Study on the requirements and options for Radio Frequency Identification (RFID) application in healthcare

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Preface

This report provides an assessment of the main drivers, obstacles and uncertainties surrounding the deployment of RFID in healthcare in Europe. It identifies the most promising RFID applications in the healthcare delivery domain by reviewing the costs and benefits, as far as possible, and assessing enablers and obstacles to full deployment of RFID. Finally, the report provides an evaluation of the current market for RFID in healthcare in Europe and its future potential.

The analysis is based on a thorough review of academic and grey literature and available data sets, a Delphi survey of experts followed by semi-structured key informant interviews, and seven case studies of RFID applications across Europe and the US.

The initial objective was to provide a full cost-benefit analysis of RFID in healthcare. However, the lack of cost data and very limited monitoring of actual value generation - through efficiency gains in logistics and resource allocation, the restructuring of operational processes, as well as the reduction of errors, hospitalisation time, etc – in European hospitals meant that such an analysis was not possible. Instead, we assessed the individual cases where data was available and developed a framework for conducting this analysis in the future and to stimulate the effective monitoring and capturing of cost-benefit data in care delivery settings.

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Glossary

ADRs	adverse drug reactions
AMC	Amsterdam Medical Centre
CBA	Cost-Benefit Analysis
CDO	Care Delivery Organisation
ER	Emergency Room
JAMA	Journal of the American Medical Association
Jena/UKJ	University Hospital Jena
Geneva/HUG	University Hospital Geneva
GTL cycle	Gartner’s trends and glimmers cycle
MIT	Massachusetts Institute of Technology
OR	Operation Room
PDA	Personal Digital Assistant
PTL	Patient Throughput and Logistics management
RFID	Radio frequency identification
ROI	Return on Investment
RTLS	Real Time Location Tracking
WMH	Wayne Memorial Hospital

Executive Summary

Objective of this report

This report is part of a wider study on Radio Frequency Identification (RFID) applications in healthcare, and draws on inputs from an extensive review of scientific an grey literature; an analysis of market data, a two stage Delphi survey of key experts from industry, and academia, care providers, and others; a number of semi-structured expert interviews and seven case studies. By combining these methodologies the report provides a review of the deployment of RFID in healthcare settings in Europe, grounded in theory, expert opinion, and practice.

The report first gives a high level overview of the European market for RFID in healthcare. The report then identifies and reviews the drivers and enabling factors, the obstacles and the critical uncertainties affecting the current and future deployment and up-take of RFID and similar technologies in healthcare settings. Through an assessment of the case studies and supporting data sets the cost and benefits of RFID applications in healthcare have been assessed. Due to shortages in data, especially in Europe, a full cost-benefit analysis and an extrapolation of these to assess the overall contribution of RFID to the efficiency and quality of care in Europe is not (yet) possible. However, a framework for assessing costs and benefits is developed and where possible applied to single implementations. Finally the most promising[1] RFID functionalities and application domains are identified.

What is RFID?

Radio Frequency Identification (RFID) is a technology used to help identify, authenticate, track, and trace objects and people; and to gather and store information about them and their environment. The technology has been successfully applied in logistics and retail industries, where its use is now common. In Healthcare many applications are being tested in logistics to improve the operational management efficiency of healthcare delivery and quality of care.

All RFID systems consist of a transponder, a reader, a database and a software programme for processing the data collected. RFID systems can be closed or open. A closed system is defined for a strongly delimited environment (in terms of data exchanged and frequency power). Closed RFID systems do not need to be compliant with other data formats or frequency allocation schemes. Open systems, by contrast, have interfaces to other systems outside their own area of definition and may be functionally or organisationally external. RFID transponders are made up of silicon memory chips and copper or aluminum antennae, and are often sealed in paper or foil covers. Passive transponders have no processing capability and no internal power source. By using

[1] Promising in respect to reducing costs, improving quality of care and feasibility of roll out

innate properties of electromagnetic fields, the chips are turned on when an electro-magnetic reader is present, allowing them to simply transmit a serial number. Passive RFID chips usually only work within a range of five metres and are extremely reliable (compared to active transponders) with a near-unlimited lifetime. However, the current technological and operational focus seems to be in active transponders. These transmit signals of their own accord using internal power supplies and more powerful processing and memory storage facilities, which allow them to act like microcomputers. Generally, active transponders can transmit data up to a maximum distance of 30 metres.

The main drivers and enabling factors, obstacles, and uncertainties of RFID deployment in healthcare

The following paragraphs provide an overview of the main drivers, obstacles enabling factors and uncertainties associated to the implementation and use of RFID systems with healthcare delivery organisations.. While going through the list, it is important to emphasise that the order of the presentation does not reflect any specific rankings but a coordinated summary of the evidence collected for this study, through: literature review, Delphi survey, validating expert interviews and case studies.

Factors favouring RFID deployment in healthcare

The study identified a number of drivers for the development and implementation of RFID systems in healthcare settings:

Patient safety and quality of care

1. Patient safety/care quality improvements and associated cost savings resulting from RFID technology (including working routines, medication commissioning and processing, requiring visibility)

Organisational and financial needs and benefits

2. Management challenges resulting from the size and complexity of medical and other healthcare delivery activities (eg supply chain management)
3. Process transparency/traceability; distinct from supply chain management of medical devices/objects/equipment

Advocacy and Leadership

4. Senior management leadership and commitment to push forward the implementation of RFID and acquire staff support and involvement
5. Government policies or public/private initiatives aimed at fostering the use of RFID as part of a drive towards operational and strategic innovation; including publicity leading to a temporary “hype”, around the technology and its benefits for healthcare.
6. Capacity and the nature of the healthcare system as a leading indicator for the wider environment in which RFID is used and disseminated

Obstacles to RFID deployment in healthcare

The evidence collected through the case studies and interviews with experts have highlighted several operational obstacles to the deployment of RFID in healthcare delivery organisations. As technology advances, these obstacles can be overcome. However, at the present, they are to be noted as issues. These obstacles are:

Technological issues

1. Wireless infrastructure is not uniformly available within healthcare delivery organisations;
2. Electromagnetic interference between eg RFID readers and medical devices
3. Difficulty of physically integrating parts of RFID technology (eg tag size) with the object of interest (eg metal containers, tag size)
4. Limited portability of RFID technology due to insufficient battery capacity

Data management, security and privacy

5. Errors in overall system integration associated with the use of RFID

Organisational and financing issues

6. Relatively high hardware and implementation costs compared to competing technologies such as barcodes or DataMatrix.

Uncertainties affecting future RFID deployment in healthcare

The evidence collected also identified thirteen uncertainties affecting future RFID deployment; some of these factors can evolve into obstacles but can also lead to faster implementation. These are:

Technological issues

1. Managing scalability
2. Integrating RFID within the physical environment of the healthcare delivery organisation
3. Determining maturity of RFID technologies and applications
4. Using common standards

Data management, security and privacy

5. Identifying and addressing privacy concerns
6. Preserving data integrity and reliability
7. Managing integration of RFID generated data

Organisational and financing issues

8. Fostering change management

9. Pushing for user's adoption and compliance
10. Determining the RoI by correctly establishing costs and including non-monetary benefits
11. Supporting healthcare processes with RFID (translation)
12. Matching RFID system with the organisation complexity/variability and institutional context
13. Setting RFID within culture/norms of the health system

Developing a conceptual framework for assessing costs and benefits

The initial objective of conducting a full scale cost-benefit analysis (CBA) of RFID deployment in healthcare in Europe was abandoned due to a lack of relevant data. It became apparent that – particularly in Europe – there is a lack of systematic data collection by the healthcare institutions through ex-ante and ex-post evaluations of technological innovations in healthcare systems.

The majority of existing evaluations largely fail to account for non-capital saving benefits. They also seldom detail the implementation costs associated with the launch of RFID applications (including business case development, system integration and initial tagging). The lack of transparency in evaluations also leads to a failure in identifying the social case for investing in healthcare RFID.

Instead, a three step approach was conducted:

- selecting and conducting case studies of promising RFID applications (potential for affecting cost and quality of healthcare, market-readiness)
- conducting 'economic' evaluations of the applications based on the quantitative data on outcomes collected during the case studies
- developing a conceptual framework for the evaluation of the economic impacts of RFID in healthcare

Costs and benefits for economic evaluation of in-hospital RFID applications

Implementation Costs
Hardware costs
Software costs
Middleware costs
Installation costs
Training costs
Process re-design costs
Labor costs (including business case development costs, system integration costs)
Maintenance Costs
Software costs
Hardware costs
Data back-up costs
Labor costs (system maintenance and expansion)
Efficiency Gains
reduction in capital expense outlays for purchasing assets and inventory
reduction in capital and operative expense outlays for renting and managing equipment
labor savings from automatic data capture and transfer
labor savings from improved process status visibility
cost capture improvement via automatic data capture
reduced care-provider turnaround rate due to improved work satisfaction
increased patient through-put
decreased patient subversion
Quality Gains
elimination of wrong patient/wrong medication errors
elimination of wrong patient/wrong procedure errors
improved care coordination leading to more timely & available care
improved coordination of auxiliary services (eg transportation)
improved patient satisfaction
improved infection control capacity
improved asset preventive and corrective maintenance
Other Gains
improved regulatory compliance
reduced insurance premiums
improved process and event audit capacity
improved management & forecasting capacity

Source: RAND Europe.

These categories can be used to guide the collection, integration and interpretation of the evidence necessary to transparent, systematic and comprehensive evaluation of RFID deployments in healthcare. They illustrate the benefit and costs associated with the use of RFID applications in healthcare settings that a a cost-benefit analysis (CBA) – let alone a full economic evaluation - of RFID applications in healthcare needs to consider.

Case studies: Assessing the cost and benefits of existing RFID applications

Seven case studies were conducted:

1. *Treviglio Caravaggio (Italy):* Application: active RFID system which displays the location of each orthopaedic patient (identified by a numeric code) during their clinical journey in order to provide immediate feedback to relatives at the emergency ward lounge.

2. *Birmingham Heartland Hospital (UK):* The application: "Safe Surgery System" comprises a digital operating list, enabled by automated patient recognition. It is a passive pre-operating theatre decision support technology (process management & identification system) using printed RFID wristbands and digital photo identification linked to an electronic pre-operative checklist.

3. *Amsterdam Medisch Centrum (NL):* Three simultaneous RFID pilots including: a) identification/localisation of persons in OR b) OR materials tracing; and c) blood products tracing.

4. *Jena University Hospital (Germany):* The application: a pilot of an RFID-assisted medication commissioning and medication preparation (at bedside) for patient safety in the intensive care unit using the platform's auto-ID infrastructure to identify, track and match medication accurately and in real-time from the hospital's pharmacy until they are administered to patients.

5. *Geneva University Hospital (CH):* Two applications. First: an RFID-based garment tracking application (1995-2008) to manage daily collection, ironing and redistribution of garments across 4 sites, 7 distributors, distribute 28,000 garments per week. Second: an RFID-based application for chemotherapy procedures, allowing to electronically capture the chemotherapy process from prescription to administration and commissioning of chemotherapy preparation.

6. *The Wayne Memorial (USA):* RFID-based real time asset management solution; tracking & management of portable assets & equipment.

7. *Royal Alexandria Hospital (UK):* RFID-based real time asset management technology. The application is used at present only by clinical technicians – to locate equipment (currently only IV pumps) for preventive maintenance, and covers predominantly IV pumps along with other key movable assets.

Of these seven cases one represents a failed pilot (AMC), two have decided to opt for DataMatrix solutions instead of RFID (Geneva and Jena), and the others have successfully implemented RFID, mostly in combination with other technologies like WiFi.

The case studies provide useful insights into the relevant costs and benefits that may be expected to arise and need to be monitored; as represented in the conceptual framework above. In addition the cases also allow us to draw some general insights:

- Most successful applications so far seem to be in logistics and operational management; and less in patient care and quality of care improvement.
- Compared to logistics, patient care delivery applications face greater implementation problems; in particular because critical treatments and processes require near 100percent

reliability and because the complexity of hospital environments raises the likelihood and consequences of electromagnetic interference between technologies

- We found no integrated ICT solutions in information about RFID applications is generated and processed in a structural and integrated manner

- Implementation and running costs vary significantly across cases and applications. This implies one size does not fit all, and therefore that 'pilots' should be chosen carefully and findings generalised only with caution. The further implication is that some applications are more 'likely' than others, but there is no automatic presumption that the ones most likely to lead RFID implementation are the 'best' according to balanced cost-benefit criteria.

