with a counterfeit product that is then sold on the street.'

Juan Carlos Ramirez, ID link's director of business development

In this case, Purdue Pharma deployed an RFID-enabled system in the process of identifying and tracking drug dispenses to secure the drug supply. In other words, by improving tracking and operational processes, RFID management capability ultimately enhance pharmaceutical structure performance. In addition, supply chain context and physical resource had been taken into account during the implementation. We can therefore support our P3, P4, P6 and P9 of the research proposition.

5.3 Qualitative and quantitative results

From in-depth analysis of RFID-based mini cases, we summarise the results in terms of patient management, asset management and staff management. These categories are made based on the impacts in the various functional application areas of each case, such as, following the transcripts from cases 2, 4 and 5, respectively:

Implementation of an asset tracking solution brings benefits by optimising staff time and equipment utilisation (case 2).

RFID technology was employed in Southwest Medical Centre to track hernia meshes, thereby reducing the likelihood of expired and missing products (case 4).

An RFID-based solution was implemented to improve the inventory-management process, thereby reducing the time needed to locate teaching and training assets, and losses from theft and other reasons (case 5).

The asset management category, as described in the above transcripts, or similar with asset management or inventory management descriptions, enables the tracking of equipment and samples and the reduction of loss in each case. Therefore, we summarise the following cases related to asset management, as shown in Table 5.3.1, which represents almost 48% (see Figure 5.3.2) of total RFID applications in the area we analysed. Thereafter, we summarise cases based on the type of patient management, as shown in Table 5.3.2, in accordance with the description of monitoring or tracking of patients for better quality of care or patient safety, which represents 25% of the application area. Staff management with 17% of the total application area, focuses more on enabling management to optimise workflow. We have searched for information related to staff management to improve workflow and efficiency, then we have generalised these results as shown in Table 5.3.3.

Figure 5.3.1 shows the breakdown of healthcare cases by IT vendors (including SAP, Oracle and Cerner). A significant difference can be seen in the asset management group compared to RFID applications. General IT vendors tend to implement asset management systems in less than 3% of the total application areas, and implement staff management systems in more than 57% of the total. RFID vendors tend to implement asset management in 48% of the total, the largest percentage. Therefore, a significant characteristic of RFID can be seen through considering various modules implemented by both types of vendor.

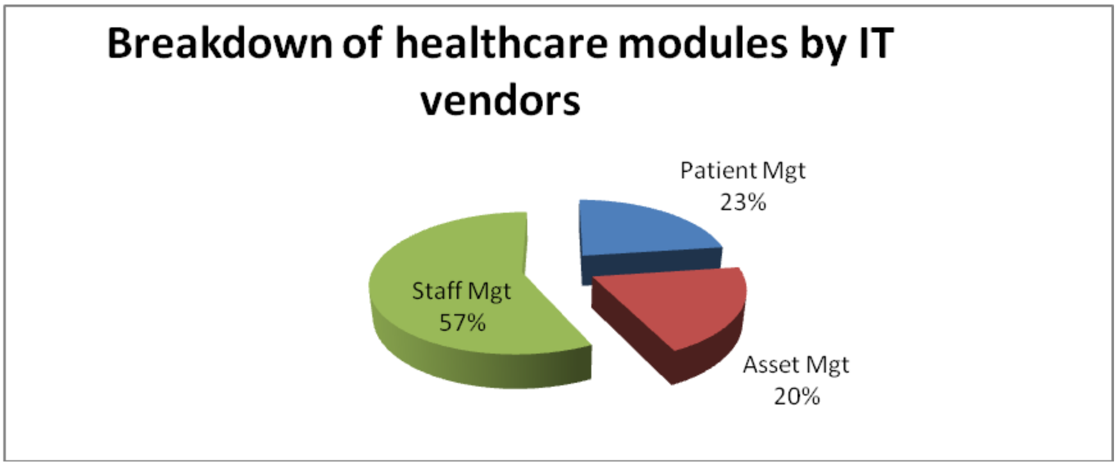


Figure 5.3.1 Breakdown of IT impacts on healthcare processes

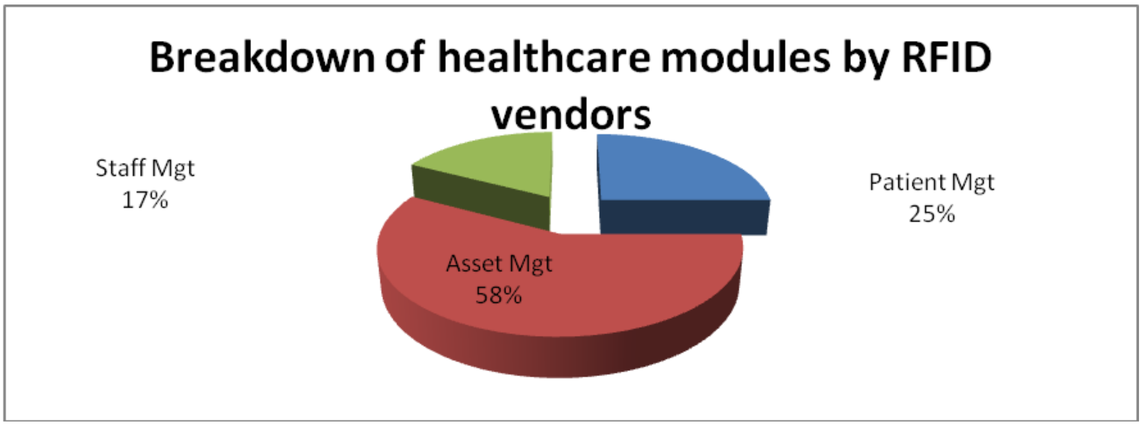


Figure 5.3.2 Breakdown of RFID impacts on healthcare processes

As shown in Figure 5.3.3, line one represents the functional application areas and line two refers to different vendors. As F > Fcrit and P-value < 0.05 in both lines (F is the value of the test statistic and Fcrit is the critical value), we proved that there is significant difference between healthcare functional application areas and different vendors.

