2012

Business Value of RFID-Enabled Healthcare Transformation Projects

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Publication Details

Abijith, A. and Fosso Wamba, S. (2012). Business Value from RFID-Enabled Healthcare Transformation Projects, Business Process Management Journal, Vol. 19, Issue 1.

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Abstract

Purpose – This paper aims to assess the business value realised from radio frequency identification (RFID)-enabled healthcare transformation projects as compared with other industries. The paper starts with a review of RFID technology in the healthcare industry and further extends to an in-depth analysis of mini-case studies collected from RFID Journal, a leading professional journal dedicated to RFID technology, in order to identify the major benefits of the implementation of RFID systems as well as its business value achieved. In addition, there is further analysis that is being carried out on other industries to have an overview of the benefits of RFID implementation.

Design/methodology/approach – Key findings on RFID systems are being obtained from a thorough review of case studies collected from the RFID Journal's database – which for this purpose, provided 20 cases from the healthcare industry and 49 cases from other industries–, so as to assess the business value of RFID-enabled healthcare transformation projects.

Findings – Implementation of RFID systems in healthcare resulted in enhanced automational, informational and transformational effects that helped to eliminate paper-based processes, manual processes and low visibility of patients, staff, equipments and data, etc. Such a transformation definitely gave rise to high financial performances, patient satisfaction and better decision quality on their treatments, which in turn provided a high control, co-ordination and planning of the healthcare organisation. Further, the results showcase the business value of RFID technology and the benefits gained within the healthcare sector, in comparison with other industries. Overall, our case analysis has indicated that implementation of RFID clearly produced evident effects at the process level of an organisation, thus leading to substantial gains at the organisational level.

Implications – The paper expands the current body of knowledge in assessing the business value of RFID-enabled organisational transformation in the healthcare sector and marshal's sufficient data on the overall benefits achieved by RFID implementation both in healthcare and in other industries. The results from this study may serve as a checklist for managers in the healthcare sectors who are looking towards implementing/exploring RFID technology. Additionally, this paper identifies potential areas for future research on RFID-enabled healthcare transformation projects.

Originality/Value – This paper delivers a review of case studies on RFID-enabled transformation projects and process innovations, mainly in the healthcare industry, albeit it extends to other industries. For this reason, a review on RFID technology is being discussed while 69 cases are being scrutinised. The results from this paper therefore provide significant evidence of RFID-enabled healthcare and organisational business value.

Keywords

Radio frequency identification, IT, Healthcare, Case Studies, Process Innovation

Disciplines

Physical Sciences and Mathematics

Business Value of RFID-Enabled Healthcare Transformation Projects

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1. Review of RFID

Radio frequency identification technology (RFID) in modern terms is defined as ''a wireless automatic identification and data capture (AIDC) technology'' (Fosso Wamba et al., 2008). The basic RFID technology consists of readers (beacons), tags (transponders) and end servers to process the information collected from the tags (Garfinkel and Rosenberg, 2006, Asif and Mandviwalla, 2005, Barjis and Fosso Wamba, 2010). Even

though RFID technology has been there for more than five decades and has been studied extensively (Fosso Wamba and Ngai, 2011, Fosso Wamba, 2011, Fosso Wamba et al., 2008, Asif and Mandviwalla, 2005, Garfinkel and Rosenberg, 2006, Polizzi, 2004, Finkenzeller, 2003), it is only in recent times that the technology has been of prime importance in healthcare. Due to its recent developments and the rapid decrease in costs of its infrastructure (Moscatiello, 2003, Sarma, 2001, Roberti, 2006), this technology has become a major technology for the future of the healthcare industry thanks to the niche advantages (toughness, user-friendliness, non obstructive property, value proposition) which it brings into the organisation (Garfinkel and Rosenberg, 2006). Furthermore, it brings efficiency by optimizing multiple business processes through the enhancement, automation or even elimination of existing processes and the provision of new intelligent and smart processes which can automatically trigger the actions to be performed (Fosso Wamba et al., 2008). As a result, there is a better incorporation of relevant and accurate flows of data into information systems, as well as business process optimization through automation, enhanced system-to-system communication and improved inter- and intra-organisational integration (Fosso Wamba 2011).

Studies show the following in the healthcare industry: (a) the objective of RFID is expected to automate the tracking of drug usage, medical supplies, medical equipments, in supply chain and inventory management, thereby reducing the work load of doctors, nurses and other hospital employees, and resulting in significant cost savings (VanVactor, 2008); (b) thanks to the implementation of RFID, there is an improved patient safety, an elimination of paper-based mechanisms, and consequently a reduction of medical errors and patient waiting time (Chowdhury and Khosla, 2007). Due to the potential market of RFID, healthcare investments in this technology are projected to rise from US$90 million in 2006 to $2.1 billion by 2016 (Harrop and Das, 2006). Moreover, RFID applications like WISH (wireless information systems for healthcare), which is already implemented in the United States to automate the work routines of healthcare professionals and reduce medical errors (Yu et al., 2006), are expected to upgrade the role of RFID in the future of healthcare as well as its benefits (see Table 1).

Table 1: Benefits of RFID in healthcare as summarised by Wen, Chao-Hsien et al (2010)

Benefits	Findings
Increased safety or reduced medical errors	Reduced misidentification of patients, medical articles, patient charts and images. Improved patient drug compliance by monitoring dosage taking process. Affection control during disease fashion.
Real-time data access	Provide real-time data access for health professionals via hand-held wireless PDA; e.g., contact history of patients, online laboratory data and radiology report.
Time saving	Identify empty beds >20 minutes earlier (67% of time). Identify a time reduction of more than 50% in the daily activities of hospital staff.
Cost saving	A 500-bed hospital could save $1 million annually. Reduce theft loss and unnecessary waste. Bon Secours Richmond Health System finds that RFID saves $2 million annually owing to a real-time location system.
Improved medical Process	Streamline patient admission to ICU. Process can be improved, so patients can have less waiting time and enhanced care experience.
Other benefits	Improve drug supply, resource utilization, and patient satisfaction.

Despite this potential of RFID-enabled transformations in healthcare, there is a shortage of studies on the current level of deployment of the technology in the healthcare setting. Therefore, the objective of this study is to bridge this knowledge gap, by answering the following research questions:

1. What is the business value of RFID-enabled healthcare transformation projects as compared with other industries?
2. What is the current deployment level of RFID technology in the healthcare sector compared to other industries?

In order to address these questions, this research draws on the extant literature on IT-enabled organisational transformation, the emerging literature on RFID technology and RFID-enabled healthcare transformations, as well as on an in-depth analysis of a series of mini-cases from the *RFID Journal*, a leading professional journal dedicated to RFID technology adoption and use in various sectors.

The rest of this paper is structured as follows: Section 2 deals with the proposed model, while Section 3 presents the research methodology followed by the sample excerpts of mini-case studies in Section 4, the results of the research are outlined in Section 5, with a discussion of key findings, Section 6 includes the research limitations, implications and future research directions and finally, Section 7 serves as the conclusion.

2. Proposed Model

Drawing on the emerging literatures on RFID technologies (e.g., (Curtin et al., 2007, Fosso Wamba et al., 2008, Wamba and Chatfield, 2009), on the impact of ITs at the process level (e.g., (Mooney et al., 1996, Davenport, 1993) and at the organisational level (e.g., (Mooney et al., 1996), as well as on our initial archive data analysis, the research model below is proposed in order to focus on the key impacts of RFID on the healthcare sector. This research model is based on six propositions that are identified as being able to significantly affect the healthcare sector through the adoption of RFID and process innovation. Further topics focus on the relationships between the six proposed propositions.