- There are significant differences in perceived benefits among case studies that depend in part on the organisational implementation of RFID and the commitment to innovate and/or improve process automation

- There is a need better monitoring of cost/benefit data against pre-investment baseline in order to quantify the added value and ROI of technology investments

The case studies suggest that there is apparent potential for realising economic benefits in addition to improving the delivery of care when RFID applications are successfully adopted in a healthcare setting. This requires taking account of technical, organisational and financial issues.

The most promising (RFID) functionalities

Applications were assessed to determine their ability to reduce costs and to improve quality of care. The Delphi survey (assessing the views of experts from industry, academia, care providers and 'others') indicated that asset (especially inventory) management applications are rated highest for cost reduction. While patient tracking applications are seen as most likely to raise quality of care, staff tracking is judged to be less relevant on both cost and quality criteria. Views differ between respondent groups, with practitioners especially sceptical about the cost and quality benefits of staff tagging.

The most promising functionalities are the following:

- **Tracking assets:** RFID systems can allow healthcare delivery organisations to have a better operational overview of their medical assets, with positive results in terms of tools availability and general asset management.
- **Tracking patients:** Tracking patients allows for a better through-put and offers the potential for reducing errors. This application is particularly relevant to patients with dementia requiring the tracing and monitoring of their whereabouts within healthcare institutions, and possibly also in the community.
- **Identification of patients:** RFID systems can improve the overall reliability of identification and authentication of a patient. The potential benefits of their uses are an increase in patient safety connected to the reduction of errors, such as in cases of drug prescriptions and administration.

- **Automatic data collection and transfer**: as in other operational domains, RFID applications can improve the automatic collection of data and their transfer to back-office mechanisms which manage the overall supply chain management of an healthcare delivery organisations;
- **Monitoring of patients through sensing:** RFID can help in the collection of health-related data to be match with relevant indicators.

The identification of these promising areas for RFID deployment suggest that significant potential benefit can be achieved from this and complementary technologies. The actual ability to achieve these benefits depends largely on organisational, financial and technical considerations.

Conclusions

The overall picture of the potential of RFID in healthcare is nuanced: there seem to be many arguments in favour of a wide RFID roll-out (especially in hospital logistics and operational management), but considerable impediments remain. Moreover, there are important organisational factors that have to be taken into account for successful implementation of RFID. Based on the evidence collected during this study, it is possible to reach a set of conclusions about the potential use of RFID within healthcare delivery organisations in Europe:

Technical:

1. RFID is not unique in many of its functionalities. Other, more consolidated technologies such as barcodes and DataMatrix offer similar functionalities. In several contexts, RFID are seen as complementary to these technologies, increasingly in combination with WiFi infrastructures.
2. RFID applications need to be integrated in pre-existing technological environments, including medical equipment and ICT. Hence, the need for their "technological neutrality", in a sense that their supporting hardware and software should be in a position to be integrated with open standards as in the case of web services.
3. Interference of RFID and other wireless equipment with (critical) electronic equipment in the care delivery environment, especially operation and intensive care wards, remains the single biggest obstacle to RFID roll-out in healthcare, as there is a direct risk to patient safety.
4. Physical constraints like tag size, ability to attach tags, the hospital environment still impede or complicate the implementation of certain RFID applications.

Organisational

5. RFID is not only an IT instrument, but an important support tool for management and care delivery. It will only deliver its full expected results if it is embedded within the overall organisational and operational structure of the institutions. The introduction of RFID is likely to lead to operational and organisational changes.
6. Therefore, RFID application design, development and implementation require the strong commitment of senior management and the direct engagement of all relevant interests (data protection, workers' interests, ethics, etc.), especially during the design and testing phase.

7. Full endorsement by individual stakeholders within a healthcare delivery organisation may also require appropriate change management mechanisms to induce behavioral change and increase operational ability to exploit the new functionalities. The motivation needs to be constantly reinforced to avoid the risk of reverting back to the "old" way of doing things.

8. This points to the importance of awareness and ownership. The organisational and operational evolution may lead to a certain level of degree of resistance from interested parties, especially among those individuals who are concerned about the lack of regulatory and normative certainty associated with the use of RFID in the healthcare domain. Also there still exist – justified or not - negative perceptions about the overall potential health risks associated with the use of RFID. This is particularly important where a RFID system is rapidly implemented, risking low levels of awareness and buy-in among stakeholders. These issues need to be addressed in full transparency and due attention should be given to communication and awareness raising activities.

Financial

9. Beside the organisational aspects of RFID deployment, there must also be appropriate attention and resources allocated to the actual technology. Investments vary substantially among the different technological providers. It is apparent that no off-the-shelf RFID systems exist that would be ready to be implemented by healthcare delivery organisations. The lack of these COTS solutions (commercial off-the-shelf) is also confirmed by the fact that there are significant differences on the individual costs and solutions of RFID implementation. This has been strongly demonstrated in this study where costs were limited in the case of the Caravaggio-Treviglio or prohibitive in the case of the use of RFID by the Geneva and Jena hospitals.

Political/policy

10. Negative perceptions among different categories of users still exist and need to be taken seriously. It requires a continuous,frank and open sharing of information about potential societal risks associated with the use of these tools, for example privacy breaches. The sharing of information, nevertheless, should involve all interested stakeholders and users of healthcare delivery organisations.

11. All of these factors are to be supported by appropriate national and international policies aimed at creating an innovation friendly environment. These are to support healthcare delivery organisations in looking beyond their current technological infrastructure towards solutions, such as (but not specifically)RFID, that can improve their operational framework provided that they reflect the interest and objectives of all involved stakeholders.

12. However, caution should be exercised when considering additional regulation, carefully balancing the policy objectives with the risk of impeding the roll-out of beneficial RFID applications.

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Thank you.

CHAPTER 1 Introduction

1.1 Objectives of the report

This document is intended to deliver the results of work package two (WP2), as described in the February 2008 Inception Report, of the *Study on the Requirements and Options for RFID Application in Healthcare*. It constitutes the third deliverable (D3) – Final Study Report - for this project. To this effect, the report intends to:

- Perform an economic analysis of the RFID market and its prospects in Europe
- Understand the technology in healthcare settings
- Identify the most important drivers, obstacles and critical uncertainties that influence the use and dissemination of RFID in healthcare
- Compare the costs and benefits in a selected set of healthcare delivery applications and develop a framework for conducting a cost-benefit analysis of RFID applications in healthcare delivery
- Identify the most promising RFID functionalities and application domains

Finally, this document aims to contribute in a substantive way to the overall aim of establishing what policy options the Commission has to positively affect the current and future development and application of RFID and similar technologies in healthcare in order to improve efficiency and the quality of care.

1.2 Scope of the report in the context of this project

The scope is limited in the sense that this document does not attempt to:

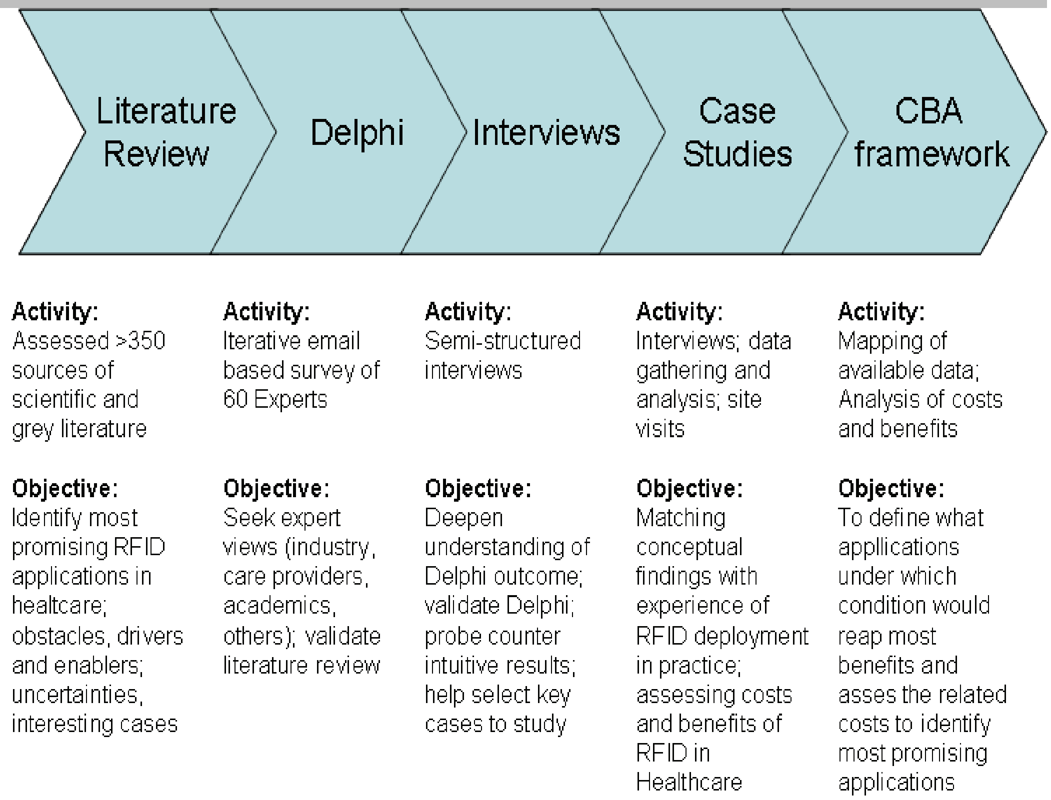
- Assess the pharmaceutical or medical devices supply chain, although it may note instances where the delivery of care has an upward vertical effect on these supply chains
- Purport to make policy; rather, it aims to inform policymaking through the project's open-ended character

1.3 Approach

The results presented in this report were achieved through multiple methods. It is a given that we capitalised on the comprehensive review and analysis of the literature, and the findings of work package one (WP1) to achieve the aforementioned objectives. However, work package two focused on the following approach, as detailed in our Interim Report for WP2 on *Preparatory Actions for Assessment of Potential Benefits and Obstacles of RFID Implementation*. Our multi-method approach contained the following research tools:

- High-level review of sources on the RFID market and its prospects in Europe. Using information from our previous literature review and market analysis estimates from leading market research organisations such as Garner Group, IDC, Foster and Sullivan and IdTechEx
- A two-staged Delphi exercise with experts and key stakeholders; based on the outcome of an extensive literature review
- Seven case studies of current and/or established healthcare applications (or trials) of RFID technology
- Complementary semi-structured interviews with experts in academia and industry
- Cost-benefit/consequence analysis of the case study data

Figure 1 process map of the inputs to this report



1.4 Policy context

One general motivation for this study relates to the ranking of RFID as the tenth most innovative technology of the past 25 years, according to the Lemelson Center at the Massachusetts Institute of Technology. More specifically, in a European context, this research is driven by the European Commission's recognition of RFID as a key opportunity in pursuit of the Lisbon objectives, particularly the development of the Single European information space. The European Commission considers RFID to have a role in stimulating innovation through a wider adoption of, and investment in, Information and Computer Technology. Innovation, especially in health and social care, is one enabling factor of new services that aims to support independent living. RFID itself is considered by the Commission to be a means for strengthening the internal market for products and services. In terms of healthcare services and delivery, RFID technology can be and has been applied to a variety of different processes and parts of a healthcare organisation with the goal of increasing efficiency in healthcare management, saving costs, reducing medical errors and improving patient safety and quality of care. But, whether the full potential of RFID technology, especially in healthcare, can and will be realised in practice, and what policy interventions are required to this end, remains a question for further research.

Indeed, the Commission does not take for granted that the potential of RFID technology to achieve a number of laudable policy and other goals is sufficient reason to decide on further introduction of RFID in Europe. Rather, it is clear that RFID raises a number of important policy concerns and any attempt to realise the potential of RFID must actively address these issues. Notably, the Commission provided a platform for raising these concerns during a consultation process that took place throughout 2006, and that would support preparation of a Communication on RFID[2]. The issues raised were articulated as follows:

- In general, citizens see no need for stimulation of RFID uptake by the European Commission, possibly with the exception of RFID in identifying and tracing of dangerous goods and pharmaceuticals
- The main concerns expressed by citizens are related to the uncertain impact of RFID exploitation on privacy. The consultation resulted in a clear request for development of a combination of technical measures and a legal framework to prevent abuse
- In general, both citizens and businesses indicate that not enough awareness about the possibilities, opportunities and threats of RFID exist
- For some areas, not enough is known to be able to establish whether measures should be taken or not (including impact on health, and impact on the environment)
- Industry is interested in using RFID for innovative applications, but is holding back because of uncertainties with regard to future demands in terms of privacy protection measures and standards

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[2] COM(2007)96 Final - Radio Frequency Identification (RFID) in Europe: steps towards a policy framework {SEC(2007) 312

- Industry asks for access to information about implementation and potential of RFID
- Industry is asking for the European Commission to ensure establishment of standards on a global level

In summation, the European Commission found in its public consultation that there was some reluctance for European-level intervention, yet a majority of people that replied to the consultation favoured further research on the possibility of increasing patient safety and possibly reducing the costs of healthcare. Thus, the most relevant policy context for our study can be found in the intentions of the Commission, announced in its Communication on RFID in March 2007, to do the following over the next two years:

- Continue to analyse the options to respond to the concerns and to address the issues at stake, taking into account the discussions with the relevant stakeholders
- Pursue ongoing initiatives in cooperation and dialogue with relevant stakeholders (in some areas)
- Further more detailed debate between concerned stakeholders, in other areas such as security, privacy, and other policy issues, in order to deepen the analysis of follow-up actions.