Source of variation	F	P-value	F crit
Application areas	4.662446	0.022075	3.490295
Vendors	4.092204	0.025561	3.259167

Figure 5.3.3 Results of breakdown on modules and vendors

Table 5.3.1 Impacts of asset management on cases

Case No	**Case Study**	Project	Fundamental Challenges	RFID-enabled Application	Impacts of RFID Implementation
2	**Memorial Sloan-Kettering Cancer Centre**	Asset-tracking system	Manual processes Line of sight required	Inventory management	Financial rise Reducing the amount of lost equipment Optimising staff time and equipment utilisation
4	**Integris healthcare provider**	RFID-enabled inventory management	Manual processes for inventory management	Inventory management	Increased ROI Order replacements in real time
5	**Paul L. Foster School of Medicine**	RFID-enabled inventory management system	Manual processes for inventory management	Inventory management	Inventory operational process efficient reducing cost
6	**The Lahey Clinic Medical Centre**	Real-time locating system	Wasted time searching for a medical device	Tracking of assets	Improving operational efficiency
10	**Nice University Hospital**	Tracking surgical samples	Manual, paper-based traceability process Time-consuming and error-prone	Identify specimens Tracking of samples	Traceability and security of samples
13	**Intermountain’s Mckay-Dee Hospital Centre**	RTLS	Time-consuming	Tracking of assets	Increase efficiency
15	**University of Texas Southwestern Medical Center**	RFID-enabled tracking system	Paper-based purchase forms Stock tracking time	Tracking of product supply Inventory management	Real-time tracking of products

					Improved inventory management
18	**Memorial Hospital Miramar**	RTLS	Paper-based processes	Tracking and monitoring of equipment and patients	Improved workflow High-quality healthcare
20	**Taipei Minicipai WanFang Hospital**	RFID-based emergency room observation system and medical auditing system	Unsatisfactory performance in emergency room	Emergency management and medicine inspection	Improved treatment quality
24	**Jena University Hospital**	RFID-enabled tracking system	Dispensing errors	Tracking of medical producers	Improved security Improved pharmacy management
25	**Royal Wolverhampton Hospital**	RTLS		Tracking location of patients, staff and equipment	Improved efficiency
27	**El Camino Hospital**	Automated pharmacy system	Manual prescription Risk of error	Medication tracking Inventory management	Improved inventory management Improved accuracy
28	**Vanderbilt Children's Hospitals**	Real-time tracking system	Manual processes	Location of asset tracking Utilisation tracking	Prevented loss of equipment Reduced medical error rate
29	**Purdue Pharma**	Drug management system		Counterfeiting and diversion of drugs	Secured drug supply
30	**Children's Hospital Colorado**	RFID-based temperature monitoring system	Labour-based monitoring	Monitoring the temperatures of blood-related containers	Reduced temperature fluctuation Safer
31	**Sacred Heart Medical Centre**	RTLS	Manual management of pump usage	Tracking of assets	Increased ROI Improved workflow
32	**North Carolina Hospital**	Blood cooler tracking system		Tracking of blood coolers' condition	Ensure coolers do not get lost

					Meet temperature requirement
33	**Medical Marijuana Companies**	RFID-based tracking system	Manual processes	Tracking the drug	Help producers meet state requirements
35	**Saint Luke's Hospital**	RFID-enabled inventory management system		Material management	Reduced cost Improved efficiency and accuracy
37	**Geisinger Medical Centre**	RFID-enabled robot delivering system	High-value pharmaceuticals could not be trusted to robots	Deliver medicine	Labour saving Improved workflow
38	**Argentine pharmaceutical distribution company**	Pharmacy tracking system	Rapid expansion	Tracking of drugs	Increased profit margins Increased safety of products
40	**WellSpan Health's York Hospital**	RTLS	Time-consuming, tedious task	Tracking mobile assets	Saving time Improved efficiency
41	**Wholesaler Max Pharma**	Medicine tracking system		Tracking of medicines Monitor temperature	Visibility of products
42	**Tift Regional Medical Centre**	RTLS	Manually checking temperatures within refrigerators	Identifying location of assets	Improved workflow
44	**Gador Laboratories**	Pharmacy tracking system		Tracking of drugs	Against counterfeiters Secure drugs supply
45	**Frisbie Memorial Hospital**	RFID-based tracking system	Manual processes	Track equipment and temperature of medicine	Increased ROI Secure drugs
46	**Mission Hospital**	RTLS	Manual processes	Manage equipment	Increased equipment utility rate Patients' satisfaction

53	**Union Hospital**	Hybrid infrared (IR) /RFID hybrid system	Labour-based searching	Tracking of assets	Improved efficiency
57	**Howard Memorial Hospital**	ZigBee-based RFID system	Manual tracking	Monitor location and condition of high-priced equipment	Improved efficiency
58	**New York Medical Centre**	Wi-Fi based RFID system		Track location of emergency equipment	Enable location of items quickly Improve asset visibility
59	**Georgia Hospital**	RTLS		Asset management	More effective Lower cost
61	**Mediarte**	Drug management system	Manual market medicine	Medicine management	Secure drug supply

Table 5.3.2 Impacts of patient management on cases

Case No	**Case Study**	Project	Fundamental Challenges	RFID-enabled Application	Impacts of RFID Implementation
1	**Pantai Hospital Ipoh**	RFID automates routine tasks	Growing patient load Chronic scarcity of skilled caregivers	Patient temperature monitoring and location tracking	Enabling administrators to provide quality patient care Improving operational process efficiency and accuracy
3	**Jacobi Medical Centre**	RFID-enabled patient ID system	Manual processes Labour-based access to	Workflow optimisation Patient identities	Improving operational efficiency and working conditions Increasing safety Less errors
7	**Netherlands Hospital**	Test three RFID applications simultaneously	Combine different RFID applications on one and the same infrastructure	Patient and staff tracking Medical equipment tracking Blood tracking	Optimise schedules Reduce supply-related cost Improving operational processes
8	**Lucile Packard Children's Hospital**	RFID-based tracking system	Manual processes	Tracking of babies Tracking of patients, staff and equipment	Preventing mistaken babies Improve efficiency
9	**Commonwealth Newburyport Cancer Centre**	Tracking patients and their charts	Selected the wrong medical charts	Patient tracking Automating processes	Deliver correct treatment to correct patient
14	**St. Vincernt's Hospital**	Patient tracing and real-time clinical information system	Volume of patients	Patient tracking	Improved quality of care Increased revenues

16	**Providence Saint Joseph Medical Centre**	Patient-tracking system		Patient tracking	Personalise visitors Improved services
17	**Mississippi Blood Service**	Blood product tracking	Shortages and distribution problems	Blood inventory management	Real-time information about blood product Improved efficiency
19	**Taipei Medical University Hospital**	Location-based medical service		SARA prevention and isolation	Improved patient and staff safety
21	**Show Chawn Memorial Hospital**	Intelligent digital health network		SARA prevention and isolation	Improved patient and staff safety Information sharing
22	**Koo Foundation Sun Yat-Sen Cancer Centre**	Specialised healthcare system	Manual checks for drug dispensing process	SARA prevention	Improved patient and staff safety
23	**Birmingham Heartland Hospital**	Safe surgery system		Surgery procedures	Improved efficiency Improved patient safety
26	**Curves International**	Personal training system		Automated health management for fitness	Motivational Customer's satisfaction
36	**Nyack Hospital**	Automated tracking system	Time-consuming and cumbersome	Tracking medication-taken processes	Improved quality of care
39	**University of Pittsburgh team**	Orthopaedic implant tracking system		Tracking of orthopaedic implant	Improved quality of care Against counterfeit
47	**Innsbruck University Hospital**	RTLS		Tracking for emergency room	Improved security Improved quality of care Improved workflow
51	**St. Gallen Canton Hospital**	Tested RFID tags		Interfere with functionality of imaging devices	Minimally affected No effect on CT