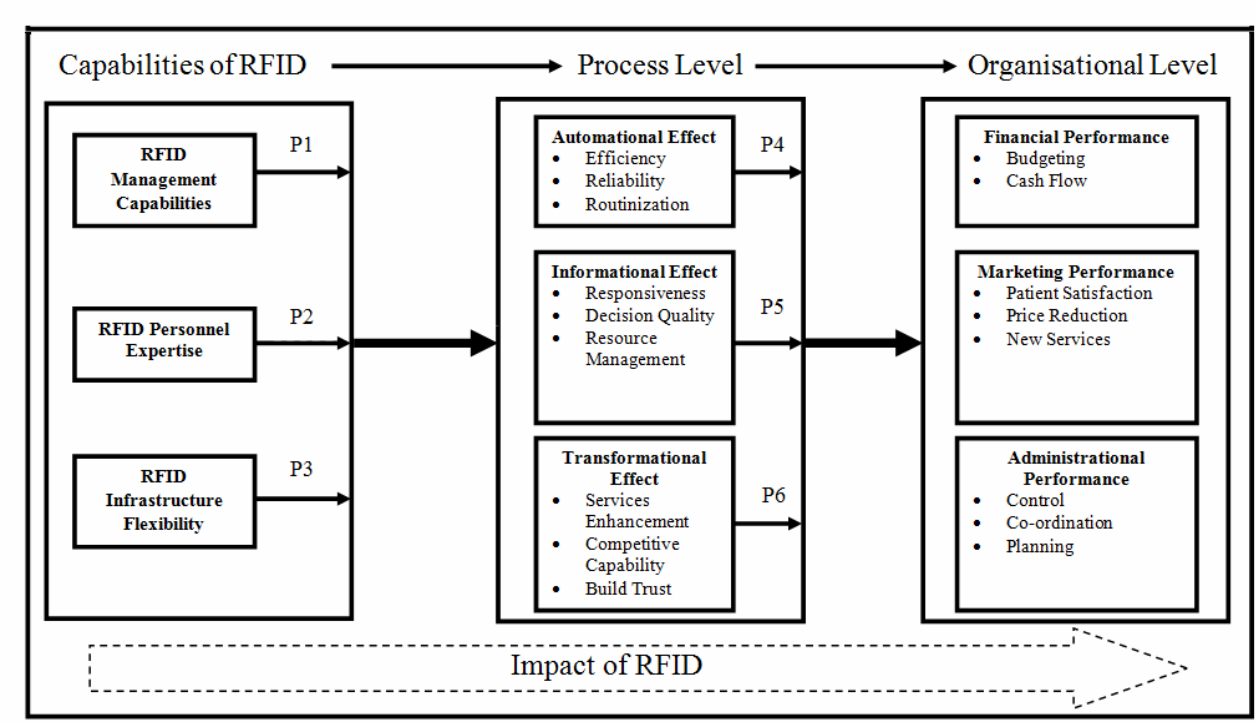

Fig 1: Research Model

2.1 Capabilities of RFID

Kim (2011) has recognised that the impact of ITs depends on the capabilities of IT an organisation possess. Capabilities of ITs can be categorized into IT management capabilities, IT personnel expertise and IT infrastructure flexibility. Since we are mainly focusing on RFID technology, our exercise will consist in identifying the capabilities of the said technology within healthcare organisations. In other words, we will be searching for the RFID management capabilities, the RFID personnel expertise, and RFID infrastructure flexibility. These three variables are taken into consideration because the RFID personnel expertise influences RFID infrastructure flexibility and RFID management capabilities, whereas RFID management capabilities, in turn, affect the RFID infrastructure flexibilities, and consequently the overall RFID capability of the organisation, RFID being considered as an IT (Kim, 2011). Since the three factors are interrelated, they will frame our primary research model.

Proposition 1: RFID management capabilities have a significant positive effect on RFID capabilities, which are positively associated with the impact of RFID at the process level

Capability of the organisation to manage its IT resources and transforming them into a business value is known as IT management capabilities (Peppard, 2007). Deployment of precise IT to correct business processes is one of the critical factors for a successful business process innovation (Melville et al., 2004). Thus, adequate management capabilities and deployment of RFID to the required business processes can have an effective impact in terms of automational, informational and transformational process. Better RFID management capabilities generate a better compilation of business processes and better decision quality, which in turn provide proper control, co-ordination and planning of the healthcare organisation.

Proposition 2: The RFID personnel expertise has a significant positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level

The fundamental necessities, such as professional skills, IT awareness, IT management, and the other facilities that are needed for an IT staff to perform the given tasks effectively in an organisation, are considered as the IT personnel expertise (Lee et al., 1995). They are required to understand the RFID elements of the healthcare organisations, such as RFID systems, tags, transponders, and receivers, etc., in order to better manage the resources of organisations. The relational knowledge of RFID by the IT staff also proves their ability to communicate and work together with people, which builds trust. This can indeed enable the IT staff to support the RFID infrastructure of healthcare organisations by providing better solutions which respond to changing business environments. Lack of RFID skills and expertise in organisations undermine their capability to swiftly redesign the process, thus failing to respond to the continuous changes in the markets (Rockart et al., 1996). Hence, healthcare organisations need highly skilled IT expertise in order to develop competitive RFID systems while aligning IT strategies with business strategies (Bhatt and Grover, 2005). Thus RFID personnel expertise can have a significant impact at the process level of the organisation.

Proposition 3: RFID infrastructure flexibility has a significant positive effect on RFID capabilities, which is positively associated with the impact of RFID at the process level

The capacity of organisations to develop, diffuse and support various information systems in an efficient manner in changing business environments and strategies (partnerships, mergers, strategic alliance etc.) is known as IT infrastructure flexibilities (Weill et al., 2002). A better IT infrastructure enables healthcare organisations to utilize IT resources efficiently and effectively to support structural redesigns. Therefore, it is critical for an organisation to have a flexible IT infrastructure to support RFID, which may be of valuable support in terms of competitiveness. Furthermore, with a flexible RFID infrastructure and integrated information systems, compatibility and modularity can be achieved to enhance service delivery by the healthcare organisation, thereby enabling strategic innovation in its business processes (Weill et al., 2002, Rockart et al., 1996). Consequently, this has an impact at the organisation's process level.

2.2 Process Level

Davenport (1993) had identified nine variables (automational, informational, sequential, tracking, analytical, geographical, integrative, intellectual and dis-intermediating) when assessing the impact of ITs. Mooney et al (1996) set out three complementary effects ―automational, informational and transformational― (which include all the nine variables) to evaluate an IT process impact. Since we are researching the impact of RFID at the process level, we have taken into account the three effects proposed by Mooney to frame our research model.

Proposition 4: The automational effect has a significant positive impact at the process level, which is positively associated with the impact of RFID at the organisational level

Automational effects refer to the efficiency perspective of value consequent upon the implementation of ITs (e.g. case of RFID) as a capital investment. Automational effects are primarily associated with operational processes (Mooney et al., 1996). Within this dimension, three significant values—efficiency, reliability and routinization—can be derived for the betterment of a healthcare organisation. Increase in

efficiency of a healthcare organisation leads to better administrational performance (control, plan and coordinate) and patient guiding processes, thus giving rise (Lillrank, 2003, Reijonsaari; et al., 2004) to service innovations, patient satisfaction (increases the reliability of the healthcare organisation) and financial performances through price reduction for the patients and profits for the organisations.

Proposition 5: The informational effect has a significant positive impact at the process level, which is positively associated with the impact of RFID at the organisational level

Informational effects are derived through the ability of ITs to collect, store, process and disseminate information within and among organisations. Hence, with RFID being the principal IT in our research model, the greater the ability to derive the informational effects from RFID systems, the better is the organisation in making quick and effective quality decisions. In this regard, the organisations are able to perform administrative tasks such as controlling, communicating and planning accordingly (Mooney et al., 1996). The informational effects can allow a better resource management of healthcare organisations, as the assimilated data are better controlled, processed and available in time for quick responsiveness (Hofflander, 1999). Therefore, the ability to utilize the information to make quality decision affects the financial and managerial stability of healthcare organisations.

Proposition 6: The transformational effect has a significant positive impact at the process level, which is positively associated with the impact of RFID at the organisational level

The transformational effect refers to the significance that is consequent upon ITs in order to support process innovation and transformation. Transformational effects focus on reengineering processes and redesigning organisational structures to better respond to factors like customer satisfaction, competitive market, improving quality, enhanced services, etc., by improving and merging the overall operational and management processes. Hence, with the ability of RFID systems to support process innovations and transformations, the three variables we are considering in this research model are services enhancement, competitive capability and build trust, as it is believed that these factors are important enablers in an organisation needing change in service delivery (service enhancements), response to market needs and developments (competitive capability) and trust building. Transformational effects are closely related in the support of healthcare transformation through process innovation and re-design.

Thus, overall we can believe that the deployment of RFID to the right organisation's processes will positively influences outcomes at the organisational level.

3. Research methodology

Archival data analysis has been adopted in this research due to the numerous distinct advantages it can bring to our study over other data collection methods (Yin, 1999). The prominence of archival analysis has been mirrored in the literatures (Kohli and Hoadley, 2006, Vikram and Caroline, 2011, Nir and Nikhilesh, 2011, Mehrjerdi, 2011) in the healthcare sector. Further, since RFID has been an emerging technology in the healthcare, archival analysis suits our research as it is aimed to explore the RFID-enabled innovation in healthcare. Therefore, in this particular research, greater part of the raw materials to be analysed comes from the mini-case studies published in the RFID Journal. It should be noted that several cases developed in the RFID Journal are concerned with other industries; to answer our research questions, we therefore retrieved all the

mini-cases on RFID technology, and they involved sectors such as: aerospace, consumer packaged goods (CPG), defence, healthcare, logistics, manufacturing, packaging and retail. As the prime journal on RFID-related topics, the RFID Journal is an outstanding "source for timely, objective news and information about RFID and its many business applications". All the retrieved cases were then analysed for them to be classified either as RFID-enabled healthcare mini-cases or RFID-enabled non-healthcare mini-cases. Overall, we obtained 69 mini-cases, 20 of which dealt with the healthcare category and 49 with other industries. The last stage of our process was an in-depth analysis of the various mini-cases to answer our research questions.

Some of the mini-case studies were concerned with global RFID adopters looking forward to transforming their businesses and healthcare. The reason behind choosing these cases from the RFID Journal's database is that the journal appears as one of the prominent information and publication sources for RFID technology, along with its current developments and applications. Moreover, the studied cases were published upon approval by the various organisations from the healthcare sector and other industries; and therefore they can provide verifiable facts including the contact details of the said organisations, the personals of their members who were involved in these cases, and some quotes from their interviews. This enhances the credibility of the information provided, to a great extent, and serves as the data to support the proposed research model and to further develop a detailed and in-depth analysis for each proposition in this research. Thus, we believe the archival data in the mini-case studies can illuminate the significance of RFID impacts in the healthcare sector and give us the first hand experiences from the organisational perspective.