In responding to public support for further research, our study aims to contribute to the first of the Commission's three intentions. It fits with a number of initiatives of the Commission in the field of RFID[3], the 'Internet of Things'[4], telemedicine [5]and more, that improve patient safety and the quality of healthcare.

1.5 Report outline

Within the scope set out by the Tender Specifications of DG INFSO, and the Inception Report, this document is organised into six main sections:

Chapter 1 Introduction

Chapter 2 examines the way to full and effective deployment through an issues analysis of the primary documents of the project (ie Delphi survey report, transcribed interviews and case study reports). The qualitative analysis of the documents aimed to draw out the big issues implicated in the use and dissemination of RFID in healthcare in terms of drivers, obstacles, and critical uncertainties.

Chapter 3 compares RFID costs and benefits as revealed by the in-depth case studies. This chapter is intended to develop a list of the relevant costs and benefits to be taken into account in future analysis of RFID applications in healthcare delivery.

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[3] Eg CIP ICT PSP Theme 7: Internet Evolution and Security (including RFID); Objective 7.2: Strengthening SME competitive advantage through RFID implementation. (One pilot type B, budget € 3m)

[4] Eg 5th Call of ICT Theme in FP7; Objective 1.3 "Internet of Things & Enterprise Environments"

[5] Eg Communication from the Commission on Telemedicine for the benefit of patient, healthcare systems and society 4.11.2008; COM(2008)689 final

Chapter 4 assesses first the results of the Delphi survey, to establish a broad consensus on what RFID applications have most potential for saving costs and/or improving quality of care. The results are reviewed based on the interviews and case studies to establish the most promising RFID applications and what factors are critical for successful deployment.

CHAPTER 2 Deploying RFID in Healthcare in Europe: Drivers, obstacles and critical uncertainties

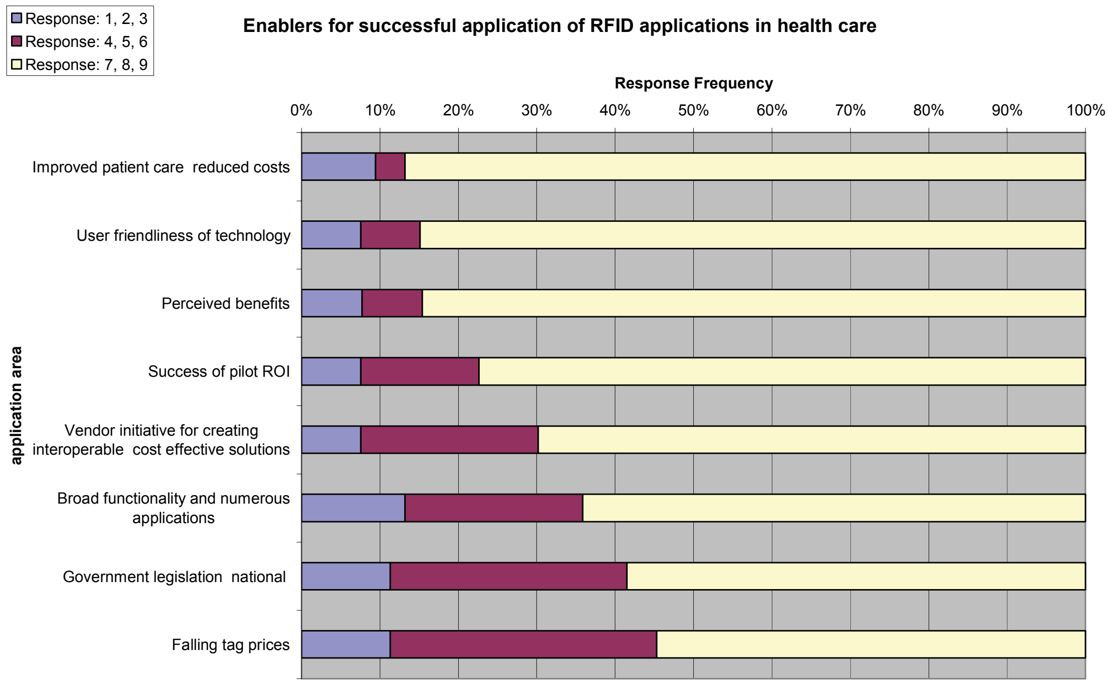
This chapter reviews the findings from the expert interviews and the Delphi survey results from the perspective of identifying prominent issues. The Delphi survey builds on a literature review in which we identified application areas for RFID in health, barriers and enablers. The aim of the Delphi survey analysis was to prioritise the identified items. We used the informed opinions of 60 experts and stakeholders in the area of RFID in healthcare, and elicited these opinions in a structured way by use of the Delphi method. The full report on the Delphi methodology and results of the survey can be found in Appendix B. We then validated the outcomes in semi-structured expert interviews. This chapter provides the outcomes of the Delphi and the interviews. The results are further confirmed though qualitative findings in the case studies.

2.1 Key drivers and enablers

Drivers push the deployment of RFID in healthcare and as such are more endogenous, whereas enabling factors create a friendlier environment for such deployment and thus have an exogenous nature. Below we do not make an active distinction between the two as in this section we are primarily interested in identifying factors with a positive effect on deployment. They include suggestions for the successful delivery of potential value propositions and key features such as, for example, their user-friendliness.

An initial prioritised list of enabling factors and drivers was generated by the review of literature and ranked by the Delphi survey of experts (Figure 2).

Figure 2 Enablers for successful application of RFID applications in healthcare



2.1.1 Identifying the drivers and enabling factors

From the Delphi survey, it is apparent that different stakeholders have different views on the importance of various enablers. Academics and healthcare providers generally rate enablers higher then the industry, especially in quality of care indicators like user-friendliness, functionality, improved care 'broad functionality', 'improved patient care/reduced costs'.

Figure 2 illustrates the enabling factors for successful application of RFID applications in healthcare as indicated by experts in the Delphi survey. Through interviews and case studies these results have been tested and enriched with experience in practice. From this comparison, it emerges that elements such as senior management leadership and general hype are also to be taken into account in conjunction with more operational factors such as technology and general costs. Based on the collected evidence it is possible to list the six drivers of RFID use and dissemination in healthcare according to patient care and safety, organisational and financial needs, and active advocacy and leadership:

Patient safety and quality of care

1. Patient safety/care quality in terms of RFID technology contributing to real improvements in quality and associated cost savings (including working routines, medication commissioning and processing, requiring visibility)

Organisational and financial needs and benefits

2. Management challenges resulting from the size and complexity associated with medical activities (ie supply chain management) conducted in healthcare delivery environments
3. Process transparency/traceability; distinct from supply chain management of medical devices/objects/equipment

Advocacy and Leadership

4. Senior management leadership and commitment to push forward the implementation of RFID and acquire staff support and involvement
5. Government policies or public/private initiatives aimed at fostering the use of RFID as part of the drive towards operational and strategic innovation; including publicity leading to a temporary "hype" around the technology and its benefits for healthcare
6. Capacity and the nature of the healthcare system as a marker for the wider environment in which RFID is used and disseminated

2.1.2 Patient safety/care linked with cost-savings

Patient safety is increasingly recognised as a key healthcare policy area in Europe as evidence is growing on the human and financial costs associated with adverse events in acute care (eg surgery), prescriptions and other aspects of healthcare. Even minor disruptions or errors in care at the patient's bedside can have severe consequences. The figures of yearly deaths due to adverse (drug) events, of increased hospital costs from longer stays and litigation, and of the preventability of such events, all contribute to motivating investment in new technologies that can help "mistake-proof" the patient journey by automating and tracking care processes. Indeed, as one of the experts noted, "patient care does not depend on a specific technology but on the processes and tools. RFID can contribute partially in some areas." In the case of medication error and adverse drug events, the case study of University Hospital of Jena highlights how RFID can support the electronic capture of change and date of expiry of medications that ensures the right medication in the right dose has been given by a certain nurse to the right patient at the right time. Thus, RFID dissemination in healthcare is seen to drive improved patient safety and care by virtue of the technology's ability to support better healthcare delivery.

Patient safety and wrong side/site/patient surgery has been a clear motivation for the Birmingham case. It has improved patient safety by capturing the identification and avoidance of four near-misses in Surgical Directorates. Nevertheless, there is an overall finding among the cases and the Delphi survey that empirical evidence of improvements in patient safety is not sufficiently recorded and that the issue of patient safety remains in the realm of 'potential' due in part to the imperfect performance of the technology.

Patient care among specific populations was given a particular focus on this issue by a few expert interviewees. In particular, there were some references to the burden of chronic disease with an ageing population (changing demographics); one respondent suggested that the use of RFID as an enabling technology "to reduce the percentage of veterans living in medical facilities" can give a "big push" to RFID applications in healthcare. Another interviewee stated that a "focus on ageing sounds promising" as a main driver of demand for RFID given that "in healthcare it would be the caregivers that need to look after the elderly and people with chronic diseases."

The prominence of this driver was reinforced by the results of the Delphi survey which demonstrated that experts felt that improvements in patient care leading to reduced costs are the most important enabler of RFID dissemination in healthcare. As a key driver, improved patient care and safety was considered by some experts as "tightly linked" to reductions in costs and, together, act as an enabler of the speed and breadth of RFID dissemination in healthcare.

However, some of the expert responses articulated an emphasis on the bottom line and "proven performance (ROI and hard savings) of RFID technology" as "a much stronger factor" driving their demand than improvements in patient care quality or safety. The main reason why cost-savings are more of a driver than improvements in patient care – although the two are interrelated – is that "in actual investment/decisionmaking processes, it always comes down to costs" – a point highlighted with an example of hospitals seeking a solution that provides better documentation to support the hospital's need to charge or claim an expense. Ultimately, whichever side of the coin is emphasised, it is important to remember what one expert clearly articulated, "eventually we will see improved patient throughput with gains in market share and income, but these [improved patient care with reductions in cost or cost avoidance] are hard to analyse today".

2.1.3 Operational management challenges (supply chain and logistics)

Another driver of RFID in healthcare is the optimisation of supply chain management since it allows the fast and efficient processing of vast amounts of items fast and efficiently, without requiring line of sight recognition. Several case studies raised issues of "low asset visibility" whereby assets could not be located easily or, occasionally, at all; or staff reported asset shortages, or assets accumulated in hospital hallways. At the Geneva hospital, RFID dissemination was primarily driven by the need to ensure that equipment and other items are available at the right time and the right place, thus sparing money. In particular, the financial motivation for improvement in logistic efficiency through automated asset tracking and logistical management was highlighted in the case of blood products, which are a temperature-sensitive, high-value product.

Similarly, IV pumps are often the scarcest and most needed assets which are frequently "subject to hoarding by nurses" – as one interviewee expressed it. This can hinder the ability to locate such valuable equipment for preventive maintenance. Thus, the ability to link personnel, maintenance requests or needs, and expensive medical items to be serviced for regular maintenance or repair was also identified as a driver of RFID dissemination in healthcare.

2.1.4 Process transparency/traceability

Here, we distinguish the issue of process transparency/traceability from the above issue of logistics management, as the latter pertains specifically to problems in the supply chain of medical devices/objects/equipment and their localisation within a site. However, healthcare processes involve more than ensuring that medical objects are transported from one point to another.

Complexity and volume of healthcare provided to patients has been increasing with modern medical technology and innovation. The combination of these characteristics requires a greater need for patient tracking and serialisation of patient identification. The case of Treviglio-Caravaggio has highlighted the operation managerial problem of patient volume and the associated increase in repetitive treatment interactions as a driver of RFID technology as the solution.

Medication commissioning and preparation, medical device/product inventory and care working routines are all *ex ante* situations often considered to be a black box. This situation exists in healthcare because most activities and patient care are documented by hand on charts and are not as comprehensive as automated methods. In the UK, for example, it is still the case that most hospitals still admit patients by producing a hand-written wristband identification which can be illegible or incomplete. Thus, many interviewees and respondents felt that RFID technology can help to increase the quality of documentation of patient care, bring documentation closer to the patient and make information readily available in real-time. In essence, RFID can create process transparency and traceability without which real improvements in the process of patient care..