				Risk to scanned patient	
54	**Ospedale Treviglio-Caravaggio**	RFID-enabled tracking system		Tracking of patient	Better understanding of patient flow Better patient safety
55	**Blood Center of Wisconsin**	Blood bank tracking system	Manual tracking source of the inefficiency	Blood products tracking	Reduced waste Improved efficiency Increased security
60	**Shady Palms assisted-living facility**	RFID-based tracking system	Limited area	Dementia patient management	Provide secured areas

Table 5.3.3 Impacts of staff management on cases

Case No	**Case Study**	Project	Fundamental Challenges	RFID-enabled Application	Impacts of RFID Implementation
11	**Special Olympics**	RFID-based automating system	Paper-based work Time-consuming prone to errors	Automating registration process Information management	Improving information management Improving efficiency
12	**Intermountain Healthcare**	Automating tracking system	Time-consuming Prone to errors	Automating tracking laboratory samples	Increased efficiency Decreased variation in process
34	**The UC San Diego Moores Cancer Centre**	RFID-based tracking system		Track amount of time	Improved efficiency and accuracy
43	**Oregon Clinic**	Automated accessing system	Manual accessing processes	Automatically accessing electronic records	Automated access to files Improved security of files Meet government requirement
48	**Apollo Hospital**	RTLS		Tracking of patients	Improve the flow of patients
49	**Hartford Medical Group**	Tracking system		Track efficiency of medical visits and staff	Providing a baseline of analytic data regarding each centre's efficiencies
50	**South Carolina Hospital**	RFID-based tracking system	Lack of inpatient beds Hard to locate	Track assets and manage beds	Improved workflow
52	**Grady Hospital**	RTLS	Time-consuming	Patient status through procedures	Improved utilisation of operational room
56	**Virginia Mason Clinic**	Hybrid RF-IR system		Pinpoint room, locating patient and staff	Improved workflow

From the dataset obtained as shown in table 4.5.3, Spearman's Correlation Coefficients between the independent variables (including RFID management capability, RFID infrastructure flexibility, RFID personnel expertise, industry characters, trading partners context, macro environment, physical resource, human capital resource and organizational resource), and the dependant variables (operational and management processes as per the proposition) were calculated. As there is no dependent variable shown to be affected by multiple independent variables, there was no need to do a multi-variety analysis of the data. The results of these calculations are shown below:

Table 5.3.4 Evidence of relationships of the model

	IV / DV	RM	RP	RI	IC	TP	ME	PR	HR	OR
Correlation Coefficient	OP	.654**	.329**	.428**	.283*	.362**	.314*	.240	.428**	.237
	MP	.058	-.176	.082	-.017	.034	-.007	.059	.141	.093
Significance	OP	.000	.010	.001	.027	.004	.014	.062	.001	.066
	MP	.658	.175	.531	.898	.795	.955	.652	.279	.478

**. Correlation is significant at the 0.01 level (1-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

IV=Independent Variable; DV= Dependent Variable; OP=Operational Process; MP=Management Process; RM=RFID management capability; RP=RFID personnel expertise; RI= infrastructure flexibility; IC= Industry Characters; TP= Trading Partners Context; ME=Macro environment; PR=Physical Resource; HR=Human Capital Resource; OR=Organizational Resource.

The significant ($p<=0.05$) positive correlation coefficients, as shown in above Table 5.3.4, was between the relevant variables of the model, supported the P1,P2, P3, P4, P5, P7 of research propositions shown in Figure 3.3. More specially, the results supported the following: the more the organisations fulfil RFID capabilities, the better the healthcare processes achieved (P1, P2, P3); the more the organisations consider environment context, including industry characters, supply chain context and macro environment, the better the healthcare processes achieved (P4, P5); the more the organisations consider organisational context (human capital resource), the better the healthcare processes driven (P7). These correlation figures provided evidence of association between the constructs of the proposed model.

5.4 Discussions

According to the above results from the analysis of case studies, Table 5.4 was made to clearly show our proposition results, which provide the evidence that RFID capabilities, environmental and organisational contexts have played an important role in the development of the healthcare area through improving operational and management processes.

Table 5.4 Results of the proposition (from 61 RFID-based cases)

No	Proposition	Results	Case Study No	Counts (%)
P1	*Proposition 1 (P1): RFID personnel expertise has a positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level.*	Supported	2, 5, 6, 9, 10, 12, 17, 24, 34, 56, 60	11 (18)
P2	*Proposition 2 (P2): RFID infrastructure flexibility has a positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level.*	Supported	1,2,3,4,5,6,7,8,9,10,12,13,14,16,17,18,19, 20,21,24,25,32,40,41,43,44,46,47,50,51, 54,55,58,60	34 (56)
P3	*Proposition 3 (P3): RFID management capability has a positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level.*	Supported	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,1 9,20,21,23,24,25,26,29,30,31,33,35,36,38, 40,41,43,44,45,46,47,48,49,50,51,52,54, 55,56,57,58,60,61	50 (82)
P4	*Proposition 4 (P4): Competitive environment has a positive effect on environment context, which is positively associated with the impact of RFID at the process level.*	Supported	2,4,5,6,7,10,11,12,15,17,18,19,20,21,22, 23,24,25,26,29,32,33,38,40,41,43,46,47, 48,55,61	31 (51)
P5	*Proposition 5 (P5): Macro environment has a positive effect on environment context, which is positively associated with the impact of RFID at the process level.*	Supported	1,7,10,11,12,17,19,22,24,32,33,35,36,41,4 3,55	16 (26)
P6	*Proposition 6 (P6): Physical capital resource has a positive effect on organisation context, which*	Supported	1,2,3,5,6,8,9,10,11,12,14,15,17,18,20,21,	37 (61)

	is positively associated with the impact of RFID at the process level.		22,25,26,29,36,41,43,45,46,47,48,49,50, 51,53,54,55,56,57,58,61	
P7	*Proposition 7 (P7): Human capital resource has a positive effect on organisation context, which is positively associated with the impact of RFID at the process level.*	Supported	1,2,3,4,7,10,12,14,15,16,17,18,23,24,25, 26,31,35,36,40,41,43,44,46,47,49,52,54, 56,57,58,59,60	33 (54)
P8	*Proposition 8 (P8): Organisational resource has a positive effect on organisation context, which is positively associated with the impact of RFID at the process level.*	Supported	43,55,58	3 (5)
P9	*Proposition 9 (P9): Healthcare operational process improvement from RFID will have a positive effect on the performance at the organizational level.*	Supported	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18, 19,20,21,23,24,25,26,29,33,35,36,40,41, 43,44,46,47,48,49,50,52,54,55,56,58,60, 61	44 (72)
P10	*Proposition 10 (P10): Healthcare management process improvement from RFID will have a positive effect on the performance at the organizational level.*	Supported	2,4,5,10,14,15,16,18,22,23,30,36,38,41, 43,45,46,47,48,50,54,55,57,58,59,60	26 (43)