4. Sample excerpts from the case study analysis

4.1 Case Study 1: Integris Journey to RFID

Integris Health is the largest healthcare provider in Oklahoma, USA. To perform their hernia operations, this health structure had to stock a large quantity of hernia mesh patches of various models, sizes and styles. As these implants were tracked manually, it resulted in costly errors and lost income.

In the hospital, nurses had to pull several hernia meshes from a surgical cart to make sure that a doctor has the correct size in the operating room; and sometimes the nurses failed to return the unused patches to the cart upon completion of the procedure. Furthermore, since the meshes were entered manually into a log, this led to low visibility in the tracking of hernia meshes, so as to check for expiration dates to return back to their manufacturer in time. Sometimes even the patients were not being charged for it. To overcome this issue, Integris saw the potential of RFID technology to overhaul the manual process in tracking hernia meshes and therefore minimize the probability of expired and missing products, and fetching a hard dollar return on investment.

Integris initiated a four-month pilot programme for hernia meshes tracking in its acute care facility, Southwest Medical Center, in Oklahoma. During the pilot programme, a cross-functional team was established; it comprised doctors, nurses and the IT staff who were all involved in the mesh product process in one point or another. In the pilot program, nurses were tagging hernia meshes and owing to bar code, they were able to extract information from its model, serial number and other data. The tagged meshes were stored in a smart shelf where an RFID interrogator was placed to continuously monitor and record each movement of the meshes.

'[Smart Shelf] It knew at any particular time what you had on that shelf,'
- Jerome R. Gardner, VP of Special Projects and Consulting Services.

According to Gardner, the estimated ROI at the pilot programme covered the cost of all lost and missing products in Southwest Medical Center, which amounted to more than US$111,500. On the other hand, the ROI linked to expired products was around $223,000, but the large, extrapolated ROI came from lost revenue, which was around $614,600. As the pilot was more centred on the ROI, it was important to consider also the soft benefits achieved; and according to Gardner, it was believed that RFID brought improved patient care and safety, and that this technology could help eliminate waste processes in the hospital.

'RFID could have a significant impact in health care by optimizing business processes, improving decision support, increasing security and safety, and improving communications.'
- Jerome R. Gardner, VP of Special Projects and Consulting Services.

From the above mini-case study, it is possible to identify the benefits of RFID in hospitals and the healthcare industry as a whole. Not only did the pilot programme testify that RFID can help solve the problem faced by Integris, but it also showed that the technology could give rise to huge financial gains for healthcare. Hence, it is important for the hospital's IT management to identify the capabilities so as to improve the IT Infrastructure of the hospital, notably by bringing a positive impact on automational, informational and transformational effects in the organisation. This mini-case study provides evidence to the support of propositions P4, P5 and P6 of the research.

4.2 Case Study 2: Nice University Hospital

Nice University Hospital is a multipurpose public healthcare institution located in Nice, France. Nice University Hospital maintains around 57,000 biological samples in its bio-bank at any given moment. The biological samples were traced and documented using manual and paper-based methods, which were very time-consuming and error-prone. The same also caused a loss of samples and compromised security, thus leading to poor patient care.

To address the above-mentioned issues, it partnered with Secure Communication Solutions (SCS) to bring innovative solutions such as an RFID-based system in order to provide better traceability and security of samples in its cryogenic facility —that stores surgical specimens for clinical and translational research— and launch a pilot programme (MISTRALS) with SCS and other partners. The objective of the pilot programme (MISTRALS) was to create a more efficient, accurate and secure way to identifying specimens within the bio-bank and track their movements as they moved from the hospital's pathology laboratory to the bio-bank.

'In the MISTRALS project, we aim to [address these challenges] by ensuring the traceability and timely delivery of the bio specimen samples.'
- Paul Hofman, Biobank Manager and one of the RFID pilot's leaders.

According to Hofman and Lagardère (IT manager), RFID technology was chosen over other technologies as it offered advantages such as tracking, lacked line-of-sight requirement, tags' ability to withstand cold temperatures and other harsh environments, long read-range capabilities, and the ability to track items in real time.

The outcome of the trial was admirable: not only did RFID eliminate the manual processes and saved more than 50% of time consumption, but also it enabled the firm to keep track of the samples and their movements, prevented the samples from getting lost and addressed other security issues.

'The traceability of information, both clinical and pathological data, will be excellent with this system,'
- Paul Hofman, Biobank Manager and one of the RFID pilot's leaders.

It is true that some concerns were raised during trial, such as the ability of RFID to work under sterilized environments, the fact that hand-held readers may not be ideal for the healthcare environment; yet the facility did not modify the trial as it did not affect the system performances though there were no hand-held devices that suited such an environment. Furthermore, the success of the pilot trail gave the hospital staff the confidence which they needed to further expand its uses to other areas and facilities.

'In 2011, we plan to expand the RFID technology [to] logistic processes,'
- Cécile Lagardère, IT Manager.

It emerges from this mini-case study that RFID technology can provide the healthcare industry with several advantages. They include the elimination of manual and paper-based processes, an improved traceability and tracking of the samples, a reduction of time consumption, and several other advantages leading to improved data security and management. Therefore, a proper use of the right IT in healthcare brings optimism as regards the technology's capacity to improve on automational, informational and transformational effects. So this mini-case study provides data to support propositions P1, P2, P4, and P5 of this research.

4.3 Case Study 3: Intermountain Healthcare

Intermountain Healthcare is a not-for-profit healthcare system covering 21 hospitals and more than 100 clinics in Utah and Southeastern Idaho. It is known as the 'Most wired' technology savvy healthcare organisation. Its latest innovations include the adoption of RFID not only to cut down the processing time in its laboratory testing, but also to automate the whole processes, with the aim to improve speed, accuracy and samples tracking.

'The business drivers for the automation system were our need to increase efficiency, decrease variation in process times and decrease staffing requirements to deal with staff shortages,'
- Sterling Bennett, Medical Director of the Intermountain Central Laboratory and Chair of the Urban Central Region department of pathology.

The Accelerator Automatic Processing System (AAPS), manufactured by Inpeco and marketed by Abbott Laboratories, was selected by Intermountain for the automation of laboratory testing. With the installation of the AAPS, automation was being carried out from the delivery of specimens to the lab analysers and storage facilities. The integration of AAPS brought in configurable middleware which helped in the management and tracking of the lab's data so as to improve operational efficiency, cut down processing errors and help make turnaround times quicker and consistent.

As reported by Bennett, automating the laboratory testing processes enabled Intermountain to boost its productivity without any additional staff; the automation process took less space compared to the manual processes where it is incumbent upon the staff to register the data of every sample, place the tube in the

centrifuge and put them in the analysers to begin the testing. Overall, the manual process was consuming 40 minutes extra time due to handoffs between the staff members.

'We were running out of space in our hospital labs, and knew that we would need to introduce new tests to keep up with the requirements of medical care,'
'We also have a labor shortage, and were looking for ways to do more testing with fewer people.'
'[Automation] has changed processes in that many routine, repetitive steps are now automated rather than being done manually.'
- Sterling Bennett, Medical Director of the Intermountain Central Laboratory and Chair of the Urban Central Region department of pathology.

Not only did automation trigger higher productivity by cutting down the time consumed for Intermountain, but also it decreased the cost per test done, enabled a predictable processing time and facilitated the location of samples. The new system also proved to handle multiple sample tube sizes, thereby enabling quicker sampling and easier integration of other components into the healthcare system.

'[Integration] this was important for us to maintain our enterprise-wide, multi-hospital laboratory analyser standards,' Bennett stated.

This mini-case study has the potential identifying the benefits which can be gained from RFID technology. From its findings, it appears that IT management capabilities, IT personnel expertise and IT infrastructure flexibility play a decisive role in the incorporation of ITs into healthcare while positively influencing automational, informational and transformational effects, thus leading to better marketing and administrational performance. Hence, this mini case study supports propositions P1, P2, P3, P4 and P5 of this research.

5. Results and discussions

Based on the detailed analysis of the cases, it was evident that RFID technology had the potential and wide range of options and services for the improvement of the healthcare sector. As an answer to our research Question 1, Table 4A (Appendix 1) summarizes all the mini-cases that were examined and simplifies the key findings from each case study within the healthcare sector; similarly, Table 4B (Appendix 1) summarizes all the mini-cases of the non-healthcare sector. The first column names the case study; it is followed by the challenges identified or the services needed by that particular organisation, next is the type/time period for implementation, and the cost of the overall project. The key findings and outcomes of RFID implementation are eventually recapitulated.