The issue of process transparency as a main driver of RFID dissemination in healthcare has been identified in several case studies: namely, Jena, AMC and Geneva. In the Geneva case, process transparency was an issue driving the use of RFID for asset tracking and for the pharmacy. RFID was used to track biological swabs from operating theatre to laboratories, reduce transportation time and wrong-destination "as well as [clarify] responsibilities." In the pharmaceutical context, the driving force of the RFID application was a motivation "to increase quality and traceability of chemotherapy preparations".

2.1.5 Leadership - expertise and commitment

The particular role and excellent reputation of the leader or a champion to implement a new RFID technology has been identified by those experts involved in interviews and the Delphi exercise as a key enabler (driver) of RFID use in healthcare. In several cases, such leaders or champions were characterised by the possession of medical and/or technological expertise as well as having a particular role-based status through which the leader was imbued with and could utilise managerial control/power/influence to drive an RFID application. In the Birmingham case, the RFID application at the hospital was the "brainchild" of a particular consultant surgeon whose status as such provided internal clout among staff; in the WMH case it was noted that strong department director leadership supported the use of the technology; and, a key to success at the Centre for Communication and Informational Technology in Jena was stated to be the "expertise and commitment of key personnel". Similarly, leadership can be also a key component of effective collaborations that then drive the use of RFID in healthcare. This point was noted in the Jena case whereby project acceptance was also facilitated by "the close collaboration" between two hospital institutions in addition to the particular role and reputation of key personnel.

2.1.6 Government policy and private sector interests - Innovation

Several expert interviewees saw the role of government as a potential enabler and/or driver of RFID, depending on the policy. More specifically, the driving influence of government occurs through the provision of financial incentives (eg by having dedicated funds for technological innovation) or by directly promulgating mandates favouring RFID adoption. In terms of enabling factors, a 'pro-innovation' government health policy can be aimed at establishing favourable conditions and assisting SMEs in developing and piloting an RFID application to improve processes of care. As clearly emphasised in the context of the Wayne Memorial Hospital case study, even without having a pivotal role, government regulations can act as an incentive for the adoption of RFID technology to the extent that these applications provide organisations with a tool to comply with regulations.

Technological and process innovation calls for a cross-sectoral and cross-departmental work. This aspect is particularly relevant when examining the role of the private sector in the context of public-private partnerships. The private sector is more likely to invest in RFID if it is in a position to create "interoperable cost-effective solutions.

The role of government policy in fostering RFID is particularly evident in the case of the AMC case in The Netherlands. Here, the Government was a clear driver by leading the initiative of an RFID application, but the recipient never took ownership. The AMC represents an example of a government pushing RFID, but 'missing the point' which can lead to a failed test, reputational damage, and possibly a setback in the deployment of the technology. This case, in particular, raises a set of important points for government policies such as the need for fostering stakeholder involvement in order to maintain alignment between the interests of the various involved actors and the expected functionalities of the RFID system.

Heavy promotion and hype of RFID (through Government innovation campaigns, innovative companies, the media etc.) can drive its use in healthcare, as hospitals may want to give an image of innovativeness. One interviewee from Wayne Memorial Hospital, stated that "there was increasing use and hype associated with RadarFind." Another interviewee remarked that the market for RFID in healthcare in Europe was "past the hype" and "ready for mass-market commercial deployment." What this quote suggests is that publicity in the form of "hype" is perhaps most relevant as a driver at the early stages of deployment (ie not mass scale) and that there is a cycle of hype. However, the hype can also have negative impacts, as (hyped) negative opinion-making creates insecurity and image problems which limit investment.

Finally, from an industry perspective, government regulation on technological innovation was seen not as a driver but as a hindrance to adoption because it could lead to higher compliance cost and administrative burden. Nevertheless, it was suggested that government could play a positive role by actively engaging in standard-setting processes, particularly in supra-national (global) efforts.

2.1.7 System capacity – management structure

The project has highlighted two examples related to the larger issue of system capacity as a driver of RFID dissemination in healthcare. System capacity refers to features of the management structure either at a local site level, or at a regional level. At a local level, the case of WMH has shown how the "technologically-enlightened management team, simpler management structure, involving fewer levels and a capacity to quickly make decisions" can strongly influence the dissemination of RFID in healthcare in particular, but also technology more generally. Similarly, the latter example shares features with another example of regional level system capacity. As explained by one of the experts, Canada would be an interesting RFID market to follow because "it has teeth (regional health authorities in most of the provinces are coordinated) and it has the money. It also has a tradition in healthcare to be driven by proof of concept and evidence-based medicine."

Although these two examples may not indicate that system capacity is a key issue in the suite of drivers of RFID demand in a health context, several sources reviewed for this project stress the importance of understanding the wider environment in which RFID is disseminated from a structural perspective. In fact, bureaucratic management structures constituted a critical uncertainty, discussed in two sections below, of future RFID innovation and dissemination in terms of limited system capacity of top heavy administration in the UK's NHS.

2.2 Obstacles

Whereas the literature review and Delphi survey focused on high level obstacles possibly impeding the future of RFID deployment in healthcare (addressed in the next section), the case studies and expert interviews brought to light a number of practical obstacles to RFID deployment in healthcare. Most of these obstacles can be addressed through technical advances, but are still noted as issues in current applications.

The six main categories of obstacles can be categorised under technology issues, data management concerns and business processes, and organisational matters. The six barriers are:

Technological issues

1. Limited pervasiveness of wireless infrastructure within healthcare delivery organisations
2. Interference between different technologies (eg RFID readers and medical devices)
3. Difficulty of physically integrating parts of RFID technology (eg tag size) with the object of interest (eg metal containers) `
4. Limited portability of RFID technology due to insufficient battery capacity

Data management, security and privacy

5. Errors in overall system integration associated with the use of RFID

Organisational and financing issues

6. Relatively high hardware and implementation costs when compared to competing technologies such as barcodes or DataMatrix.

2.2.1 Limited pervasiveness of wireless infrastructure/connectivity problems

This obstacle was one of the reasons why staff in the AMC were not convinced that RFID technology would be the right solution to reduce the administrative burden and produce a flawless measurement of processes, particularly given the fact that wireless communication is not available in the OR. As an interviewee from the California Healthcare Foundation remarked, "the physical infrastructure of hospitals does create dead zones and this needs to be remembered." Similarly, in locations where wireless infrastructure is available, the "connection problem" of WiFi reliability under certain Windows applications, or of PDAs regularly [starting to roam] to find the best WiFi network was another issue concerning this obstacle to RFID dissemination in healthcare.

2.2.2 Interference

The existence and consequences of interference present a critical obstacle to RFID dissemination in healthcare because healthcare provision should not cause harm to the patient and RFID interference is a risk to patient safety. In the AMC case, early measurements of interference showed it to be a critical issue of concern (with results being published in the Journal of the American Medical Association) and resulted in one of three pilots not being conducted as originally planned. In the Geneva case interference posed major reading problems, whilst in the Jena case it was decided after the publication of the JAMA article.

There are two main aspects of interference that could prevent tracking of materials fully and in real-time:

- interference with certain medical devices in operating rooms (OR), or technical installations (eg elevators, air-conditioning, etc.)
- interference between passive and active RFID signals, whereby active tags overrule passive ones

The apparent consensus is that the technical issue of interference and physical constraints can be considered an obstacle to RFID use in healthcare and is still an issue for specific instruments in hospitals. However, some experts felt that this particular obstacle could and would be overcome: interference "will be solved in the long run" and the "right technology for location and safety in the healthcare environment requires purposeful selection such as active low power 900MHz technology."

2.2.3 Difficulty of physically integrating and/or attaching RFID equipment

The physical size of the RFID tags, or handheld readers, can be an obstacle to RFID implementation in healthcare. Size was an issue identified in four different case studies (AMC, Jena, Geneva and WMH). Ampoules are one example from the Jena case of some medical items or assets that, in the WMH case were explained "cannot be tagged due to their design or tag size". Thus, having the "right size" for users is a key obstacle to RFID dissemination in healthcare and can mean that in some cases (eg AMC), RFID cannot serve as a single solution when there are multiple requirements of RFID to operate at two different frequencies that each require a different size tag.

Physical attachment of RFID tags to moving objects or to objects with varying temperatures is problematic when objects cannot be tagged by design or when attached tags are not secure. For example, one case found it is difficult to glue to frozen surfaces such as frozen blood plasma. Another found that RFID does not work on metal surfaces such as metal-coated bags; and yet another found that most of the tags were sticky tags that easily broke.

2.2.4 Portable power

Three case studies raised the issue of power as a physical constraint to the use of RFID in healthcare. Power issues pertained to the RFID tags, the RFID readers, and the Personal Digital Assistants (PDAs) used in the RFID application. More specifically, in the WMH case, battery failure created a big set back for [application] utilisation, and in the Jena case, batteries of readers required frequent recharging (more than once in 24 hours). The added task of power management negatively affected user acceptance and utilisation of the RFID application. It introduced delays in care which could undermine the value added by automation. In particular, the automatic sleep-mode of screens meant that, in two cases, staff had to execute "time-intensive" emergency re-booting of the entire system (Geneva; WMH), and in Geneva this additional task "would delay scanning process by 3-5 minutes".

2.2.5 Mistakes and technical errors in data handling and systems integration

There are different types of error related to RFID technology that present obstacles to its use in healthcare settings. In some cases, the printing of labels was erroneous and printer software did not notify the user when errors occurred, resulting in "considerably diminished confidence in the printing process" (Geneva). As a notable obstacle, other kinds of technical error are exemplified by imperfect reading rate of RFID tags (ie not 100percent); by RFID chips not programmed in printed labels, or by hardware not responding to human contact (eg touch-screen). This obstacle to RFID dissemination is amplified by the fact that technical error also requires costly error-management.

2.2.6 Cost

The current market of RFID technology is such that RFID tags are more costly than other technologies used to support healthcare delivery and processes, such as barcodes. Cost was an issue repeatedly identified in our documents as a "major barrier" to RFID dissemination in healthcare. The result of the "relatively high cost of RFID" was, in some cases, either pilot failure or a "move towards a cheaper DataMatrix solution[6]." Similarly, the higher price differential between the cost of barcode and the cost of RFID has meant that, in the Birmingham case, the "cost factor was one reason for re-quoting the system to a client hospital that only wants barcode-tagged wristbands [rather than both]" and cost also seemed to lead to initial "reluctance at the Trust Board level" to pilot the application.

This obstacle concerns a general issue of emerging technologies, similar to the high costs of the first mobile phones. Hence, as one respondent in our Birmingham case noted, "until there is mass production to bring down the price of RFID tags, cost will remain a barrier to general implementation." Indeed, one of the experts commented that "at the moment [RFID tags] are still too expensive but the price is dropping fast. Costs and size of tags should shrink and will really lead to more uptake. We are still confronted with the non-dropping costs of readers."

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[6] But it may be worth noting that this favourable assessment of the cost of DataMatrix may underestimate eg lifetime cost of ownership or life-cycle cost, in which case the 'obstacle' is a combination of limited information (on through-life costs and expected subsequent developments), imbalanced expenditure/capital budgets and excessively high discount rates.

By contrast, the Delphi survey showed that, overall, tag costs were perceived as being of low importance (relative to other barriers) but harder to overcome as an obstacle. Across the different stakeholders it was felt that tag prices are coming down and will not be a major barrier in the future and that as long as there is a solid business case (proving ROI) costs are not much of an issue.