First, all three RFID capabilities positively affect healthcare processes and improve healthcare performance as they are interrelated. Specifically, RFID management capability (with 82% of the total), as shown in Table 5.4, provides a collection of processes in planning, decision-making, coordination and control, which are the primary necessities for implementation of an RFID system. RFID infrastructure flexibility is necessary due to the need for support in changing environments. According to the cases analysed, all of the healthcare organisations have implemented own information system already, whether bar coding, ERP or EHR, for service delivery 56% of them mentioned that RFID infrastructure flexibility positively impacts the implementation of RFID system compatible not only with the existing systems, but also with future systems. It exactly suggests that the factor of compatibility from Rogers' diffusion theory positively affect the adoption of an RFID technology in a healthcare organisation. RFID personnel expertise plays an important role as the deployment of RFID as an innovation

having to rely on intra- or extra-organisational experts. In the cases we have examined, about 18% of organisations clearly mentioned that they have developed RFID systems in collaboration with RFID solution vendors or experts.

All in all, RFID personnel expertise impacts both RFID infrastructure flexibility and RFID management capability, and both RFID personnel expertise and RFID management capability impact RFID infrastructure flexibility, thereby influencing healthcare processes.

Second, the social and organisational variables have to been taken into account when assessing the success or failure of RFID systems in hospitals, (Fisher and Monahan 2008). From the environmental perspective, the context of industry characters (with 28% of the total) and trading partners (with 41% of the total RFID applications in the area we analysed), drive the development of RFID technology, especially in the asset management module, usage upstream in the supply chain, which forces those downstream to develop. However, industry standards also have to be considered because of interference with other equipment in hospitals, which negatively impacts the adoption of RFID. The macro environment (with 26% of the total), as shown in Table 5.4, plays an important role in driving the adoption of RFID in the area of blood-related products due to their sensitive and temperature-related characteristics and in infectious diseases prevention through distance tracking and monitoring provided by RFID technology.

Third, in the organisational context, physical capital resource (with 61% of the total RFID applications in the areas analysed), as shown in Table 5.4, positively affects the adoption of RFID due to the requirements of this technology. The impacts of this factor are intangible and immeasurable. We have analysed this factor as an enabler considering managing of data. The implementation of an RFID technology has to rely on access to raw materials to fulfil its function; therefore, we believe that physical resources have a significant impact on the adoption of RFID technology in the healthcare sector. The implementation of an RFID system affects human capital resources (with 54% of the total), as shown in Table 5.4, which mainly reflects users' satisfaction. Organisational resources (5), as shown in Table 5.4, relating to organisational structure, policies and work practices, have less effect on our results,

because the adoption of technology is affected by external and environmental drivers rather than internal organisational resources.

The results indicate close relationship between RFID capabilities and healthcare performance. Healthcare organisations' implementation of RFID technology was always analyzed from the aspects of patient management, asset management and staff management. Compared to other IT technology, RFID technology has been implemented to a great extent in the asset management healthcare module as the technology can improve operational and management healthcare processes, ultimately impacting healthcare performance.

5.5 Conclusion

This Chapter introduced the qualitative and quantitative data analysis adopted in this study and presented results from the analysis of 131 case studies, including in-depth analysis of 61 RFID-enabled healthcare applications. From analysing, we have clearly found that RFID capabilities combined with the environmental context (including industry characters, the supply chain context and macro policy) and the organisational context (including physical and human resource) can enhance operational and management healthcare processes, ultimately influencing healthcare performance.

6 CHAPTER 6: CONCLUSION

6.1 Introduction

In this context, through the study of relevant background knowledge, the main drivers and obstacles will be identified to advance the development of RFID in healthcare. Application areas are also identified according to functionalities; the potential benefits brought by RFID technology in hospitals support tracking and better managing patients, staff and assets. Furthermore, theories of diffusion of innovation and the TOE framework are introduced for examining the factors that affect the adoption of RFID technology. Based on the above, we reach the results from the analysis of 131 case studies, including 61 cases analysed in depth. Table 5.4 was created to clearly show our proposition results, which is evidence that RFID technology has played an important role in the development of the healthcare area through improving operational and management processes. In the final Chapter, we summarise research findings regarding all the research questions, and then present contributions and implications, the obstacles encountered when we were carrying out this research and outlined future research.

6.2 Summary of key findings

The purpose of this research is to examine the factors affecting the adoption of RFID technology in the healthcare area on an organisational level and identify potential functional application areas for RFID technology. Fisher & Monahan have pointed out that when assessing the success or failure of RFID systems in hospitals, social and organisational variables have be taken into account (Fisher and Monahan 2008). Therefore, we examine these factors in accordance with the TOE framework whilst combining the organisational and environmental contexts. To achieve our goal, we have conducted an in-depth analysis on 61 cases. Table 5.4 has clearly shown our proposition results. Next, we will conclude our key findings by answering the questions we presented in Chapter 1.

Research Question 1: What are the drivers and challenges affecting the development of healthcare?

IT has a significant impact on the healthcare industry. Implementation of IT has transformed the way healthcare services are delivered. Apart from the technological

factors, social factors such as the ageing population, political factors and sector factors also drive the development of healthcare to be of high quality, accessible and affordable.

On the other hand, the development of healthcare is facing many challenges. Through the analysis of case studies, we summarise these challenges from three perspectives: asset management, patient management and staff management.

Asset management, inventory management and searching for equipment occupy a large proportion of the time during the manual processes. Because it is hard to anticipate an exact product that might need to be used over and above prescribed inventory, it contributes to inventory wastage reflected in the lowering of economic performance.

From the patient management perspective, the lack of nurses or physicians, mismatching imaging results with patients and other medical errors lead to a decrease in clinical performance.