Table 4A and Table 4B (Appendix 1) evidently present the benefits reaped by the healthcare sector and other industries by implementing RFID technology, and at the same time they clearly show the business value of this technology when it comes to healthcare and organisation. The implementation of RFID technology in this regard actually transformed the process, which becomes intelligent and automatic, thereby eliminating many manual and paper-based processes. The main distinct features of RFID included flexibility, coupled with the ability of the RFID tags – to be tailor-made in monitoring temperature, vibrations, humidity, radiation– and light, the technology was used for: (a) tracking medications, equipments, staffs and patients; (b) monitoring real time vital signs of patients; (c) reducing medical errors and improving patient care quality within the healthcare

sector; and (d) monitoring from cheese ripening processes, food plates and automated check-ins, so as to control diamonds movements, defence assets and radioactive materials, etc. In short, a limit to the potential of the technology is only imagination. In the other hand, though the costs and ROI regarding implementation of RFID recently proved to be a major concern, there is clear evidence that many cases are dealing with quick ROI. As RFID technology is characterised by its capacity to anticipate the integration of intelligence into the existing organisations' processes in order to enhance the capabilities of such organizations in terms of identifying, tracking and tracing entities – together with other benefits such as cost savings that the technology can generate across the value chain –, RFID in healthcare is forecasted to become a $2.1-billion global business by 2016 (Tu et al., 2009); so this is eloquent proof that industries are willing to invest more and more in RFID technology. Although the benefits achieved at the process and at the organisational levels thanks to RFID implementation within healthcare is at par to those achieved in other industries, in terms of RFID deployment level in healthcare, it appears that the technology is still at the initial stage of penetration. From the 20 cases concerning healthcare that we have studied (Table 4A), RFID-related projects were still at the pilot stages in 8 cases (40%), while only 12 cases (60%) provided evidence of full implementations (Table 5, Appendix 2). In contrast, from the other 49 non-healthcare-related RFID transformations, only 2 cases (4%) had not gone beyond the pilot/trial stage, that is, 1/20 case in manufacturing and 1/15 case in the retail category. This noticeably indicates that even though the results show the potential of RFID to revolutionize the business process and bring in benefits, IT is still a weak component when it comes to healthcare.

5.1 Capabilities of RFID

The results obtained enable us to say that the capabilities of RFID in the organisation were critical, notably for the measurement of the impact of the technology. The same mini-case studies demonstrate that the three factors (RFID Management Capabilities, RFID Personnel Expertise and RFID Infrastructure Flexibility) were interrelated, and that many of the exiting IT resources of the organisation were integrated into its information system in order to treat the patients or provide any other healthcare services. Table 3 shows that the better RFID capabilities in healthcare, the better deployed are the RFID systems, and this also combines the existing IT resources with automated processes leads to better decision quality, which in turn provides a proper control, co-ordination and planning of the healthcare organisation. Though there was only modest evidence of the impact of Personnel Expertise on the knowledge of RFID by the organisations' personnel and staff's, quotes and lines from interviews helped us to evaluate the RFID awareness in such organisations. Furthermore, organisations are resorting to RFID vendors for RFID-related services and are sending their staffs for extensive training that may increase their awareness of and relational knowledge on RFID. The fact is that organisations are eager to efficiently develop, diffuse and support RFID systems so as to change their business environment and strategies, partnering with RFID solution providers and organisations which may help them redesign their processes for better competitive capability and service enhancements. The outcomes of the mini-case studies presented in Table 4A and Table 4B (Appendix 1) are evident proof that infrastructure flexibility also plays a crucial role in enabling organisations to realize the advantages of RFID. Such results are consistent with those obtained by Rockart and Earl (1996), Weill and Subramani (2002), and Byrd and Turner (2001). All these capabilities can lead to major impacts at the process level, which, if well managed, can lead to high levels of business value realized from RFID-enabled healthcare transformation projects.

5.2 Process Level

Deployment or adoption of RFID solutions in organisations was primarily aimed at eliminating paper-based and manual processes, the low visibility of patients, staff, equipments and data, and so on. The automational effect was the most realized advantage gained through RFID adoption (Table 3). Organisations definitely succeeded in eliminating many of their superfluous processes, reducing errors and improving other processes associated with their operations. The analysis of the outcomes of the mini-case studies indicated that the automational effect in the organisations significantly improved the efficiency, reliability and routinization of their business processes. This enhanced flow of business process enabled them to provide better services to patients while improving administrational performance. With regard to the informational effect, it was quite evident that most of healthcare organisations had developed their own information system for the collection, storage, processing and share of the information required. However, factors such as the increase in information and resources within organisations' systems, and economic constraints degraded this informational effect. As a result, the organisations were bound to continuously adapt to the challenges. Evidence from the mini-case study results illustrates that the capabilities of RFID enabled organisations to derive more informational effect and make quick and quality decisions created high responsiveness and better management the resources, while enhancing the administrational performances. It is largely seen from the mini-case studies that the re-engineering of processes and the redesign of organisational structures thanks to RFID implementation enabled changes and transformations that resulted in better preparedness for customer/patient satisfaction, improved quality, enhanced services, etc. In short, RFID-enabled transformation projects (healthcare and non-healthcare sectors) can lead to tremendous strategic and operational benefits.

6. Limits and Implications

6.1 Limitations

Any empirical research has limitations, so goes with this research also and it needs to be addressed to present opportunities in terms of future research. Large amount of analysis rely on the archival data from the mini-case studies, though it has provided significant amount of information there might have been a slight bias in the data contained in some cases as it comes from the healthcare organisations who have already implemented the RFID technology and might be of the organisations that had the resources and capabilities in the deployment of IT. Even if the sample size meets our research objectives, lack of statistical significance limits the generalization of the attained results. Therefore, further research towards increasing the sample size, field work, observations and interviews can give an enhanced statistical analysis and results which in turn can be used for generalization. The mini-cases were retrieved from only one dataset: RFID Journal. Future research may extend the search to others datasets including McKesson, Cerner, SAP, Oracle, and Microsoft. A similar methodology adopted by Brocke and Sinnl (2011) can also be considered: in their research on BPM, articles from BPM journals and BPM conferences were considered as the first point of analysis as it was assumed that most of the research problems on BPM were discussed therein; similarly, analysis and comparison can be done using articles from the RFID Journal dealing with RFID-enabled transformations in healthcare versus articles from major information systems and operations management journals such as the European Journal of Information Systems (EJIS), the Information Systems Journal (ISJ), the Information Systems Research (ISR), the Journal of AIS (JAIS), the Journal of MIS (JMIS), and the MIS Quarterly (MISQ)—which has been proposed by the AIS

senior scholars (Ngai and Wat, 2002). As a matter of fact, all these may also get an overview of current RFID technological implementations and adoptions.

6.2 Managerial and Theoretical Implications

From the managerial perspective, the key finding (e.g., automational effects, informational effects and transformational effects) from this research towards RFID implementations in the healthcare organisations can serve as checklist to healthcare managers looking towards implementing/exploring RFID technology. Effects of RFID technology at the organisational level (e.g., financial performance, marketing performance and administrational performance) analysed in this research can serve as a confidence for the higher management in the organisations looking towards investing in IT for their organisations. The data in the mini-cases may assist managers on where to concentrate their resources and efforts during the time of implementations. Overall, the results obtained can help the healthcare executives who are in a dilemma with "the next technological investments for their organisations".

The most important theoretical implication of this paper is that it adds to the current body of knowledge on exploring RFID-enabled business value in the healthcare sector. By, providing the key findings and benefits at the process and the organisational level of adopting RFID in healthcare, it expands the current knowledge in RFID-enabled organisational transformations in the healthcare. This study may serve as an opening for future research directions on RFID-enabled service innovation within the healthcare sector. Further, future research can be expanded on finding the interrelationships between IT management capabilities, IT personnel expertise and IT infrastructure flexibility in RFID enabled projects in healthcare. Other interesting directions can consist in examining the business value of RFID through factors such as throughput, inventory costs, labour costs, reporting, operational flexibility, wastage, utilization, cycle times and many other factors suggested by Mooney, Gurbaxani et al. (1996) may be initiated. Similarly, this study focuses solely on RFID technology; further research may well include determining the impacts of co-adoption of multiple systems at the same time (e.g., RFID and enterprise resource planning) within the healthcare sector.

7. Conclusion

This paper has discussed the business value of RFID-based systems implemented in healthcare, together with their advantages and benefits, while comparing the healthcare sector with non-healthcare industries. Detailed analysis from the cases clearly indicates that RFID is an interesting technology whose use shows a high degree of flexibility, whether it is in pilots/trial period or in full scale deployment. Our studies also revealed that RFID systems were integrated into the already existing systems with less effort. The evolution of RFID technology in recent years has made it an essential IT for many organisations, which have been rely on such a technology to find their way in a global competitive business environment. Further, considering the capabilities of RFID technology that are being identified in this study, there is no doubt that the level of adoption forecasted will be attained. In this regard, an overview of the benefits and business value of all RFID-based systems studied in the 69 cases featured the RFID properties presented in Table 2. The various properties (including flexibility) of the RFID technology have made it indispensable in a wide range of industries. However, despite such a vast potential (Table 2), the prominence of the technology in the healthcare sector appears to be very limited, thus clearly pointing out the necessity to investigate its specific applications that may

be suitable to healthcare organisations. It is true that the ongoing trials and studies indicate a gradual diffusion of RFID in the healthcare sector; however, when compared with other industries harvesting the benefits of RFID technology, the healthcare industry has so far just touched the surface of its applications.