However cost may still be a difficult obstacle for a number of reasons:

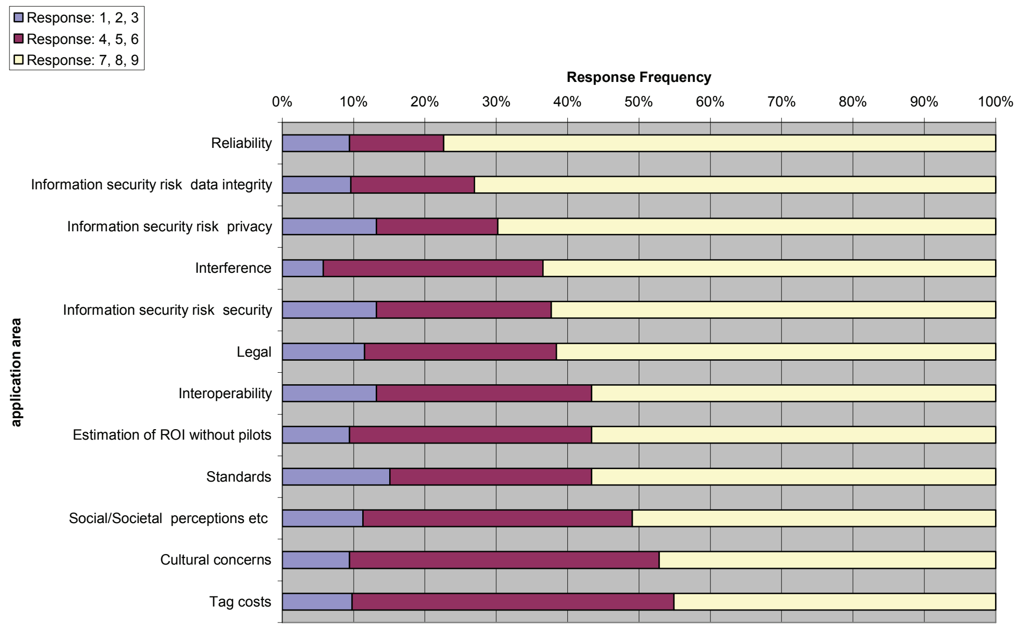
1. RFID requires "pervasive network coverage" such as integrating antennas into walls (eg for baby protection systems) and major costs are related to building/construction costs, running replacement services, and electricity as well as costs linked with accuracy such that room-level granularity with RFID "can only be achieved with choke-points due to physical laws, which add costs."
2. Hospitals are not ready to carry the costs and are not yet convinced of the benefits.
3. True costs need to be calculated by tagged item and by application which requires professional planning for which care providers may not always be well equipped.
4. System failure is a cost, and the challenges of effective back up remain unresolved.

2.3 Critical Uncertainties

There are a number of critical uncertainties, which can seriously affect the nature and intensity of the use and dissemination of RFID in a healthcare context. The majority involve a human element or a structural factor that can influence the technology over and above its physical constraints (discussed in the previous section). Another key feature of this category of issues concerns the two-way direction of effect, meaning that critical uncertainties are issues that may produce positive or negative effects/impacts in the future without any certainty if and how the impact will be produced. The most relevant of uncertainties relate to the scope, perceptions and concerns about privacy, setting, translation, resistance to change, time, culture and organisation-level complexity and variability. These factors are described individually below, though they also affect each other in the way they impact the likely RFID deployment in healthcare.

The Delphi identified the three most important uncertainties, or potential obstacles, for successful implementation in the future as issues concerning 'reliability', 'data integrity' and 'privacy' of RFID applications: 70percent of respondents or more rated these categories as important. Interestingly, 'tag costs' were perceived as the least important obstacle. Still, all 12 categories are an apparent concern, given that across all categories only a small percentage (10-15percent) assigned a rating of low importance.

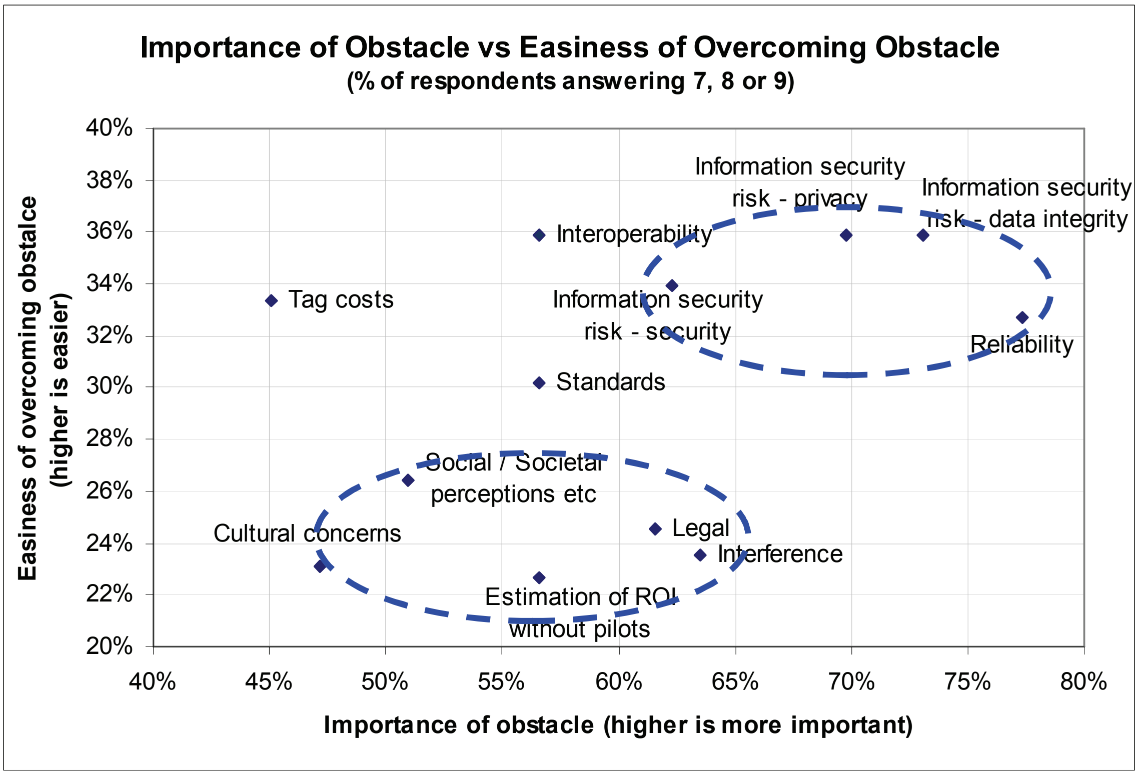
Figure 3 Importance of uncertainties involved with successful deployment of RFID applications in healthcare



Different respondent groups express largely the same views when asked to assess importance of different uncertainties. However, views diverge when it comes to the difficulty of overcoming these potential obstacles, especially for those related to information security risk. Academics thought that those related to data integrity and privacy would be harder to overcome compared to providers and industry.

Figure 4 shows the experts' view of the difficulty of dealing with these uncertainties and potential obstacles. A slightly counter-intuitive outcome is that the most important are also seen as the easier ones to address. It could be that these have been identified by the various stakeholder groups and have been debated in more depth and therefore investment may have gone into finding solutions; whereas the less pertinent uncertainties might have not received the same level of thought.

Figure 4 Importance of uncertainties to successful implementation of RFID and easiness to overcome these potential obstacles



The results of the expert survey were validated through interviews and case studies, to enrich the theoretical assessment with real life experience. This allows taking the high level analysis of obstacles and uncertainties relevant to a wide deployment of RFID down to the level of specific applications within healthcare deliver settings.

It proves that when looking forward the practitioners come up with largely the same uncertainties (perceptions and privacy, cultural norms, ROI, data integration, etc.); although - as with the previous section - more emphasis is given to human factors, such as 'resistance to change', 'user compliance', scoping of the application, etc. The 13 uncertainties that emerge are:

Technological issues

1. Managing scalability
2. Integrating RFID within the physical environment of the healthcare delivery organisation
3. Maturity of RFID technologies and applications
4. Using common standards

Data management, security and privacy

5. Identifying and addressing privacy concerns
6. Preserving data integrity and reliability

7. Managing integration of RFID generated data

Organisational and financing issues

8. Fostering change management
9. Pushing for user's adoption and compliance
10. Determining the ROI by correctly establishing costs and including non monetary benefits
11. Supporting healthcare processes with RFID (translation)
12. Matching RFID system with the organisation complexity/variability and institutional context
13. Setting RFID within culture/norms of the health system

2.3.1 Scalability/scope

The real implementation of RFID in healthcare practice raises the critical issue of determining the initial scope from the point of view of assessing the risks to future scalability. The notion of scope in terms of scalability is critical because the process of adoption is gradual and small scale implementation can help identify positive and negative aspects without incurring significant financial investments and possible resource loss. The RFID application at the WMH, RadarFind, was initially implemented for its IV pumps but quickly expanded to other portable equipment. However, despite the fact that several cases raised the issue of starting on a small scale and the importance of avoiding "big bang" RFID, it remains uncertain how this approach can generate the necessary risk assessment information. This point was most clearly articulated in a manufacturer's comment that "pilots are a silos approach and they fail to show the true benefits and costs of the technology" being fine-tuned within the silo but then "cannot be scaled facility-wide."

However true this point may be regarding reported returns on investment, this comment appears to overlook the human element of RFID adoption and application compliance which is inherent to the concept of scalability. More specifically, the concept of scalability, or scope, is also relevant to user training whereby the "value of staged staff training" was recognised at WMH because a "more gradual introduction" of the application was needed for those staff with limited or no technical skills and for trained staff to gain a practical understanding of how an RFID application is useful to them personally in real time. Thus, a small scale may produce positive effects in the case of training but the uncertainty revolves around how such training can have differential impact individual users.

2.3.2 Integration of RFID in the physical environment

The physical location in an acute care setting is a critical uncertainty that can hamper use and dissemination of RFID, particularly in the case of the Intensive Care (IC) and the Emergency and Operating Rooms (ER and OR). In the OR setting, the environment is used most of the time and any interference with medical devices in this area can be life-threatening to a patient. As a result of the physical characteristics of the OR setting, the AMC case found that any testing/experimenting with RFID technology in an OR is difficult. One interviewee stated, "you don't want to have systems that may fail and the question of what would be the back up when there is system failure has not been resolved yet." More generally, the multi-floor, multi-room hospital environment means that from a practical perspective the engineering of a successful implementation critically depends upon understanding the physical characteristics of the particular frequency, protocol, environment and product in order to tailor each RFID application to the setting in which it will be used .

2.3.3 Maturity of the technology and the applications

Time is always an uncertain factor in the adoption of a (new) technology. It usually takes longer than expected (three times) for an application to mature and disseminate. It is suggested that RFID technology may be reaching maturity only now. As such maturity is one of three theoretical reasons why there may not be wide scale dissemination of RFID yet. An interviewee suggested that "maybe in five years [RFID] will be ready for wider implementation." However, the exact length of time it will take for RFID technology in healthcare to 'mature' is clearly an uncertainty. Moreover, this unknown is critical because, as the WMH case highlights, the lengthy process of "tailoring an RFID application to a client's specific needs" is "pivotal to its success."

2.3.4 Using common standards

A small number of interviewees showed contrasting views on the direction of effect of standards on the use and dissemination of RFID in healthcare. One respondent noted that the most critical uncertainties are the "acceptance of standards and promulgation of mandates/regulation on RFID implementation." It is worth noting here that the issue of standards is a critical uncertainty because they will either "really make the market grow over the next 10 years" or their promulgation "can actually impede adoption" since, as argued by the interviewed experts, any regulation may end up being misguided due to the fact that "most policymakers are not well educated about the technologies of RFID and their appropriate uses."

2.3.5 Identifying and addressing privacy concerns

Another issue with a clear human element is the critical uncertainty of perceptions that surround and hamper RFID dissemination in healthcare. In particular, the perception of risks to privacy was a clear issue that in some cases presented a real barrier to RFID use, but in other cases did not. Our Delphi survey revealed how privacy was one of the three most important barriers to RFID applications. Interestingly, it was felt to be relatively easy to overcome compared to most other barriers. One example of how this apparent barrier of privacy concerns can be overcome is most evident in the Jena case. Here, data protection "was considered by design and motivated the decision to limit information stored on the tag." More importantly, the processes for data protection were defined "in cooperation with a number of stakeholders to ensure that concerns were properly addressed." But while these collaborative decisions may have produced a positive effect on perceptions of privacy risks in this case, the same approach in another case or context may not produce a similar effect – herein lies the critical uncertainty of this issue.

More generally, social perceptions of RFID technology and cultural norms were issues felt by the largest percent of respondents (35percent) to have less importance as a barrier but the hardest barrier to overcome. While the collected evidence offer no specific insight into why this result was found, one could argue that social perceptions and cultural norms encompass a range of issues that have perhaps been given less attention or prominence as issues of privacy which have been at the forefront of ethics committees and public debate.

Moreover, the greater the generality of this issue, and the more diffuse is the problem of perception as a barrier, the more difficult it becomes to find a solution. Despite the difference in relative importance and relative ease of overcoming the barrier between perceived privacy concerns and other social perceptions/cultural norms, three cases and eight interviewees stressed the role of human perceptions about RFID technology, its potential benefits and its monitoring as critically influencing RFID use and dissemination in healthcare. As the AMC case demonstrates, suspicion of the consequences of staff tracking and timing of communication are key uncertainties surrounding the use of RFID. The Jena case showed that discussing RFID actually creates mistrust of the healthcare provider among patients who are confronted with the possibilities of medical error which they had not considered before (ie RFID as a solution to a problem/risk that they thought/hoped did not exist).