Paper-based work and the lack of staff management lead to long waiting time for patients, as well as poor treatment procedures as reflected in decreased structural performance.

Research Question 2: What is the impact of IT in terms of the value chain concept in the healthcare sector?

Most activities can be identified through analysis of the healthcare value chain. It is therefore possible to remove or reduce uncertainty within a supply chain in order to facilitate a more predictable response to changes in downstream demand (Rachel Mason-Jones 2000). IT pervades each link in the healthcare value chain due to the fact that each value activity creates and uses information. IT can support the management and process of accomplishing activities and provide the resource for integrating related technologies. IT also plays a vital role in linkages between activities from the control of information flow to the coordination and optimisation of each value activity in the chain. A fundamental improvement in the healthcare value chain will occur when IT is deployed to capture product information. This will allow upstream players in the value chain to analyse and forecast the entire length of the chain. On the other hand, IT must be easily integrated into practitioner work flow, because all these players provide digital

data to various storage and retrieval entities and receive information from different sources.

Research Question 3: What is RFID capability and what is the role of RFID capability in healthcare processes?

RFID technology can automatically and wirelessly collect and transmit real-time information to tagged persons or items (Fosso Wamba, Lefebvre et al. 2008), which can be used to optimise operations and support tracking of patients, staff, assets and other suppliers. RFID as a category of IT has the common characteristics of IT capability, which is able to create routine and standard transactional processes. RFID capability includes RFID management capability, RFID personnel expertise and RFID infrastructure flexibility. All three RFID capabilities positively affect healthcare processes, thereby improving healthcare performance due to three elements that are interrelated. RFID personnel expertise impacts both RFID infrastructure flexibility and RFID management capability, and both RFID personnel expertise and RFID management capability impact RFID infrastructure flexibility, thereby influencing healthcare processes.

On the other hand, RFID technology not only has the common characteristics of IT, but also has unique character, especially in asset management. We can observe a significant difference from comparison between Figure 5.3.1 and Figure 5.3.2; more asset management applications are used by RFID technology compared to other IT.

Research Question 4: How do the RFID capabilities improve healthcare processes, which ultimately impact healthcare performance?

The impacts of RFID implementation in healthcare have been discussed from three perspectives: clinical performance, structural performance and financial performance. More specifically:

- Improvements from the perspective of clinical performance

Physicians can obtain real-time and accurate information regarding patients' status (including medical treatment) by utilising RFID technology to improve tracking processes and prevent errors, thereby improving quality of care.

- Improvements from the perspective of structural performance

Hospitals deploy RFID technology to automate administrative-oriented tasks thereby relieving nurses for care-related work, which means that RFID capability enhances workflow efficiency by improving operational processes. In addition, the implementation of RFID-based asset tracking systems could optimise staff time and equipment utilization by eliminating manual processes. Finally, with the availability of RFID technology, physicians are able to attend to more patients compared to physicians working in a traditional healthcare setting.

- Improvements from the perspective of financial performance

RFID capability improves inventory management processes, reduces labour-based searches for assets and cuts losses from theft, thereby reducing costs.

Research Question 5: What are the roles of environmental and organizational contexts in an RFID-enabled healthcare area?

When assessing the success or failure of RFID systems in hospitals, the social and organisational variables have to been taken into account (Fisher and Monahan 2008). From the environmental perspective, industry characters and trading partners drive the development of RFID technology. Especially in the asset management module, usage from upstream in the supply chain forces downstream to develop it. However, industry standards also have to be taken into consideration, as interference with other equipment in hospitals. Furthermore, the macro environment or industry standards play an important role in driving the adoption of RFID in blood-related products due to their sensitive and temperature-related characteristics, and in infectious diseases prevention through distance tracking and monitoring provided by RFID technology.

In terms of organisational context, physical capital resource positively affects the adoption of RFID due to the requirements of this technology. The impacts of this factor

are intangible and immeasurable. We have analysed this factor as an enabler due to the consideration of managing data. The implementation of an RFID technology has to rely on access to raw materials to fulfil its function; therefore, we believe that physical resources have a significant impact on the adoption of RFID technology in the healthcare sector. The implementation of an RFID system has effects in human capital resource, which mainly reflect users' satisfaction. Organisational resource relating to organisational structure, policies and work practices have zero effect on our results, because the adoption of technology is affected by external and environmental drive rather than internal organisational resource.

Therefore, to understand the environmental and organisational contexts, it is critical to evaluate that RFID capability ultimately improves healthcare performance by enabling healthcare processes.

6.3 Contributions and implications

This research has benefited from a growing body of researches working on the adoption and use of RFID in healthcare settings and the enabling role of RFID for improving process performance. We have examined the factors affecting the adoption of RFID technology in the healthcare area at an organisational level, and identified the potential functional application areas of RFID technology. Furthermore, we have examined these factors in accordance with the TOE framework whilst combining the organisational and environmental contexts.

In addition, the analysis of RFID impacts in the healthcare sector is presented in terms of the process. The reason for using this method is the combination with the value chain concept, as previously mentioned, so as to remove and reduce uncertainty within a supply chain to facilitate a more predictable response to changes in downstream demand (Rachel Mason-Jones 2000).

The implications of integrating more technologies related to RFID technology are significant. Structural, clinical and financial performances can all be greatly improved with proper implementation of this technology. Through the integration of other IT and RFID, assets, patients, staff and medicine can be managed more effectively with lower overall operational costs and less time needed to locate patients and assets.

6.4 Limitations and future research

There are limitations in this study, as with all researches. This research introduces strong evidence in its analysis of variables that potentially affect healthcare processes, thereby improving healthcare performance. However, RFID is a fairly new topic in the healthcare and process areas. There are not many measurable and tangible results of RFID implantation in the healthcare area that could be accessed for our research. In addition, this research is a cross-sectional empirical study. Data collected are therefore a snap shot of the perceived evaluation from the cases studied.

Finally, there are some unsolved findings concerning organisational resources, relative advantage and complexity. Further investigation is necessary to explore the significance these factors might have in relation to adoption intention.

Future work that are proposed to:

- Extending this research methodology, combing qualitative and quantitative methods to provide more statistical evidence to support the findings.
- Conducting the same research focusing on specific functional application areas, and then individually draw conclusions for each specific area.
- Undertake further investigation on the effects of organisational resource, relative advantage and complexity on RFID adoption at the organisational level.