Table 2: Summary of the benefits realised from RFID Technology capabilities

Specific business value of RFID-enabled healthcare transformation projects	Common benefits of RFID-enabled transformation projects	Benefits of RFID-enabled non-healthcare transformation projects
1. Complete automation from patient check-ins to check-outs 2. High granularity of critical information on medial assets, staffs and patients 3. Real-time monitoring of patient's vital signs and conditions 4. Prevented financial losses for healthcare organisations 5. Reduced treatment costs and low losses of assets 6. Collaborated multiple areas of interest on patient's treatment decision, thus improving decision quality 7. Enhanced security and traceability 8. Reduced consumption of physical space 9. Enhanced medical dispensing systems 10. Bed turn overtime in 30 mins 11. Faster exchange of patient's data between medical institutions 12. Freed staff from superfluous procedures 13. Enhanced accuracy in patient's EHR and billings 14. Enhanced patient care quality and trust.	1. Automated manual and paper-based processes 2. Eliminated erroneous and time consuming processes 3. Capability to integrate with multiple existing technologies 4. Provided real-time visibility of assets, staffs and end-to-end supply chains 5. Assisted compliance with regulations and policies 6. Increased productivity from staffs and reduced workforce needs 7. Automated inventory counts and replenishments 8. Increased reliability in the workflow 9. Efficient resource utilization 10. Helped in overcoming financial losses 11. Enhanced decision qualities in the organisations 12. Assisted in automated budgeting and scheduling 13. Increased financial profits and quicker ROI's within months 14. Provided superior control on processes and planning for the management 15. Reduced waiting times.	1. Real-time, 24/7 monitoring, from cheese production and diamond caches to military assets and radioactive materials 2. Real-time monitoring of conditions in hazardous areas, while providing notifications and triggers 3. Replaced unreliable performance measurement systems 4. Cut-done time in locating confidential orders 5. Manufacturing cycles of military assets increased by 71% 6. Enhanced customer relationships 7. Created accountability of missing assets 8. Replaced cartons to reusable trays, thus saving costs of nearly $500,000 annually 9. Tools required for production is assessed within 30 minutes 10. Inventory savings up by 50% ($714,000) 11. Shortened turnaround time for repairs and maintenance 12. Effective distribution of cargos at right time to right people 13. Eliminated silo information systems, integrated warehouse and production lines 14. Supply production increased by 4 times 15. Increased creditability and accuracy of the information 16. Enhanced decision quality and controls, predicted bottlenecks in processes 17. Inventory replenishment time cut varying from 25% to 70% 18. Increased competitive ability of the organisation 19. Enabled preserving product quality of sensitive and fragile materials 20. Powered 24/7 self serving stores and automated check-ins 21. Assisted shoppers in intelligent product selection and faster shopping experience 22. Assisted data compilation in enabling greater depth in business analytics in stores and organisations 23. Enhanced security and fraud detection leading to 100% accuracy 24. Enabled real-time individual feedbacks on customer's fitness during trainings 25. Automated tallying of bills and invoices in restaurants

Overall, findings from the present study showed that, RFID technology has the potential to transform the technologically challenged healthcare sector as well as technically weak organisations. The process view approach enabled us to investigate the impacts of RFID at the level it is being implemented and adoption of archival analysis assisted in realising the business value of RFID technology and its impact to the organisation and value chain. Thus upon utilizing the process view approach and archival analysis method, it was possible to support our propositions as shown in Table 3.

Table 3: Summary of the Proposition Results

No	Proposition	Results	Case Study No.	
			Healthcare	Non-Healthcare
P1	*RFID Management Capabilities has a significant positive effect on RFID Capabilities, which is positively associated with the impact of RFID at the Process level*	Supported	2,3,4,5,6,8,9,10,11, 12, 13,15,16,20	21,22,23,25,26,27,28,30,31,33,34,35,39,41,43,44, 45,46,47,48,50,51,52,53,56,58,59,60,61,62,63,64, 65,66,67,68,69
P2	*RFID Personnel Expertise has a significant positive effect on RFID Capabilities, which is positively associated with the impact of RFID at the Process level*	Supported	2, 3,7,12,13,16,17	21,22,23,24,25,27,28,29,30,31,32,33,34,35,36,38, 40,41,45,48,50,52,55,56,62,67,68
P3	*RFID Infrastructure Flexibility has a significant positive effect on RFID Capabilities, which is positively associated with the impact of RFID at the Process level*	Supported	3,4,5,6,7,8,9,11,12,13,14,15,16,17	21,22,25,29,31,32,33,35,36,37,38,39,40,41,42,43, 44,45,46,47,48,49,50,51,52,53,54,56,57,58,62,64, 66,67,68,69
P4	*Automational Effect has a significant positive effect on the Process Level, which is positively associated with the impact of RFID at the Organisational level*	Supported	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20	21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36, 37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52, 53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68, 69
P5	*Informational Effect has a significant positive effect on the Process Level, which is positively associated with the impact of RFID at the Organisational level*	Supported	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16, 17,18,19,20	21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36, 37,38,39,41,42,43,44,45,47,48,49,50,51,52,54,56, 57,58,59,62,63,64,66,67,68,69
P6	*Transformational Effect has a significant positive effect on the Process Level, which is positively associated with the impact of RFID at the Organisational level*	Supported	1,4,5,6,7,8,9,11,12,13,14,15,16,17,18, 19,20	21,22,23,25,26,28,29,30,32,33,36,39,40,42,43,44, 45,46,47,48,49,50,51,53,55,56,57,58,59,60,61, 62, 63,64,65,66,67,68

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9. Appendices

9.1 Appendix 1: Summary of Case Studies

Table 4A: Summary of the mini-case studies within the healthcare sector

Case No.	Case Study	Challenges Identified and Services Needed	Type/Time Period for Implementation	Cost	Key Findings and Outcomes
	Hospitals/ Labs				
1	**Integris Health**	Manual processes, Low visibility in tracking products, Financial losses	4-month pilot	NA	Eliminate manual processes (A), Faster processing (I), Continued tracking of products movements (I), Optimized care and safety (A), Prevented financial losses (F)
2	**French Biobank (Nice University Hospital)**	Manual and paper-based process, Improve traceability and security of samples, Eliminate error-prone processes, Improve data security and management	NA	NA	Eliminate manual and paper based processes (A), Improved traceability and security of samples (I,T), Better data security and management (I), Eliminate time consumption activities (A)
3	**Intermountain Healthcare**	Manual process, Low turnaround time, Less visibility for tracking samples	NA	NA	Eliminate manual processes (A), Fully automated processes (A), Quicker turnaround time (A, I), Consistent and error-free (A), Better tracking (I), Less workforce needs (A), Occupy lesser physical space (O)
4	**Memorial Hospital Miramar**	Track patients, Eliminate routine processes, Free staff's time in administrational work for better patient care	NA	NA	High granularity of tracking patients in real time along with hospital equipments (A, I), Integrate with other systems to cut down routine process (A), Effective medical dispense system (A,T,O), Bed turnover time to 30min, up from 2 hours (A, I)
5	**Jacobi Medical Center**	Manual and paper-based processes, Free up staff time, Simplify patient identification	2 months and extended further	$325,000 for installation and $65,000 annually for tags	Complete automation of paper-based processes (A), Faster exchange of patient's data (A,I), $1 million savings annually (F), Free staff from superfluous work (A,I)
6	**St. Vincent's Hospital**	Shortage of information on free beds, Patients diverted to other hospitals, Low patient visibility, Few manual processes	Less than 6 months pilot and roll out	$1.7 million for the whole project	Free up beds in less time (A), Eliminate data entry (A), Less training (I,T), Real-time patient visibility (A,I), Integrated data (A), Quick ROI (151% in 12 months) (F), Net revenue increase of $2.58 million (pilot phase) and additional $5.5 million in the next few months (F),
7	**University of Amsterdam's**	Inefficient processes, Improved patient safety and services, High revenue	3-month pilot	More than $900,000	Automated, efficient processes (A), High resource utilization (I, Ad), Real-time patient tracking (A, M, I), Accurate billings (Ad, T), High

	Academic Medical Centre	consumption, low visibility of patients, assets, medical records, blood products and beds			visibility of inventory and stocks (I, Ad), Reduced supply-related cost by 5% (F), Blood tracking and tracking for patient's safety (A,T)
8	**Pantai Hospital**	High patient load, Scarcity of skilled resources, Paper-based inefficient processes, Time consuming tasks	NA	NA	Streamlined, efficient workflow (A, I), Elimination of paper-based and time-consuming processes (A, T), Increased patient safety (M, A), Anywhere and anytime data availability (M, Ad, A), Real-time visibility of patients and their data (A, I)
9	**Tan Tock Seng Hospital**	Low visibility of tracking patients, slow information flow across the organisation, Time-consuming processes	NA	NA	Complete visibility of patient's movements and vital signs (A, I, M), Increased staff efficiency (I), Faster bed turnover, reduced waiting time and enhanced productivity (Ad, T, M), enhanced integration of patient's data (T, I)
10	**Texas Tech University Health Sciences Center**	Poor manual inventory management, Loss of assets, Inefficient processes, Low visibility of assets	NA	NA	Automated inventory management (A,I), Reduced loss of assets (Ad), Elimination of theft (A, Ad), Real-time visibility of total inventory, missing inventory and reports (A,T,M), Elimination of paper works and errors (A), Substantial financial savings (F)
11	**Lucile Packard Children's Hospital**	Tracking and securing of newborns, patients, staffs and medical assets	NA	NA	High visibility of tracking, safeguarding and securing newborns (A, M, Ad), Real-time location information of staffs, patients and assets (I,T), Improved patient safety (M)
12	**Lahey Clinic Medical Center**	Poor inventory management, Inefficient resource utilization, Time-consuming redundant process, Low visibility of assets	4 months approx	NA	Automated inventory management (A,I), Real-time visibility of assets (I, Ad), Efficient process and resourced management (A,I, Ad), Freed up staff time (M, T), Centralized equipment location information (I, M), Enhanced patient care quality (M)
13	**East Savo Hospital District**	To improve process, To ensure data security and patient safety, Enhance accuracy and save time, Improve asset tracking, Staff safety	3-phased approach, 4-month pilot program for point of care systems	NA	Stringent access controls to maintain data security and patient safety (Ad, M, I), Elevated real-time patient monitoring and immediate access to accurate patient records (A, I, M), Saves 54 nurse hours per month from redundant process (A, T), Enhanced personnel safety, resource and asset management (M, Ad, I), Quick ROI in 12 months (F)
	Diagnostics / Treatment Centers				
14	**Commonwealth Newburyport Cancer Center**	Manual and paper-based process, Improve patient safety and treatment methods, Ensure quality standards and eliminate treatment errors	Few months	$95,000 for installation and $19,000 annually for the support and software upgrades	Eliminate manual and paper based processes (A), Complete automation of patient check-in and treatment (A,T), "Plug-and-play" systems (I,T), Increased productivity (A), Enhanced patient safety (A,M), Eliminate treatment errors (A, I, Ad)