2.3.6 Data integration

The development of models for data integration between RFID recordings and other information sources, and subsequent useful analysis, can be a critical uncertainty that may hinder the use and dissemination of RFID in healthcare. Why data integration is important for the use and dissemination of RFID is not because RFID deployment depends on it – which it does not – but because user acceptance of RFID is partially dependent on the perception of its usefulness and its potential to aid in understanding and monitoring processes that can then be improved. This factor was particularly notable in the AMC case where the usefulness of RFID recorded temperature on blood products was dependent on a model to relate the RFID data and the core temperature of the clinical sample with other information sources on room temperature. A number of experts raised the issue of vertical integration, or interoperability, or synchronisation with existing structures, such as administrative, billing or clinical datasets, as being a key ingredient to maximising the benefits of RFID. The positive impact of data integration as a technical problem at the “boundary between two parts of the process” arises from creating mastery of the whole RFID supply chain. But what makes this issue a critical uncertainty is the fact that if and how data integration produces the positive impact in the future is unknown. One key explanation for this uncertainty is that achieving mastery of the whole RFID supply chain as “proven difficult to solve” (Geneva).

2.3.7 Reliability – data loss or poor quality

Data captured by RFID tags must be absolutely reliable in order for subsequent analysis to be of any use – whether or not this data can then be integrated with data from other sources. As the AMC case showed, if the tracking of waste products is incomplete due to lack of reliability of recording, or poor quality tags, then there is no way to interpret data captured. Not only does incomplete reliability of RFID captured data make subsequent analysis and understanding difficult, but it can also create a “degree of mistrust in the system” which was exemplified among the nurses in the WMH case. In another case, the “importance of quality of information was well recognised” (Geneva). The importance of reliability in this case was highlighted by the consequence of poor data quality, namely, the costs of “error management". The latter was identified as a barrier to RFID implementation because in this case there was "difficulty in finding out which tag [was] lost in the system and silent tags can only be identified in time."

Indeed, the Delphi expert survey has found that reliability and data integrity were two of the three most important barriers to use and dissemination of RFID in healthcare. In its extreme, one expert suggested that when RFID applications use derived location systems to determine where tags are physically, they can "easily generate up to 40percent incorrect information" or error messages. But, even when the data quality of RFID tags has an overall error rate of 1-2percent, others have considered this to be "prohibitively high" as demonstrated by the Jena case. Given that the practice of medicine aims to follow the creed of "First, Do No Harm", there is an unspoken zero percent tolerance of failure of medical equipment and tools in healthcare delivery settings where a patient's life is can be at stake. Although data loss or poor quality data constitute a critical uncertainty in their own right, and are therefore discussed separately, one expert noted a dependence of reliability on achieving data integration, "RFID is reliable when properly integrated."

Finally, achieving full accuracy is stated by a number of interviewees as one of the biggest RFID problems for use and dissemination, since costs are linked with accuracy and the issue therefore affects the ROI. "There is an inverse relationship between accuracy and costs because, for example, room-level granularity with RFID can only be achieved with choke-points due to physical laws, which add costs", as one interviewee expressed it. Thus, the challenge is to find a way to improve accuracy without increasing costs given that better granularity and performance and higher cost are correlated. Apart from costs associated with technological improvements, higher costs are the result of increased human resources. In the Geneva case, the formalisation and validation of all processes by users (eg clinicians, nurses, specialists, etc.), upon which data reliability critically depends, required considerable time investment. In addition to clinical process validation, other human resources are needed with enough technical skills to localise the actual errors

2.3.8 Change management and dealing with inherent resistance to change

A critical uncertainty broadly related to RFID as a new technology is the fact that human beings who use the technology are creatures of habit and any change to working practices will be confronted with resistance to some degree – "change is always resisted" as one nurse from our Birmingham case stated. Human psychology of how people respond in terms of "resistance against getting yet another thing to do" must be addressed before RFID can be implemented in healthcare where work practices can be especially ingrained in the subconscious of staff as a matter of clinical training. In other words, how will the use of RFID influence the retention habits of medical staff, given that RFID applications present a new way of thinking; and its benefits are not immediately obvious? Notably, two case studies suggested that resistance to change differs among medical staff to the degree that the "more reluctant" staff in these cases tended to be "older" and/or not familiar with Information Technology *per se* (WMH; Birmingham).

2.3.9 Adoption/user compliance

The use of RFID in healthcare can be hampered critically by individuals who do not fully adopt the application in their work practices because the technology depends on the human-enabled element for its use in healthcare. In other words, adoption will not happen if users do not comply or buy into it. Given this human factor of the RFID user, it is perhaps unsurprising then that our Delphi results showed that "user-friendliness" was perceived as the most important enabler by care providers, whereas industry respondents considered it of less importance.

Our study revealed a number of ways in which user compliance with an application could be less than optimal and these included, but are not limited to, staff frequently forgetting to wear tags; having to remove patient wristbands for certain routines; recharging batteries of hand-held readers; losing components of the RFID application (eg a special pen - Geneva); needing to slide the status tag indicator key (WMH); and having information and related analysis that is not "simple and intuitive for the end-user." This latter point also relates to the critical uncertainty of user resistance to change insofar as hospital staff may lack the necessary technical skill to work with complex applications.

In brief, user non-adoption occurs when the RFID application causes any interruptions to routine care work or creates any additional tasks, and this compliance issue is particularly true for nurses who are "overloaded to start with, and this [new/changed work] is distracting them from nursing" (WMH). Any new application needs to take this and other legacy issues – like the existing IT infrastructure, organisational processes and structures, staff skills, etc. – with which it will interact into account.

2.3.10 Return on Investment (RoI)

The cost-benefit ratio of RFID applications can be either unclear or even negative in some healthcare settings. The high cost of standard High Frequency ISO tags may be too expensive and create high operating costs that are not justified against the (potential) benefits that are often unquantifiable, such as improved quality of care, patient confidence, efficiency gains, etc., due to the generally limited monitoring information in healthcare settings. Indeed, as one expert noted, to make RFID applications "more easily justifiable as an investment" and "improve their RoI" requires the ability of RFID to be a "general solution" through "increased multi-functionality." However, in reality, despite RFID being promoted to improve patient safety, the experience across most cases suggests that hospitals are not ready to carry the costs and are not yet convinced of the benefits. Moreover, at the AMC the uncertainty of whether the RFID application investments "can be earned back over time" was one reason why it was not considered the right solution in this case.

In addition to the critical uncertainty surrounding if and how to justify the 'bottom line', there is also the issue that projected cost forecasts as marketed by industry (at its extreme, 1 or 5 cents per tag) may not be realised in practice. Cost forecasts may be unrealised by virtue of being unrealistic or inadequate, or a combination. Nonetheless, if cost forecasts are unrealised in practice, then the real RoI will be unfavourable *post facto* in the short term. Indeed, this was the case of Jena where in addition to unrealised cost projections, the "system was unreliable and did not live up to expectations" and this was most notable in terms of bulk reading, which did not produce expected benefits and accuracy levels. In other words, the critical uncertainty of RoI lies in the uncertainty of realising both expected costs and benefits. Yet, while "proven and replicable evidence on the benefits of RFID applications" is considered by one expert to be "pivotal for their dissemination", another expert noted that there is an expectation that the true RoI on 'soft indicators' (eg quality) will "come in after patient and staff tracking is implemented." The dimension of time, which constitutes a complicating factor of RoI as a critical uncertainty, was also raised by another expert who felt that not only will RFID succeed at all points “where added value is clearly visible in comparison to existing solutions” but also “if RoIs can be achieved fast, then RFID will be chosen.”

Finally, the critical uncertainty of if and how it is possible to prove a favourable RoI is underpinned by additional complications of a methodological and practical nature. In brief, the biggest RFID problems are “computing the RoI because hospitals often have other responsibilities than time-motion studies, and other priorities to satisfy, plus measuring quality improvement is intrinsically difficult. It is noteworthy to emphasise the remarkable absence of any baseline data from which to compare changes in cost and additions in benefit. The report has found that hospitals in nearly all cases have very poor cost monitoring and accounting methods. Investments are captured directly, whereas costs savings, efficiency gains, etc. are not registered. Mostly a cost base line before introduction of the application does not exist, making it impossible to determine the actual returns.

2.3.11 Supporting healthcare processes with RFID (translation)

RFID as a carrier technology requires that complex healthcare processes and work flow, such as chemotherapy provision, are translated into electronic form. This process requires knowledge to be formalised, described and then validated based on relevant documents. Electronic translation can present a critical uncertainty that improvements in technology cannot overcome since the process depends on investment of considerable time and human resources, for instance in the maintenance of documentation. Different hospital departments and different clinical staff will be more or less willing to invest time and resources to transcribe a protocol for electronic use.

A related aspect of the translation issue is the human experience of providing care in the clinical setting. Translation of clinical practice protocols into electronic form that provides a “realistic” opinion of the “problems of implementing solutions in a healthcare environment” relies largely on first hand experience. Hence the issue of translation is critical to the use of RFID when the grouping of assets, for example, may be misleading or counter-intuitive and this can create tension.

2.3.12 Matching RFID system with organisation complexity/variability and institutional context

A critical uncertainty for the use and dissemination of RFID in healthcare relates to the very nature of healthcare delivery organisations, which are known to be complicated organisations, with any one organisation having a large “heterogeneity of needs across different stakeholders. One expert explains in further detail, organisations “can have more than 400 applications operating simultaneously and this makes the adoption of additional technologies this much harder.” Part of the difficulty of disseminating RFID in healthcare at a commercial level was stressed in the WMH case which found that no standard solution can be provided for the characteristically diverse staff vocabulary which is a pivotal element of the system. A key reason for the absence of a single solution across a complex system of healthcare delivery is the inherently human element of this issue, namely, any unified lexicon that can be found for a whole healthcare organisation will be meaningful to all staff who are specific to that setting. Yet, against this complexity, it is also argued that

that RFID only makes sense if it is implemented hospital-wide and not restricted to one department only.

It is known that when a RFID application is not tailored to individual staff needs, it can have a negative impact, which was demonstrated in the AMC case. But, what is less known is if and how this negative impact will be produced. Thus, the critical uncertainty of this issue lies in creating a balance between full deployment of RFID organisation-wide and system tailoring to staff operational needs.

In addition to the inherent complexity of healthcare organisations, some healthcare organisations can be complicated further by decisionmaking structures of the wider healthcare system. In some healthcare systems, decisionmaking is decentralised with many levels of decisionmaking, creating a lengthy process (two years in the case of Birmingham) that can delay or hinder the use of RFID technology. The inherent lethargy of bureaucracy can be further compounded by the composition of decisionmaking bodies within healthcare organisations which can be comprised of individuals from various backgrounds, some of whom may be non-clinicians with little experience of acute care and the consequences of medical error (Birmingham) and/or with little expertise in Information and Computer Technology. In the Birmingham case, there are six different committees that need to be passed for a decision about a new idea to be made. This case also raised a wider institutional context issue concerning new European Commission rules for procurement as an added complexity to the decentralised decisionmaking process of the UK and other European healthcare systems.

2.3.13 Culture/norms of the health system

Different countries have healthcare models based on cultural norms that can influence or hinder the dissemination of RFID in healthcare. To the degree that the US model creates different "adoption incentives" to the European models of public healthcare, the focus on performance ownership at the provider level means that American clinicians are more willing to experiment with technologies such as RFID and to adopt good return on investment solutions. In other words, the profit and cost-saving emphases in US healthcare have created a culture much friendlier to technology adoption. Moreover, given the cross-national differences in policy-making generally between the US, which is “responsive”, and the EU, which is “pro-active and more forward looking”, culture and norms constitute issues that have an uncertain effect on the use and dissemination of RFID in healthcare.

CHAPTER 3 Assessing the costs and benefits of RFID: a review of case studies

The original goal of this chapter was to deliver a comprehensive cost-benefit analysis of some of the most relevant healthcare RFID applications presented in the previous chapters. Unfortunately, as the case summaries presented in this chapter indicate, there is a general scarcity of data for the associated costs and benefits of RFID applications in the respective settings. This is generally attributable to the low priority placed on *ex-ante* and *ex-post* evaluations of technological innovations in healthcare systems overall, and in individual healthcare delivery organisations. This appears to be a particularly severe problem for all of the European case studies that were conducted.

Therefore, to expand current knowledge on the benefits and costs of healthcare RFID, as well as to guide future evaluation efforts, the amended goals we set for this chapter are to introduce a conceptual cost and benefit framework for collecting evidence – an essential building block for conducting a comprehensive and transparent economic evaluation of in-hospital RFID applications - and to apply this framework to a set of real-life case studies of leading healthcare RFID applications in order to examine (as far as possible) the merit of RFID in healthcare and highlight the key factors that need to be considered for RFID's further dissemination.