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8 APPENDICES

8.1 List of cases from IT vendor's sites

1. Sharp HealthCare

http://www.oracle.com/us/corporate/customers/customersearch/sharp-healthcare-1-servicebus-ss-1511171.html

2. Northwestern Memorial Hospital

http://www.oracle.com/us/industries/healthcare/northwestern-memo-pse-case-study-313420.pdf

3. University of Chicago Medical Centre

http://www.oracle.com/us/corporate/customers/customersearch/ucmc-1-sun-snapshot-445979.html

4. Moffitt Cancer Centre

http://www.informationweek.com/news/healthcare/clinical-systems/232601067?printer_friendly=this-page

5. Molina Healthcare, Inc

http://www.oracle.com/us/corporate/press/523400

6. Synergetic Systems Management LLC

http://www.oracle.com/us/corporate/customers/customersearch/synergetic-systems-1-adf-sptlgt-1523908.html

7. Medical University of South Carolina

http://www.oracle.com/us/corporate/customers/customersearch/med-univer-sc-1-server-storage-ss-1480759.html

8. The University of Texas MD Anderson Cancer Centre

http://www.oracle.com/us/corporate/customers/customersearch/md-anderson-1-primavera-ss-1451134.html

9. Vancouver Coastal Health

http://www.oracle.com/us/corporate/customers/customersearch/vancouver-coastal-1-goldengate-ss-1396855.html

10. Erlanger Health System

http://www.oracle.com/us/corporate/customers/customersearch/erlanger-health-1-peoplesoft-ss-1382614.html

11. Cancer Care Ontario

http://www.oracle.com/us/corporate/customers/customersearch/cancer-ontario-1-siebel-snapshot-418025.html

12. Wolf Medical Systems

http://www.oracle.com/us/corporate/customers/wolf-medical-1-sun-snapshot-349235.pdf

13. Presbyterian Healthcare Services

http://www.oracle.com/us/corporate/customers/presbyterian-1-siebel-crm-cs-343583.pdf

14. Amedisys, Inc.

http://www.oracle.com/us/corporate/customers/amedisys-1-psft-snapshot-326907.pdf

15. National Accounts, UnitedHealthcare

http://www.oracle.com/us/corporate/customers/national-accounts-crm-on-152149.pdf

16. CSAM Health AS

http://www.oracle.com/us/corporate/customers/customersearch/csam-health-1-db-snapshot-1514424.html

17. F. Hoffmann-La Roche Ltd.

http://www.oracle.com/us/corporate/customers/customersearch/f-hoffmann-la-roche-1-db-ss-1391940.html

18. McKesson Information Solutions

http://www.oracle.com/us/corporate/customers/customersearch/mckesson-information-7-ebs-ss-523403.html

19. Luzerner Kantonsspital

http://www.oracle.com/us/corporate/customers/customersearch/luzerner-kantonspital-1-idm-ss-517453.html

20. Leeds Teaching Hospitals National Health Service Trust

http://www.oracle.com/us/corporate/customers/customersearch/leeds-teaching-hospital-1-bi-ss-513892.html

21. Haema AG

http://www.oracle.com/us/corporate/customers/customersearch/haema-1-db-ss-460223.html

22. Eczacıbaşı-Baxter Hospital Supply Inc. (application)

http://www.oracle.com/us/corporate/customers/customersearch/eczacibasi-baxter-5-jde-snapshot-418959.html

23. Ambu A/S (application)

http://www.oracle.com/us/corporate/customers/customersearch/ambu-1-crm-od-snapshot-457175.html

24. Azienda Ospedaliera della Provincia di Lodi

http://www.oracle.com/us/corporate/customers/azienda-ospedaliera-1-ebs-snapshot-367667.pdf

25. National Health Service (NHS) Lothian

http://www.oracle.com/us/corporate/customers/nhs-lothian-1-sun-snapshot-365332.pdf

26. Klinikum rechts der Isar der Technischen Universität München(German)

http://www.oracle.com/us/corporate/customers/klinikum-rechts-1-sun-snapshot-334269.pdf

27. Farvima Medicinali(Italy)

http://www.oracle.com/us/corporate/customers/farvima-siebelcrm-snapshot-322168-ita.pdf

28. Sanding spol. s.r.o.

http://www.oracle.com/us/corporate/customers/sanding-spol-1-crm-snapshot-260968.pdf

29. Hospital District of Helsinki and Uusimaa (HUS) (Finland)

http://www.oracle.com/us/corporate/customers/hospital-helsinki-hr-case-study-190251.pdf

30. Heart Link Online N.V.-Belgium (Belgium)

http://www.oracle.com/us/corporate/customers/heart-link-online-nv-sun-snapshot-080625.pdf

31. Northern Ostrobothnia Hospital District (Finland)

http://www.oracle.com/us/corporate/customers/northern-ostrobothnia-hospital-rac-183655.pdf

32. Groupe Hospitalier du Havre (Fance)

http://www.oracle.com/us/corporate/customers/groupe-hospitalier-rac-snapshot-183547.pdf

33. Deutsche Rentenversicherung Knappschaft-Bahn-See (German)

http://www.oracle.com/us/corporate/customers/deutsche-rentenversicherung-app-176473.pdf

34. Medisch Spectrum Twente (Netherlands)

http://www.oracle.com/us/corporate/customers/medisch-spectrum-twente-ebs-172836.pdf

35. Singapore's National Electronic Health Records System

http://www.oracle.com/us/industries/healthcare/singapore-customer-fact-328620.pdf

36. Kuang Tien General Hospital

http://www.oracle.com/us/corporate/customers/kuang-tien-5-db-snapshot-394214.pdf

37. Fitness First (Australia)

http://www.oracle.com/us/corporate/press/302528

38. CARDINAL HEALTH

http://download.sap.com/download.epd?context=7535A56F9C0D5790D6F560D47C44FEC62E8193247FD519B974C74DEEEC3E9D436899F5C62D81AEACC41588C281491306B3882575D79FE4C6

39. USF Health

http://download.sap.com/download.epd?context=6ABE66A81D907843FE8542DBDD50D9863EBD1A594DE1D814D678EC82DADC1E48358029EEF0C5B43F13485D3EC228FC8CF19E9838D6415836

40. Sisters of mercy Health system

http://download.sap.com/download.epd?context=E8A7EA1A7B049032F3FFF12B4CD72A8C21C5D433583BB0EC4430A15148FCCEF385A7138898A39725424C223F25B63547DB426E09A0069BC5

41. Columbia Valley Community Health

http://download.sap.com/download.epd?context=D5D0B5A2751A76AB4BF501B35F5B27474AFA65B7793B36D9A8AAAB8DCAA3DABFF26BB6A7254A8309F5FDEC6A63C2E4B6B0D4391127443C17