15	**Disney Family Cancer Center**	Track patients, Make patient visits easy, Personalize treatments to patients needs, Reduce waiting time	NA	NA	Patients tracking in real time (A,I), Reduce waiting time and better scheduling (A,I), Personalized treatments for patient needs (T,M), Reduced patient anxiety (O)
16	**Memorial Sloan-Kettering Cancer Center**	Manual process, Poor inventory management, Loss of equipments and assets, Inefficient workflow	6-month pilot followed by a large-scale roll-out	NA	Dynamic inventory management (A, Ad), Minimized thefts and accidental loss of assets (Ad, I), Optimized staffs performances and equipment usage (M, I,T), ROI in one and a half year (F), High data visibility across the organisation (I, T)
17	**Shady Palms**	Patient safety and security, Monitoring of dementia patients,	NA	NA	Centralised monitoring of movements of dementia patients (A, I), Enhanced patient care and security (T, M), Assets management (A, Ad), Increased assistance for patients (M), Better resource utilization (I, Ad)
	Pharmaceuticals/Medical Suppliers				
18	**Terso and Texas Lab**	Manual processes, Low visibility for tracking products, Thefts of products, Redundant processes, Loss of revenue	NA	NA	Automated manual processes (A), Real-time tracking of products (I), Reduced thefts (A,T), Increased access to materials (I), Reduced product price (F)
19	**Mississippi Blood Services**	No Real-time tracking of products, Low system integration, Distribution problems, Low efficiency processes	8 months to assemble	NA	Real-time tracking of products (A,I), Enhanced integration of multiple systems (A,I), Eliminate distribution problems (A), Automated process from packing to shipping (A)
20	**Cephalon**	Improved patient safety, anti-counterfeiting of products, To improve data flow and integration, Low data visibility	NA	NA	High visibility of data and data integration across the organisations (A,I), Regulatory compliance (M, Ad), improved patient safety (M)

A – Automational Effect, I – Informational Effect, T – Transformational Effect, F – Financial Performance, M – Marketing Performance,
Ad – Administrational Performance, O – Organisational Level

Table 4B: Summary of the mini-case studies of non-healthcare sector

Case No.	Case Study	Challenges Identified and Services Needed	Type/Time Period for Implementation	Cost	Key Findings and Outcomes
	Aerospace				

21	**Robins Air Force Base**	Tracking and organizing critical tools and components, Tracking and inventorying fragile and costly devices, To enhance the business process and resource management across facilities, Eliminate errors and boost efficiency	Staged deployment	NA	Automation of integration of multiple technologies (A,I), Single repository to track items to their location (Ad, T,I), Enhanced efficient inventory management (M, Ad, A), Cost cut down (F), Eliminated unnecessary purchases and redundant paper works (A, I), Saves time (A, Ad, I), Enables monitoring of items conditions (Ad, A)
22	**Killdeer Mountain Manufacturing (KMM)**	To trim costs, Boost efficiency and productivity, Improve inventory and manufacturing process management, Increase transparency in supply chain, Eliminate thrown-off schedules	3-phase development	$4-million project	Unified integration of data and high visibility of supply chain (I, T), Replaced error-prone, unreliable performance measurement system (A, T, Ad), Eliminated paper-based process (A), Cut of time in locating orders from approx. 20 min. and 1 hour to real-time location (A, M), Increased average manufacturing cycle by 71% (A, Ad, M), Savings of more than $160,000 annually (F), Improved customer relations (M)
23	**Asia Airfreight Terminal**	Traffic flow congestion, Poor delivery and collection data captures, High waiting time and turnaround time	15 months	NA	Automated optimized flow of traffics (A, Ad, I), Real-time information for customers (M), Enhanced resource management (I, Ad), Labour savings of $8.5 million per year (F), Intelligent allocation of locations (A, T), Reduced waiting time by 45% (I,T), Reduced consumption of papers, manual process and manpower resources (A,F)
	Consumer Packaged Goods (CPG)				
24	**Mission Foods**	Missing of assets resulting in financial losses, low visibility and accountability on inventory assets.	4 months	$100,000	Created accountability for missing assets (A,I), Item level tracking of assets and location (A,I, Ad), Replaced cartons to reusable trays, thereby saving costs of nearly $500,000 annually (F, A), Enhanced visibility of warehouse assets (Ad), Improved customer experience (M)
	Defence				
25	**Northrop Grumman**	Low visibility on costly government-owned devices and tools, Inefficient processes, Time-consuming and manual tasks, Superfluous overhead costs	4-month pilot and implementation	NA	Centralised database with full inventory details, automated tracking and locating of devices and tools in real time (A, Ad, I), Reduced by 2/3 the staff required for tracking special tools (A,T), Complete ROI within a year (F), Tools required for production is assessed within 30 minutes (A, I), Inventory savings up by 50%, i.e. $714,000 (A, F, M), Increased customer satisfaction (M), Proved to be the most robust system (T, M)
26	**Texas Military Force**	Needed a system to track evacuees during storm, hurricane and other emergency situations, To automate enrolling and processing of evacuees, their medical equipment and their animals from	NA	More than $4.3 million	Enabled dozens of people to be processed simultaneously (A,I,M), Eliminated labour intensive processes(A, Ad), Provided advanced, real-time notifications on rescues (Ad, M,A), Easy-to-use, intuitive and accurate system (T)

		transportation hubs to shelters			
27	**Argonne National Laboratory**	System to track radioactive and fissile materials during storage and transportation, Monitor the conditions of the containers was manual, Manage safety, security, accountability, health and environmental protection during storage, transportation and disposal.	3 years	NA	Real-time monitoring of radioactive and fissile materials contained in the cylinders (A, Ad), Enables immediate trigger in case of any abnormal situation—such as a lost seal, a sudden shock or a rise in temperature or humidity (A, I), Increased safety of personnel and the environment (M), Centralised server to monitor transportation of nuclear materials when personnel are offsite (Ad, M, I)
28	**US Department of Defence**	Low-visibility supply chain and bumps in logistics, Redundant supplies	NA	Budgeted approximately $877.6 million from 2010 to 2015	Shortened turnaround times for repairs and maintenance on schedule (A, Ad), Enhanced safety for the personnel (M), High visibility and effective distribution of cargos at right time to right people (A,I,M, Ad), Eliminated manual, labour-intensive, error-prone processes in inventory (A), Received items visibility reduced by 3.6 days and waiting time for customers by 2.5 days (A,T, Ad), Savings in inventory and labour utilization (F)
	Logistics				
29	**Graniterock**	Silo systems, Difficult to consolidate data, Concerns about customer satisfaction, Low visibility of inventory and supply movements, Manual, error-prone and slow processes	2 years	NA	Centralised system and increased data integrity (I, Ad), Automated updates on quotes and job status for customers (A,I, Ad), Enhanced competitive capability (T), Customer movement time through a quarry reduced by 50% (M, Ad), Labour savings (F), Increased customer loyalty (M)
30	**Beaver Street Fisheries**	Low visibility and traceability of supply chain, Manual shipping and receiving of processes, Concerns about warehouse management and production lines	3-phased implementation	$175,000 till date	Automation of inbound and outbound shipping (A, Ad, I), Quadrupled its supply volume (M, Ad), Enhanced tracking and tracking of products (A, T), Integrated warehouse and production lines (Ad, I), Labour cost savings (F), Enhanced business process (A)
31	**Adani Grain Logistics**	To compliance regulations, Ensure quality control of grain products, To automate depot operations	NA	More than $125,000	Automation of accurate track the incoming loads (A, I), Links the shipment information with its accounting system (Ad), Enhanced quality control (M, I), Elimination of wrong deposits (I, Ad), Compliance with regulations (Ad, M)
32	**Gerry Weber International**	To track items through supply chain and retail stores, Item loss prevention, Replace manual verification count, Centralised system	3 months	$3.9 million	Centralised supply chain management system (A,I, Ad), Enhanced responsiveness (I, Ad), Improved accuracy and enhanced customer satisfaction (M, A), Reduced labour costs (F), Increased turnover at the store level (A, Ad, T), Expected ROI in 2 years (F)
	Manufacturing				