The chapter begins by presenting the conceptual framework we developed and the methodology on which it is based. A succinct description of each of the seven case studies of leading RFID applications we conducted, their institutional context, and key cost and benefits outcomes (to the extent available) follow next. Finally, using the collective of quantitative and qualitative data gathered in our case studies, we draw conclusions on the range of costs and benefits identified for healthcare RFID in practice, and the cases' implications for the further adoption of healthcare RFID in the EU, as no direct cross-application comparisons between costs and outcomes are possible (due to heterogeneity in application goals, contexts and generational technology).

3.1 Analytical Approach

To compare the costs and benefits of RFID applications in healthcare we adopted a three-step approach consisting of:

- purposefully selecting and conducting case studies of promising RFID applications (in terms of their potential for impacting the cost and quality of healthcare, and their market-readiness)
- conducting economic evaluations of the applications based on the quantitative data on outcomes collected during the case studies
- developing a conceptual cost and benefit framework for collecting evidence for conducting an economic analysis of RFID in healthcare.

The first two components of our approach are discussed next; the third is discussed in the Framework section.

3.1.1 Case studies

The objective of the case studies analysis was to gather in-depth information on the different benefits, costs, barriers, and enablers associated with the real-life implementation of RFID solutions for healthcare delivery; including their impacts for key stakeholders and the institutional environment within which they are deployed. An additional aim of the studies was to learn how these vary across a range of RFID applications (including in– and out–patient applications).

To achieve these, we pursued a multi-case embedded research design. Within each case the research design distinguished between the effects of RFID on different groups of actors – doctors and nurses; hospital administrators; patients and their relatives, and the healthcare system – each forming an individual unit of analysis. The case studies were also designed to provide detailed cost and benefit data to be subsequently used in the Cost-Benefit Analysis (CBA) of the studied RFID applications.

For the purposes of this study, a "case" is RFID technology as it has been introduced into a healthcare organisation and is being used in the delivery of one or more inpatient or outpatient services as a part of regular operations. So defined, "cases" include contexts of use, selected on the basis of having RFID technology as a functional part of one or more healthcare delivery work flows. The work flows that integrate the technology into the setting will serve to set the boundaries of the case. Hence not everything about the context was studied - only those aspects that have to do with the technology.

The dependent variables of interest in the case study analysis relate to the potential impact of the RFID application on quality of care, its effectiveness and the efficiency of its delivery. Therefore, variables that were examined included indicators of quality of care, error reduction, satisfaction with services, cost-savings, time-savings, and ROI rates.

The independent variables of interest – the sources of the witnessed effects – include technology characteristics of the RFID application itself (eg reliability and performance); characteristics of the institutional context (eg hospital size, inpatient vs. outpatient setting, health system financing mechanisms); and the degree of diffusion of the technology (eg what proportion of intended users in the workflow actually use the application, use it appropriately, and perceive it as useful). Characteristics of the technology implementation process were also considered (eg how the application was integrated in the application setting).

For each case study we collected data using existing documentation, face-to-face and/or telephone interviews, and direct observations through site visits.

3.1.2 Case economic evaluations

The case-level evaluations we developed aimed to investigate the real-life outcomes (benefits and costs), enablers and barriers associated with the implementation of diverse market-ready RFID solutions in the inpatient setting. As such they followed a general economic evaluation approach, based on existing evaluation models for health information technology and eHealth[7].

The fundamental purpose of economic evaluation studies is to a) assess whether the benefits from the policies under consideration are greater than the opportunity cost of those policies (from its alternative uses) and b) whether efficiency is achieved, both allocational and technical. But not all economic studies can be classified as health economic evaluation studies. To clarify and facilitate understanding, it is important to consider whether both costs and consequences of the different alternatives are examined and whether these have been systematically compared. The figure below classifies different types of studies according to whether the response to these questions is “yes” or “no”.

Figure 5 Distinguishing characteristics of alternative economic evaluation approaches

		Are both costs and consequences of alternatives examined?		
Is there a comparison of two or more alternatives?		*No*		*Yes*
	No	*Examines only consequences*	*Examines only costs*	*Examines both consequences and costs*
		1A Partial evaluation 1B		2 Partial Evaluation
		Outcome description	Cost description	Cost-outcome description
	Yes	3A Partial evaluation 3B		**4 Full economic evaluation**
		Efficacy or effectiveness evaluation	Cost analysis	*Cost-effectiveness analysis* *Cost-utility analysis* *Cost-benefit analysis*

Source: Drummond M et al. Methods for the economic evaluation of healthcare programmes.

[7] The literature provides a range of tools and supporting techniques for economic assessments of healthcare information technology applications. The main economic tools are Cost benefit analysis (CBA), Cost utility analysis (CUA), Cost effectiveness analysis (CEA), and Cost minimisation analysis (CMA). Supporting techniques include Marginal Net Present Value calculation (MNPV), Discounting (Present Value calculations), Payback period and breakeven point, Affordability gap analysis (AGA), Utilisation review (UR), Value chain analysis (VCA), eHealth utilization (EHU), Different types of costing, and Contingencies. Of these, CBA is the preferred economic concept.

Given the objectives of this study, the goal of our case studies was to obtain full economic evaluations – cost-benefit analyses - of the studied applications, data-permitting. To this end, we used a retrospective evaluation approach consisting of the following steps:

1. identify scope and borders of RFID application (explicitly identifying affected processes and stakeholders)
2. develop a logic model for the RFID application (identifying goals and timeline)
3. collect data on the five distinct stages of the implementation of the application (following the *PRINCE2* project management method, encompassing the stages: i) project initiation; ii) development of pilots; iii) building/testing of pilots; iv) roll-out of pilots; v) reporting and evaluation)
4. identify the quantifiable and non-quantifiable costs of the application and collect the data on them (differentiating between implementation and maintenance costs)
5. identify the quantifiable and non-quantifiable benefits of the application; collect the data on them (distinguishing across stakeholders)
6. connect costs and benefits; analyse data and perform sensitivity analysis

Also, to ensure that the individual evaluations are transparent and comprehensive, and contribute to create a tool which policy-makers can use to assess the impacts of healthcare RFID, we created a conceptual cost and benefit evaluation framework which is described below.

3.2 Towards an Economic Evaluation Framework for the Use of RFID in Healthcare

A major issue in the widespread diffusion of healthcare RFID seems to be its return on investment (ROI), in other words whether the Net Benefits of a specific RFID application exceeds the Net Costs. One of the key steps for the adequate assessment of the net benefits and net costs associated with the implementation of any new product or process is their adequate identification. A review of published case studies (both in peer-reviewed publications and among industry case evaluations), however, reveals that such understanding is currently lacking. The majority of existing evaluations largely fail to account for non-capital saving benefits. They also seldom detail well the implementation costs associated with the launch of RFID applications (including business case development, system integration, and initial tagging).

The lack of transparency in evaluations also leads to a failure in identifying the social case for investing in healthcare RFID. It is not uncommon for a technology to be cost neutral from a provider's point of view, but beneficial from the societal point of view. This happens because different players accrue the costs and the benefits may spread to more than the one who paid. Hence, to be able to identify the perspective of an analysis, a framework for comparable, systematic and transparent analysis is needed.

To mitigate these shortcomings we developed the conceptual cost and benefit framework presented in Figure 6 below. Its main objective is to create a tool for the transparent, systematic and comprehensive evaluation of healthcare RFID by illustrating the modality of benefits and costs associated with the use of market-ready RFID applications in the healthcare setting that a full economic evaluation – a cost-benefit analysis (CBA) - of RFID applications in healthcare needs to consider.

As the majority of mature healthcare RFID applications today are confined to the inpatient setting, the framework focuses on RFID applications relating to patients, staff and assets in the hospital. Furthermore, it aims to present the range of benefits and costs that can potentially be obtained through the application of healthcare RFID, highlighting the fact that no technology or information system can by itself bring benefits.

As previously described, the conceptual framework builds upon the case-level evaluation model we developed and our case studies. The case studies we conducted deliver a setting-oriented and a function-oriented review of several key application domains of healthcare RFID. Reviewed settings include emergency department, operating room, cross-unit and hospital-wide uses of the technology. And the specific RFID functionalities that the case studies explore include hospital staff tracing, patient tracing, materials and assets tracing and management, and decision support. Using our experience from the cases, as well as the findings of the baseline literature review and the result on the prioritization of RFID's application areas, we extended the conceptual framework to cover all key domains of in hospital RFID use. Hence, the below-presented conceptual framework combines the theoretical constructs available in the literature with their real-life validation.

The next section presents the application of the conceptual framework to each of the case studies we examined.

Figure 6 A conceptual cost and benefit framework for collecting evidence for in-hospital RFID applications

Implementation Costs
Hardware costs
Software costs
Middleware costs
Installation costs
Training costs
Process re-design costs
Labor costs (including business case development costs, system integration costs)

Maintenance Costs
Software costs
Hardware costs
Data back-up costs
Labor costs (system maintenance and expansion)

Efficiency Gains
reduction in capital expense outlays for purchasing assets and inventory
reduction in capital and operative expense outlays for renting and managing equipment
labor savings from automatic data capture and transfer
labor savings from improved process status visibility
cost capture improvement via automatic data capture
reduced care-provider turnaround rate due to improved work satisfaction
Increased patient through-put
decreased patient subversion

Quality Gains
elimination of wrong patient/wrong medication errors
elimination of wrong patient/wrong procedure errors
improved care coordination leading to more timely & available care
improved coordination of auxiliary services (eg transportation)
Improved patient satisfaction
improved infection control capacity
improved asset preventive and corrective maintenance

Other Gains
improved regulatory compliance
reduced insurance premiums
Improved process and event audit capacity
improved management & forecasting capacity

Source: RAND Europe.

3.3 RFID Costs and Benefits in Real-Life Applications and Pilots

3.3.1 Treviglio Caravaggio Hospital (Italy): Emergency and X-ray Departments orthopaedic patient tracing

Ospedale Treviglio-Caravaggio, a 440-bed hospital with a comprehensive set of ambulatory practices located in Treviglio, Italy, deployed an RFID system to track its orthopaedic patients as they are admitted to the hospital's emergency wing (ED) and then move between the ED and the X-ray department receiving medical services.

The ED, a newly-built facility, admits 55 000 ED patients annually with patient volume increasing by 10-12percent annually since 2004. Of these, roughly there are 200 orthopaedic ED cases each month. ED with an average of 3-4 individual treatments per patient.

Facing a high information request volume from patients' family members, in 2004 Ospedale Treviglio-Caravaggio adopted an active RFID system which displays the location of each orthopaedic patient (identified by a numeric code) during their clinical journey on an interactive map available for viewing at the ED lounge, and at nurse stations.

Application costs

Due to non-disclosure agreements signed by the various participants in this case study the precise quantification of the costs was not possible. However, the interviews we conducted have allowed for the collection of specific qualitative cost data, such as project elapse time and RFID hardware cost. It has been possible, therefore, to extrapolate an overall final figure that was validated during the follow-on interviews.

Implementation costs include hardware costs (€100,000) and the cost of two representatives of emergency room staff for about 15 days over the entire development and delivery phases of the project. For maintenance, labour costs include a minimal cost of ED staff time for system use, such as nurse time spent on setting up and pulling down the data from patient RFID tags.

Application benefits

Similarly, a full economic evaluation should consider all outcomes (benefits) resulting from the application.

Efficiency gains:

Given the context and focus of this application, the primary effect of the technology results from the gains associated with increased patient through-put per shift and reduced average patient servicing time, which are in turn associated with productivity improvements for nursing staff and better patient visibility.

This application has been associated with savings in Emergency Department nurse time due to the decreased need for responding to requests for information on patients' whereabouts. According to the calculations (the two scenarios are projected over five years as best practices indicate that this is the life time of a IT system, see Appendix 5) the introduction of the RFID system brings savings of about €37,183 just by cutting the time a nurse talks to patients with orthopaedic problems. The monetary value may be hypothetical as the time saved is unlikely to lead to a reduced headcount. More importantly the time that is freed up can be spent on other activities that improve the services and care for patients

Other efficiency gains include:

- effect of improved ED nurse time utilisation on amount of nurse time spent with patients (to be monetised considering link with patient safety and outcomes) and nurse shortages in the ED setting (to be monetisedmonetised considering cost of additional staff)
- effect of improved staff ability to trace the patients and avoid confusion on whereabouts, better prepare sequential treatments, and spend less time answering information requests on patient through-put in the ED or the x-rayray departments

Quality gains:

- current, immediately accessible information on patient whereabouts to patient's family at ED, resulting in better quality of care and improved patient satisfaction
- effect of ED nurse satisfaction on turnaround rates (to be monetised including cost of new ED nurse training)
- effect of unique identifiers on performing correct procedures in the ED and X-ray departments (it should be noted that tags carry only a number and patient name, no patient health record or medical information) – again to be further monetised

Other gains:

- better understanding of how the X-RAY department operates (although collected evidenced does not justify changes in the operational structure of the X-ray department)

3.3.2 Birmingham Heartlands Hospital (UK): Passive operating theatre decision support technology

Birmingham Heartlands Hospital (BHH) is part of the Heart of England NHS Trust – one of highest-performing in the UK; voted Acute Trust of the Year in 2006. Still, emerging knowledge of operating list errors and health and litigation costs of patient misidentification within the UK's National Health Service, coupled with an annually growing number of surgery patients going through BHH, motivated the creation and introduction of an RFID-based system in two BHH surgical wards: "Safe Surgery System".