42. marshfield clinic

http://download.sap.com/download.epd?context=563A347900D0173C25B1FDD15D46B869ADF97FC0254E934BEA30E5AFB14C33B4BBC921AC0F5BBF63C2D290FC94E08B0ED56A979B13287B1C

43. Beaumont Health System

http://download.sap.com/download.epd?context=9E9999BC152B30C6A39B2DB6F224D0896C353452E584FF719E11FEBD94F473DF342E10AC264DD0D227388D46C440AC840C31FB055C07ADE8

44. Emdeon

http://download.sap.com/download.epd?context=C3116272FF94EC894BA2922662361949BE33CFA63227935022F8DB203777BAC0E9CA8414DCDEBE6042027C15F199CDB4CC78FDB69D399AEE

45. Emergency Medical Associates (EMA)

http://download.sap.com/download.epd?context=01D6C781C1C4D1A48CC2F16E11E114B3215B6A15D23BCDEDB6F05A80983439AB9AB150913EE9C710073D9A247BF6B3C810F11BC39B0015CF

46. Cooper Health System

http://download.sap.com/download.epd?context=0F4659C380F4B83BED8F2B084D5CC7B725818EAD31867D6718D2A853926B46FBB7F954B2058ABADAFF11351C922134714CD1BF775212CC7F

47. Hikma Pharmaceuticals

http://download.sap.com/download.epd?context=7DFC49C33142DB7FA0FA44F1704C1C597D1D6AAFF00A7EBB3FDDE76BFA40051DF82D0377B38B2C32C3E314A1341FECF09DC89EF9A7EEAD92

48. Bon Secours Health System Ltd.

http://download.sap.com/download.epd?context=202C1FF2A9D549A8458139D26037C3020BDB67B94CC0259F6DE35F9F9CFA218F9132B0994710CC75A278CC47BD8E8B30D1B4787EE0FA041A

49. Agfa HealthCare

http://download.sap.com/download.epd?context=F791995682A4A2C6C7C1B9120F3CE2977DC1D59EBAD0D4B5086388D512A3956013584CE3337D595ABD41C339CFD73950CBFC7807C053BCAE

50. B. Braun

http://download.sap.com/download.epd?context=0E27FF54D8809EABD9C9006EF56344AAEBACAFA5EF47D19700B609BB37FFD4F2FABA24043067B901990B0365B51FA78A07F46E0324B34289

51. University Hospital Aachen

http://download.sap.com/download.epd?context=C4D720C2512A3FA40F05DABBAD74BAF8A104E2D751B47325B6A0D454954857EEDF5E6A303267D58990819E2A3DBDA80D8F10BC3DB934DFFE

52. Klinikum Mittelbaden ggmbH

http://download.sap.com/download.epd?context=302582CDA772EC6DF247A969B9285E51CD5A452CC15548AE5505A35055D9DCFE21F030AA5EE63B6D1ABB52B7FB3058F8177E162E8B070BEF

53. Orbis Healthcare Group

http://download.sap.com/download.epd?context=6C2884F080342315DF6538127DB2DD3F116AD06DB271BFEA97C6EF5EE233B32CB4109C1B3D9940C028AC6FE45D988928FCA94B97F3745AFC

54. Portsmouth Hospitals nHS trust

http://download.sap.com/download.epd?context=01D6EBC711115747743622A2DD3D05277FD1BF34448FD483F120F17219110A477F1917E7FED4BFCDDCABC8BFC4C4DBBE7F9CBB3C7DFC9B37F

55. Talar Made Ltd.

http://download.sap.com/download.epd?context=CBC12C1407EBCBC6B4BBB2B4E138C7E92F4CBA39933EC25A7C7E063CC5648E83BB6C84C93D60265B4D036638A0EE81F2024306E779195D83

56. Le Noble Age

http://download.sap.com/download.epd?context=4D3D65BB5744FA2DACD139FC5F6532B2601B2070BDD579DB48DF13CF7DE4A5F708A7F2FFD895082E7234FAFB75A51D8845F7A0BB744BB96E

57. Institut Català de la Salut (ICS)

http://download.sap.com/download.epd?context=83C3CB8D3D5D3C82C6A7F805FBB7F54D9DD8191753ECB3FEC1CB62AFED6270E44F2427D85BA07612514ADE27CAFCB16B84D5F9BF785A896D

58. Vinzenz Gruppe Krankenhaus- beteiligungs- und Management GmbH

http://download.sap.com/download.epd?context=184092A0C9C67130CACA2F101C74713DD248F0C8E6829980ED53F2C2E8E6E212DC5CBDF575A38D53BBF723E5B9E932F9B3E3571FD5C37C95

59. clifford Hallam Healthcare Pty Ltd

http://download.sap.com/download.epd?context=F3526862F31BB6C906A1FA73A47A8768CF9657B1ABAC8D248EE7D93F8ADAC985C16546C9B72A946AAF55598FB576F0BAD80E16BAD1BD66A4

60. Integria_Healthcare

http://download.sap.com/download.epd?context=F4A4E978A0E5101DB4277D22B5B2922CF004D02CF0113F6EFDBEA171BB07169D40693A63862D8C59AB3B4161EA1FB4628D738F75759AE362

61. Integramédica s.a.

http://download.sap.com/download.epd?context=A90BA1B72F61A2721DC58FDF263715B66C5E2AECA6132624C0427E16A50D62B40680E30C6AEFE46E32C779B134CDA8C4D7757056BFA54995

62. Bayfront Medical Centre

http://www.cerner.com/resource/Client_Stories/Bayfront_Medical_Center/

63. Carolinas Healthcare

http://www.cerner.com/solutions/client_stories/carolinas_healthcare_system/

64. Casa Grande Regional Medical Center

http://www.cerner.com/solutions/Client_Stories/Casa_Grande_Regional_Medical_Center/

65. Eastern Maine Health

http://www.cerner.com/solutions/Client_Stories/Eastern_Maine_Health_System/

66. Heartland Health

http://www.cerner.com/solutions/Client_Stories/Heartland_Health/

67. NCH Healthcare

http://www.cerner.com/solutions/Client_Stories/NCH_Healthcare_System/

68. Penn State Hershey Medical Center

http://www.cerner.com/solutions/Client_Stories/Penn_State_Hershey_Medical_Center/