33	**Wells' Dairy**	Competitive environment, Improve inventory management, To enhance quality control, high visibility in production and supply chain.	NA	NA	Data integration provided enhanced decision quality control (T, Ad, A), Minimized costs (F), Quicker ROI (F), Increased productivity and safety (Ad, A), Enhanced resource management (I), Enabled item level tracking throughout supply chain (A), Improved shipping accuracy (A), Eliminated manual and error prone processes (A, Ad), Customer satisfaction (M)
34	**Stafford Tower Crane**	Lost or misplaced components, Potential revenue losses and project delays, Manual tracking of parts and cranes, High labour costs	NA	Between $25,000 - $30,000	Centralised inventory to track all the cranes and parts (A, Ad, I), Eliminated missing of parts (I), Quick responses to customers (I, M), No wastage of labour time (A, Ad), Customer satisfaction (M), Quick ROI (F)
35	**Nortura**	Vision to improve visibility and real-time monitoring of logistics, quality, track-and-trace and assets, Reduce human interventions and manual data	NA	NA	Real-time monitoring of products (meat) conditions (A, I, Ad), Enabled managers to assess supply chain efficiency, spot bottlenecks (Ad, I), Reduced inventory levels (I, T), Enhanced shipping visibility (Ad), Customer satisfaction (M)
36	**Columbus Brick Co.**	Inventory expansion caused inefficiencies, Superfluous process, Needed effective inventory management, Labour intensive, slow, error-prone tasks, Manual loading of brick shipments	Approximately 5 months	NA	Automated inventory information in real time (A, Ad), Loading time cut by 25% (A, I), Improved inventory management and order fulfilment process (A,I, Ad), Efficient labour and resource management (I, Ad), Cost savings (F), Customer satisfaction (M)
37	**Tomorrow's Mother**	Low visibility of inventory, Challenges and errors associated with manual counts, Needed that timely, accurate inventory data for effective business	4-month trial before deployment	NA	Automatically gathered all the inventory data from all the retailers (A, I), Predicts inventory conditions (I Ad), Eliminated errors from manual counts (A), Enhanced data integrity from standardized data (A), Less capital investments and quick ROI (F), Efficient business process and customer satisfaction (Ad, M)
38	**Custom Cupboards**	Challenges in maintaining products to meet with the production lines, Meeting customer demands, Low visibility of manufacturing flows, Human-oriented processes	NA	NA	Accelerated production (A), Precise tracking of cabinet components (A,I), Enabled monitoring the components status in production(Ad, I), Quicker fulfilment of orders as per customer requirements (Ad, M), Elimination of human oriented process (A), Instant availability of information (A, I), Enhanced product quality (M, Ad)
39	**Indexport**	Manual entry and visual verifications in logistics, No visibility of stock availability, Paper based process led to human errors, To fulfil customer requirements	NA	NA	Precise and real-time information for stocks of products (A, Ad, I), Eliminated errors in dispatching orders (T), Achieved greater efficiency and productivity (A, Ad), Enhanced customer services (M), Eliminated manual, paper-based process (A, I)
40	**Sabanci University**	To improve quality of services for students, Speed up the checkout process at various	NA	NA	Centralised data repository-enabled automation of process (A), Enabled students and staff to utilize cards for multiple purposes without delays

		campus establishments, Enable faster access rights for students			(T, Ad), Transaction reports online for users (Ad), Quicker services turnaround time (M), Improved shuttle bus services for students (M), Enhanced and faster access rights (Ad, M), Elimination of cash payments (A)
41	**Japan Pallet Rental**	Struggle in locating the assets, Drain in profitability, Difficulties in procuring accurate payment, Experienced significant pallets losses, Human intervention processes had errors	Multi-phased implementation	NA	Clear visibility of total quantity movement (A, Ad), Attained better control on inventory (Ad, I), Easier movements of pallets as required (Ad, A), Reduction of losses of pallets and time (M, A), Cost savings (F), Improved customer services (M), Trial showed reduction of CO^2 emissions by 40% (M)
42	**Valtra**	Challenges in parts replenishments and inventory management process, To track parts from warehouse as they move to the production line, Manual process involved errors	NA	NA	Automated and streamlined parts replenishments and inventory management processes (A,I, Ad), Visibility of inventory levels and parts consumptions (I, Ad), Eliminated manual processes involved in receiving and inventory counting reducing errors (A, T), Streamlined shipment process (A,T), Reduced labour costs (F)
43	**Arnold Clark Automobiles**	Low visibility of vehicles on the site, Customer service issues, To streamline sales process, Challenges in stock control	Approximately 6 months	NA	Real-time vehicle data is made available (A, Ad), Efficient, effective stock control and turnaround times (A I), Enhanced customer services (M), System identifies highly depreciating vehicles (Ad), Integrated interdepartmental communication enabled quicker workflow from valet parking to pre-delivery inspection (Ad, A, T), Increased staff efficiency and productivity (Ad, T)
44	**Levinoff-Colbex**	Compliance to government regulations, To ensure traceability of meat in the entire processing plant, To identify the infected animals, Manual process, Paper-based records	NA	NA	Real-time tracking of meat in the entire part (A,I), Eliminated manual removal of contaminated meat (A,T), Responsive internal recall systems (Ad, I), Reduced labour costs (F), ROI within a year (F), Earned lucrative new contracts (M, Ad), Protected company's brand and reputation (M)
45	**Siemens**	To increase productivity in operations line, To meet the customer's specific requirements, Challenges in responding to complex orders,	NA	Approximately $209,000	Automated, streamlined and faster production lines (A,I, Ad), Enhanced mass customization concepts (A,T), Quickly filling complex orders (Ad, M), Reduced stock inventory (I, Ad), Faster product shipments (Ad), ROI in less than 2 years (F), Competitive edge (T)
46	**Almacafe**	To boost farmer's standard of living, To minimize the production costs, Improve the quality of coffee, Enhance all quality, Tracking speciality coffee in the supply chain, compete effectively	NA	NA	Automated unwieldy and time-consuming processes (A,T), Attained 99.99% read accuracy in the warehouses (A), Customers were given quicker access to status on the orders (M), Added value to the customer services (M), To compete at the global scale (Ad, M), Increased visibility in supply chain (Ad)
47	**Sonoco**	To improve inventory management, Reduce lost shipments, Decrease amount of wastes, To	6 months	NA	Improved supply chain visibility (A, Ad), Client experienced 10% annual savings in paper purchasing (A,M,F), Replaced manual barcode

		save financial costs			scans (A,T), Eliminated wastes (T), Inventory management became faster, cheaper and accurate (I, Ad)
48	**Vale Inco**	Vision to streamline production, reduce costs and improve safety	NA	NA	Replaced manual processes (A), Enabled accurate forecasting of mine ores (Ad, T), Enhanced visibility in the production (I, Ad), Improved safety (T), Expected savings of $30 million to $70 million per year (F), Audit trial of shipments to customers enhanced visibility of orders (M)
49	**Titan Industries Ltd**	Manual system for tracking assets in lab, Difficulties in orderly inventory of assets, Lost items, Decreased productivity and delays	6 months	NA	Inventory lists automatically updated (A, Ad), Anytime anywhere visibility (A,T), Increased productivity (M, Ad), Chances of losing assets are reduced (Ad), Better inventory management (I, Ad)
50	**Alliance One Brasil Exportadora de Tabacos**	In order to achieve operational efficiency, reduce the mistakes, and expenditure	More than 2 years of testing before the final implementation	NA	Faster, more agile product management (A,I), Enhanced data accuracy of tobacco(I, Ad), Reduced labour costs (F), Enabled to preserve product quality like limiting damage on fragile tobacco (Ad, M), Witnessed 10% efficiency gains (A,T), Enhanced resource management (I), Attained confidence in the system to implement in other subsidiaries (T, M)
51	**Technicolor Brazil Media and Entertainment**	To remain competitive in the market, meet customer expectations, improve efficiency in managing raw materials, Manual processes and Tracking materials were time consuming and error-prone	More than a year	Approximately $217,000	Automated information exchange between its ERP and the processing system in material receiving area (A, Ad), Real-time visibility of flow of materials and of information on quantities (A,I, Ad), Quick ROI—43% within 7 months (F), Increased reliability of information (T), Increased competitive capability (T)
52	**Swire Coca-Cola**	Inventory management challenges, Difficulties for tracking the circulated cylinders, Manual tracking resulted in inaccurate status, errors and no real-time visibilities, Loss of 500 tanks and cylinders annually	6-month pilot before implementation	NA	Greater visibility of all the key assets (Ad, I), Reduced loss of tanks and cylinders by 50% (M), Decreased time required for inventory counts by 30% (I, Ad), Attained business analytics on usages (Ad), Reduced administrative works and inspections (Ad), Saved labour (I)
	Packaging				
53	**Sterling Services**	Vision to transform its business, Replace vending machines, To improve customer services	NA	NA	Replaced vending machines (T), Eliminated services required for vending machines (A, Ad), Automated self-services check-outs (A), No labour intensive and time-consuming tasks (A,T) Enhanced customer services and customer satisfaction (M)
54	**Minera Norge**	Needed to quickly and accurately track the slate pallets in production facility, Difficulties for identifying products in harsh weather conditions, Low visibility of stock inventory, Shipping errors and product misidentification	6 months	NA	RFID enabled quick identification of individual products under all weather conditions (A), Track products in real time (I, Ad), Automated, accurate inventory management without any human intervention (A,I, Ad), Expedite warehouse, shipping and storage (Ad), Eliminated time from manual system updates (A)