69. WellSpan Health

http://www.cerner.com/solutions/Client_Stories/Wellspan_Health/

70. UAB Health

http://www.cerner.com/solutions/Client_Stories/UAB_Health_System/

8.2 List of cases from RFID vendor's sites

1. Pantai Hospital Ipoh

http://www.rfidjournal.com/article/view/7646

2. Memorial Sloan-Kettering Cancer Center

http://www.rfidjournal.com/article/view/9125

3. Jacobi Medical Center

http://www.rfidjournal.com/article/articleview/1537/1/655/

4. Southwest Medical Center

http://www.rfidjournal.com/article/view/4098

5. Texas Tech University Health Sciences Center

http://www.rfidjournal.com/article/view/7934

6. Lahey Clinic Medical Center

http://www.rfidjournal.com/article/view/2265

7. Netherlands Hospital

http://www.rfidjournal.com/article/view/3562

8. Lucile Packard Children's Hospital

http://www.rfidjournal.com/article/view/1372

9. Commonwealth Newburyport Cancer Center

http://www.rfidjournal.com/article/view/8479

10. Nice University Hospital

http://www.rfidjournal.com/article/view/8303

11. Special Olympics

http://www.rfidjournal.com/article/view/4956

12. Intermountain Healthcare

http://www.rfidjournal.com/article/view/5172

13. Intermountain's McKay-Dee Hospital Center

http://www.rfidjournal.com/article/view/5172/4

14. St. Vincent's Hospital

http://www.rfidjournal.com/blog/entry/2549/

15. University of Texas Southwestern Medical Center

http://www.rfidjournal.com/article/view/2049

16. Disney Family Cancer Center

http://www.rfidjournal.com/article/view/7729

17. Mississippi Blood Services

http://www.rfidjournal.com/article/articleview/2472/1/655/

18. Memorial Hospital

http://www.rfidjournal.com/article/view/7431

1. Pantai Hospital Ipoh

http://www.rfidjournal.com/article/view/7646

2. Memorial Sloan-Kettering Cancer Center

http://www.rfidjournal.com/article/view/9125

3. Jacobi Medical Center

http://www.rfidjournal.com/article/articleview/1537/1/655/

4. Southwest Medical Center

http://www.rfidjournal.com/article/view/4098

5. Texas Tech University Health Sciences Center

http://www.rfidjournal.com/article/view/7934

6. Lahey Clinic Medical Center

http://www.rfidjournal.com/article/view/2265

7. Netherlands Hospital

http://www.rfidjournal.com/article/view/3562

8. Lucile Packard Children’s Hospital

http://www.rfidjournal.com/article/view/1372

9. Commonwealth Newburyport Cancer Center

http://www.rfidjournal.com/article/view/8479

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16. Disney Family Cancer Center

http://www.rfidjournal.com/article/view/7729

17. Mississippi Blood Services

http://www.rfidjournal.com/article/articleview/2472/1/655/

18. Memorial Hospital

http://www.rfidjournal.com/article/view/7431

19. Taipei Medical University Hospital

http://www.sciencedirect.com.ezproxy.uow.edu.au/science/article/pii/S0925527307001995

20. Taipei Minicipai WanFang Hospital

http://www.sciencedirect.com.ezproxy.uow.edu.au/science/article/pii/S0925527307001995

21. Show Chawn Memorial Hospital

http://www.sciencedirect.com.ezproxy.uow.edu.au/science/article/pii/S0925527307001995

22. Koo Foundation Sun Yat-Sen Cancer Centre

http://www.sciencedirect.com.ezproxy.uow.edu.au/science/article/pii/S0925527307001995

23. Birmingham heartland hospital

http://ec.europa.eu/information_society/activities/health/docs/studies/rfid/rfid-healthcare_flyer.pdf

24. Jena university Hospital

http://www.sap.com/news-reader/index.epx?pressid=6329

25. Royal Wolverhampton Hospitals

http://www.rfidjournal.com/article/view/9268

26. Curves International

http://www.rfidjournal.com/article/view/4455

27. El Camino Hospital

http://www.emeraldinsight.com.ezproxy.uow.edu.au/journals.htm?issn=1477-7266&volume=25&issue=5&articleid=1949849&show=html

28. Vanderbilt Children's Hospitals

http://www.emeraldinsight.com.ezproxy.uow.edu.au/journals.htm?issn=1477-7266&volume=25&issue=5&articleid=1949849&show=html

29. Purdue Pharma

http://www.rfidjournal.com/article/view/4889

30. Children's Hospital Colorado

http://www.rfidjournal.com/article/view/9123

31. Sacred Heart Medical Center

http://www.rfidjournal.com/article/view/9234

32. North Carolina hospital

http://www.rfidjournal.com/article/view/8708

33. Medical Marijuana Companies

http://www.rfidjournal.com/article/view/8673

34. UC San Diego Moores Cancer Center

http://www.rfidjournal.com/article/view/8648

35. Saint Luke's Hospital

http://www.rfidjournal.com/article/view/8560

36. Nyack Hospital

http://www.rfidjournal.com/article/view/7631

37. Geisinger Medical Center

http://www.rfidjournal.com/article/view/7825

38. Argentine pharmaceutical distribution company

http://www.rfidjournal.com/article/view/7823

39. University of Pittsburgh team

http://www.rfidjournal.com/article/view/8538

40. WellSpan Health's York Hospital

http://www.rfidjournal.com/article/view/8584

41. Wholesaler Max Pharma

http://www.rfidjournal.com/article/view/8509

42. Tift Regional Medical Centre

http://www.rfidjournal.com/article/view/8384

43. Oregon Clinic

http://www.rfidjournal.com/article/view/8317

44. Gador Laboratories

http://www.rfidjournal.com/article/view/8305

45. Frisbie Memorial Hospital

http://www.rfidjournal.com/article/view/8239

46. Mission Hospital

http://www.rfidjournal.com/article/view/8091

47. Innsbruck University Hospital

http://www.rfidjournal.com/article/view/7972

48. Apollo Hospital

http://www.rfidjournal.com/article/view/7659

49. Hartford Medical Group

http://www.rfidjournal.com/article/view/7668

50. South Carolina hospital

http://www.rfidjournal.com/article/view/7547

51. St. Gallen Canton Hospital

http://www.rfidjournal.com/article/view/7442

52. Grady Hospital

http://www.rfidjournal.com/article/view/7427

53. Union Hospital

http://www.rfidjournal.com/article/view/7414

54. Ospedale Treviglio-Caravaggio

http://www.rfidjournal.com/article/view/3865

55. BloodCentre of Wisconsin

http://www.rfidjournal.com/article/view/5356

56. Virginia Mason Clinic

http://www.rfidjournal.com/article/view/5315

57. Howard Memorial Hospital

http://www.rfidjournal.com/article/view/5244

58. New York Medical Centre

http://www.rfidjournal.com/article/view/5013

59. Georgia Hospital

http://www.rfidjournal.com/article/view/7802

60. Shady Palms assisted-living facility

http://www.rfidjournal.com/article/view/4610

61. Medicarte

http://www.rfidjournal.com/article/view/9065