	Retail				
55	**Blue Hills Ski Area and Campgaw Mountain**	To provide more convenience to skiers and snowboarders	NA	NA	Enumerated benefits and conveniences to skiers and snowboarders (M), Automated ticketing processes (A,T), Eliminated long queues (A, Ad)
56	**Valdac Group**	To maximize efficiency, Cut costs, Provide stylish shopping experience for customers, Streamline operations, Reduce employee and process costs, Track and monitor inventory and sales trend	More than a year of testing before implementation	NA	Assists shoppers to complete the purchases quickly without any assistants (A,I, Ad), Availability of product information for customers (M), Financial savings (F), Enhanced productivity (A, Ad), Competitive edge (T),
57	**Royal Caribbean**	Long waits at the bar, Difficulties in servicing the customers, Manual process	11 months of design before implementation	NA	Automated ease of use self-services for customers (A, T), Sales of refill packages jumped by 107% (F), More than $435,000 profits in soda fountain sales (F), ROI in less than 30 days (F), Track sales and consumptions (Ad), Enhanced resource management (Ad, I), Satisfied customers (M)
58	**Common People**	To enhance customer shopping experience, Provide onsite information for products	NA	NA	Achieved 99% read rate (A), Enabled the management to see what's selling and what's not (Ad, I), Kept labour costs down (F), Up-to-date sales and inventory information benefited to suppliers (Ad), Intuitive and interactive customer service (M), Competitive capability (T)
59	**Steinmetz Diamond Group**	Manual processing and data entry, Needed better way of monitoring diamond movements,	Phased Deployment	NA	Achieved 24/7 visibility into its global diamond caches (A,T), Enhanced automation, quality control and insights for managers (A, Ad), Shortened time needed by the employees to check inventory (A,I), Speedy production and sales inquires (M, F), Increased security and real-time alerts (I, Ad)
60	**Starwood Hotels and Resorts**	To enhance services to tech savvy travellers, roll out automatic check-in programs	NA	NA	Automated check-ins for travellers having RFID cards (A,T), Eliminated waiting in long queues (A, Ad), Enhanced customer satisfaction while creating positive experience (M), Competitive edge (T)
61	**Laxbutiken's LAXoMAT**	To serve tourist 24/7, Capture the lost sales	NA	NA	Automated self-service storage (A,T), Food serviced 24/7 to the tourists (M, A), Eliminated human-staffed point-of-sale (A), Increased productivity leading to sales (F)
62	**Vail Resorts**	To replace the existing bar code technology, Streamline lift access for skiers and snowboarders, Improve the overall experience	Two years of extensive planning and testing before	NA	Automated lift access (A, M), Provided critical information for promotions (Ad, I), Fraud detection by 100% (Ad, T), Enhancement of forecast trends and patterns for operation planning (Ad, I), Elevated

			full roll out		customer experience (M)
63	**Focus Magazine**	To capture the user's trends and usages of magazine, evaluate the reading habits	3 weeks of field tests	NA	Automatic recording of reading patterns (A,M), Data provided insights into reading habits (Ad, I), Enhanced competitive capability (T)
64	**Charles Vögele Group**	Needed item level tracking of products, To enhance the visibility of key supply chain steps, To gain control over inventory and store stocks	2 years to design and implement	NA	Achieved end-to-end transparency in supply chain (Ad, I), Automatically updated information on stock replenishments, store's inventory management for each individual items (A, Ad), More than 70% of time saved in store and warehouse inventories (A,T), 7% of increase in accuracy when picking orders in factories (T), Increased sales and accurate information for planning (M, F, Ad), Competitive advantage (M)
65	**Curves International**	Needed a monitoring and accountability system in the fitness clubs at individual identification level	NA	Approximately $8,000	Centralised database holds fitness information for customers (A), Real-time individual feedback during training (A, Ad), Highly satisfied customers (M), Highly enhanced competitive edge (T)
66	**Queens Borough Public Library**	Need fasted check-out process, Need to reduce waiting time in checkouts, Challenges in adding additional librarians	Above 3 years	Approximately $6.5 million for tags and self- checkout kiosks, and $13.5 million for self-check-in units.	Fully automated self-checkouts (A, T), Eliminated waiting times (A, Ad), Quicker services (M), Added controls on handing money (Ad), Reduced rate of losses (Ad, T), Enhanced inventory management (I, Ad), Time saving when collecting fines (Ad)
67	**Blue C Sushi**	To ensure the freshness of the food served, Enhance ordering and inventory systems, Automate the billing process	3 months	NA	Automated tracking of food plates to ensure freshness (A, Ad), Accounts inventory used in each shift (I, Ad), Easier replenishment process (Ad), Automatic collection of information on plates sold every day (A, T), Automated tallying of customer bills (F), Enhanced customer services (M)
68	**The Dairy Farmers of America**	Needed to meet the Wal-Mart's mandates on RFID implementation, Improve operations regarding the data collected from RFID, Boost profits	NA	NA	Centralised site to handle all the system changes and updates (A,I), Automated tagging of products (A,T), Efficiency of 16 cases per minute, and which can be increased to 20 to 25 per minute on demand (A, M), Errors rates decreased to less than 1% (A), Abundant data collected for analysis to improve operations, reduce costs and boost overall performance (Ad, F)
69	**Sachsenmilch AG**	To render the cheese production process more efficient, Eliminate manual labour-intensive, erroneous data collection, Comply with the European Union regulations	NA	NA	Automated cheese ripening process precisely (A), Enhanced visibility as regardscheese ripening and the types of cheese (A,T), Real-time data availability of each cheese racks with its information on stay period (Ad, I), Improved cheese development from the data being collected (I,

Ad), Compliance with the regulations (M).

A – Automational Effect, I – Informational Effect, T – Transformational Effect, F – Financial Performance, M – Marketing Performance,
Ad – Administrational Performance, O – Organisational Level

9.2 Appendix 2: Level of Deployment

Table 5: Level of Deployment of RFID-related Projects

HEALTHCARE: **Pilot/ Trials** Case 1: Integris Health (HOSPITAL), Case 2: French Biobank (Nice University Hospital) (HOSPITAL), Case 5: Jacobi Medical Center (HOSPITAL), Case 6: St. Vincent's Hospital (HOSPITAL), Case 7: University of Amsterdam's Academic Medical Centre (HOSPITAL), Case 16: Memorial Sloan-Kettering Cancer Center (HOSPITAL), Case 19: Mississippi Blood Services (MEDICAL SUPPLIES), Case 20: Cephalon (MEDICAL SUPPLIES). ***Total: 8 (40%)*** **Full Deployment / Implementation** Case 3: Intermountain Healthcare (HOSPITAL), Case 4: Memorial Hospital Miramar (HOSPITAL), Case 8: Pantai Hospital (HOSPITAL), Case 9: Tan Tock Seng Hospital (HOSPITAL), Case 10: Texas Tech University Health Sciences Center (HOSPITAL), Case 11: Lucile Packard Children's Hospital (HOSPITAL), Case 12: Lahey Clinic Medical Center (HOSPITAL), Case 13: East Savo Hospital District (HOSPITAL), Case 14: Commonwealth Newburyport Cancer Center (DIAGNOSTICS/TREATMENTS), Case 15: Disney Family Cancer Center (DIAGNOSTICS/TREATMENTS), Case 17: Shady Palms (DIAGNOSTICS/TREATMENTS), Case 18: Terso and Texas Lab (MEDICAL SUPPLIES). ***Total: 12 (60%)***
AEROSPACE, CONSUMER PACKAGED GOODS (CPG), DEFENCE, LOGISTICS, MANUFACTURING, PACKAGING, RETAIL: **Pilot/ Trials** Case 33: Wells' Dairy, Case 63: Focus Magazine. ***Total: 2 (4%)*** **Full Deployment / Implementation** Case 21: Robins Air Force Base, Case 22: Killdeer Mountain Manufacturing (KMM), Case 23: Asia Airfreight Terminal, Case 24: Mission Foods, Case 25: Northrop Grumman, Case 26: Texas Military Force, Case 27: Argonne National Laboratory, Case 28: US Department of Defence, Case 29: Graniterock, Case 30: Beaver Street Fisheries, Case 31: Adani Grain Logistics Case 32: Gerry Weber International, Case 34: Stafford Tower Crane, Case 35: Nortura, Case 36: Columbus Brick Co., Case 37: Tomorrow's Mother, Case 38: Custom Cupboards, Case 39: Indexport, Case 40: Sabanci University, Case 41: Japan Pallet Rental, Case 42: Valtra, Case 43: Arnold Clark Automobiles, Case 44: Levinoff-Colbex, Case 45: Siemens, Case 46: Almacafe Case 47: Sonoco, Case 48: Vale Inco, Case 49: Titan Industries Ltd, Case 50: Alliance One Brasil Exportadora de Tabacos, Case 51: Technicolor Brazil Media and Entertainment, Case 52: Swire Coca-Cola, Case 53: Sterling Services, Case 54: Minera Norge, Case 55: Blue Hills Ski Area and Campgaw Mountain, Case 56: Valdac Group, Case 57: Royal Caribbean, Case 58: Common People, Case 59: Steinmetz Diamond Group, Case 60: Starwood Hotels and Resorts, Case 61: Laxbutiken's LAXoMAT, Case 62: Vail Resorts, Case 64: Charles Vögele Group Case 65: Curves International, Case 66: Queens Borough Public Library, Case 67: Blue C Sushi, Case 68: The Dairy Farmers of America, Case 69: Sachsenmilch AG. ***Total: 47 (96%)***