Within "Safe Surgery System" patient, staff and asset identification form a workflow tracking and management environment, whose primary aims are to improve staff and patient safety, improve care, and automate data capture and transfer via the use of PDAs and electronic patient records. "Safe Surgery System" comprises a digital operating list, enabled by automated patient recognition, preventing wrong site/side surgeries, increasing hospital efficiency, and decreasing exposure to litigation costs. It is a passive pre-OR decision support technology (process management & identification system) using printed

RFID wristbands and digital photo identification linked to an electronic pre-operative checklist.

Application costs

Due to confidentiality reasons both the implementation and maintenance costs of the system could not be disclosed. The total implementation cost which was shared with us (£100,000) referred to the total cost calculated for a 12-month pilot in 2 wards, and assumed to include the hardware, software, training and process redesign costs. A somewhat different estimate was given of the total (implementation and maintenance) cost of "Safe Surgery System" - £4 per admitted patient for over a three-year horizon (the length of the vendor contract). This latter estimate includes service project management, configuration, installation (of software), testing and user training. Finally, the per-item per patient cost of thermal printed wristbands is £1.

Application benefits

This particular application received a patent and was commercialised. We were not able to obtain all relevant costs and benefits. Its creators do claim a positive and relatively speedy RoI. The benefits – in terms of quality of care improvements and economic burden of patient safety errors reductions for individual hospitals and the healthcare system – that can be associated with the wider deployment of this type of application are likely to be substantial. For example, it is estimated that clinical negligence payouts by the NHS in England are expected to rise by 80percent in 2010 to £713mm[8]. A typical contribution to the Litigation Authority may be 1-2percent of the total income of the hospital[9]. Achieving the highest compliance and error-avoidance can deliver substantial savings by reducing the hospital's insurance premium by as much as 30percent. At the national level this can bring a £213m reduction in clinical negligence payouts. In terms of hospital efficiency this system is likely to address the existing problem of under-utilization of operating theatre time (according to *Annals of the Royal College of Surgeons* 25percent of theatre time was underused (recent study of Orthopaedics). And expected quality of care benefits can include the avoidance of mismatches between patients and their care (493 reports from 45 reporting trusts were identified by the National Patient Safety Agency) and the prevention of 19percent of hospital-based adverse patient safety events.

Efficiency gains:

The benefits that "Safe Surgery System" brings include:

- patient through-put improvement: standing at 12-24percent (in cases per session) for the top five consultants at BHH, and calculated to be equivalent to having an extra patient per half day list (based on which it is claimed that the system pays for itself in six months[10]; RoI achieved in 4 months at BHH)

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[8] Legal & Medical, 2009.

[9] Oracle, 2008.

[10] Thoms, Kim. Executive briefing: Tags for smoother operations. Economist Intelligence Unit Limited; 2008, from the Financial Times as cited by Conklin, A.

Other efficiency gains associated with "Safe Surgery System" which have not been quantified include:

- nursing staff time saved on:
  - locating operation lists and checking patient status
  - administrative duties, as the system automatically codes procedures
- effect of OR nurse satisfaction on turnaround rates (to be monetised including cost of new ED nurse training)

Quality gains:

- improved patient safety: 4 wrong site/side near misses avoided at BHH surgical wards using "Safe Surgery System"
- value of ability to print patient-ID associated labels for specimen analysis obtained during surgery, thus avoiding risk of wrong patient/sample errors

Other gains:

- impact of automatic generation of metrics for daily/weekly analysis which result in:
  - consolidated and improved performance reporting
  - improved clinical progress government audit capability (the system uses role-based permission for editing of patient data and pre-operative lists)
  - ability to capture patient safety incidents at the point of care
- litigation risk reduction effect value
- ability to comply with NPSA Safer Practice Notice 24[11]

3.3.3 Amsterdam Medical Centre (NL): Operating room staff identification, materials tracing, and blood products tracing and monitoring

In 2005 the Amsterdam Medical Centre participated in three simultaneous RFID pilots including: a) identification/localisation of persons in OR (less than 50percent of staff participated); b) OR materials tracing; and c) blood products tracing. Although the three pilots represented different applications, they focus on similar processes and patient populations and relied on a common infrastructure. The applications were conceived and implemented as part of a pilot study in the area of RFID in healthcare, initiated by CapGemini[12] following an invitation by the Dutch Ministry of Health in 2005. The aim of the project was to stimulate key stakeholders to think about broader implementation of a new technology like RFID at the right level and have them put this into practice. Because

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[11] Enforcing printed patient wristbands from July 2009.

[12] CapGemini is a consulting firm headquartered in Paris and operating in more than 36 countries with more than 86,000 staff.

structurally embedding innovations in healthcare is not an easy task, the Dutch Ministry of Health was hoping to establish a breakthrough from existing practice through this project (CapGemini n.d.). In particular, the project aimed to demonstrate the added value of RFID applications in healthcare (CapGemini n.d.).

The three pilots were situated in the recovery room, four operating rooms, three intensive care (IC) units and the blood transfusion laboratory of the AMC. There were three disciplines involved: general surgery, vascular surgery and cardio-thoracic surgery. Based on data from the previous year (March-April 2005), it was expected that during the pilot period (March-April 2006) 8-9 patients and 13-14 blood products per working day would have to be tagged (CapGemini n.d.).

In the pilots, patients and staff were tracked from the recovery room to the four operating rooms and from the operating rooms back to the recovery room or intensive care (IC) unit. Materials were tracked from the unit storage depot to two operating rooms (general and vascular surgery) and from the operating rooms to the waste depot or back to the storage depot. Blood products were tracked from the blood transfusion laboratory to two operating rooms (both cardio-thoracic surgery) and recovery room or IC (CapGemini n.d.).

During the pilots it became clear that some of the initial goals were too ambitious and not feasible in practice. As noted earlier, for reasons of patient safety it was decided not to change any of the existing processes during the pilot. For privacy reasons, it was decided only to identify staff by function rather than by name.

The original objective was to not only track patients at the recovery room, OR and IC, but also throughout other parts of the hospital. It was decided however to limit tracking to the former areas for cost reasons. Tracking materials fully and in real-time was not possible, because:

- interference between the RFID system and medical devices in the OR prohibited the placement of RFID antennas in the OR
- the passive RFID signals (for materials) were interfering with and (based on technical specifications, unanticipated) overruling the active signals (for persons and blood)
- installing antennas on (moving) waste bins was difficult (due to the amount of waste bins, the need to include batteries for power and the need to use wireless communication which is not available in the OR)

For these reasons materials were scanned by hand when leaving and returning to the storage room and through RFID antennas in the waste disposal room. Because the latter were moved out of the waste disposal room to the hallway (as the result of maintenance work), not all materials were fully tracked (CapGemini n.d).

For blood products it was not possible to use the information on the temperature of the product (measured through RFID tags) as this would require the development of models to relate the room temperature to the registered temperature and the core temperature of the product (CapGemini n.d.).

The medical-ethical commission of the AMC declared that the study was not subject to the medical ethical research protocol. Even though it was not formally required, the AMC asked all patients for their consent to participate in the study. If this had not been a pilot, the question would probably arise as to how long a provider should keep patient-related data. This discussion is not not specific to RFID, however.

Application costs

For this case both the identification and then measurement and valuation of costs and outcomes is highly problematic. The costs and impacts are unknown because the pilot ran parallel to existing (highly critical) OR processes, rather than replacing those processes. There has been no evidence that hospital staff had used RFID system to improve patient safety, effectiveness or efficiency. The RFID pilot did not develop in full-scale application after completion of pilot.

Efficiency gains – outcomes:

- The data produced by the RFID system revealed that for 53percent (82) of the patients in the pilot, the patient went through the process as anticipated a priori. 31percent of patients went partially through the anticipated process (meaning that their data could be used for only some calculations), and for 16percent of patients the data could not be used because of large discrepancies between the anticipated process and the process according to the RFID system. The data makes it possible to observe the time a patient spent in the preparation/recovery room, in transit to the OR, in the OR, and back in the recovery room or IC. No process changes occurred.
- The data produced by the RFID system on the use of materials (grafts and sutures) was of limited use because at some point the RFID tags were out of stock and because of disruptions caused by moving the waste disposal room. As a result the RFID system suggested that only 85 out of 122 unique materials were used, while in fact nearly all materials were used. Still, without the disruptions it appears the system would have been able to produce valuable information on the use and flow of materials.
- The data produced by the RFID system on blood products revealed that only 38percent of the ordered blood products are transfused and that the rest is returned to the stock. It is not know how many of the returned products were re-used because only a limited number of blood products (ie only those used at the pilot sites) leave the transfusion lab with an RFID tag.

Quality gains – outcomes:

- RFID data allowed to observe how often staff would walk in and out of the OR[13]. No process changes were made.

[13] Other studies have suggested that minimising the movement of staff could have a positive impact on patient safety (due to less contamination of the air in the OR by harmful bacteria), and hence the data produced by the RFID system could be useful in monitoring these movements (CapGemini n.d., p. 39-42).

- It was not possible to obtain information on the temperature of the blood products that was easily interpretable and of immediate use.
- In a survey among staff participating in the pilot, staff members indicated that the information coming out of the RFID system regarding the tracking of patients (and displayed on screens accessible to staff) was confusing and of limited use to improve patient safety. Staff members were not hindered by tags attached to patients and products, but frequently forgot to wear a tag themselves.

3.3.4 University Hospital Jena (DE): Assisted medication commissioning and medication preparation

Jena University Hospital is a modern hospital built after 2000, with 300 staff, 26 clinics, more than 250,000 patients per year. The hospital was looking for a more efficient way to track individual antibiotic prescriptions from its pharmacy to individual patients, in order to improve medication and patient safety. To achieve this objective it pursued a pilot of an RFID-assisted medication commissioning and medication preparation (at bedside) for patient safety in its intensive care unit, comprising 72 beds, 100 doctors, 300 employees. The pilot used the platform's auto-ID infrastructure to identify, track and match medication accurately and in real-time from the hospital's pharmacy until they are administered to patients. The pilot covered 10 rooms of the intensive care unit (ICU) and involved the tagging of 120 different antibiotics (unit dose), all drug boxes and transport containers for the automatic transport system, RFID tagging of roughly 30percent of ICU patients (roughly 10 patients at one time), and RFID tagging of ICU medical staff.

Application costs

Due to cross-financing arrangement through the acquisition of SAP AII and a series of changes in the technology providers, technologies and pilot team no comprehensive estimate of the pilot's cost exists.

Application benefits

The ambition of this application has been reduce the risks of adverse drug reactions (ADR) – ones of the most common problems for patient safety. Applications that can reduce these incidents have the potential to produce substantial savings, as roughly 30percent of all adverse drug reactions (ADRs) are considered avoidable. Given that the economic burden of ADRs in Germany is estimated to be €400m , with an average treatment cost of approximately €2,044 [14], a 30percent reduction in ADRs would result in a €120m reduction of their economic burden at the national level in Germany (down to €280m).

RFID failed to demonstrate sufficient benefits that would justify its high costs and technical limitations. One of the main reasons for the abandonment of this RFID pilot was reported to be the high operation costs of standard HF ISO tags. Furthermore, the unsatisfactory tag quality (approximately 2-3percent of tags became damaged between first write and first read procedure) and the need for patient wristband removal (as tag and MRI suppliers did not provide clearance for the use of wristbands during an MRI scan), along

[14] Rottenkolber et al, 2008.

with the battery short-life of readers, gave rise to additional costs contributing to an unsatisfactory pilot return on investment. As an immediate reaction to the JAMA article, Jena decided to stop using RFID at the bedside and to replace RFID with a DataMatrix solution. The shift towards DataMatrix was easily implemented and is considered a success.

Efficiency gains (using DataMatrix as carrier technology):

- efficiency of care improvements
  - reduced shelf life errors
  - reduced stock and shrinkage
  - reduced staff time needed to maintain medication stock
  - improved visibility leading to overall improvement in medication inventory management process

Quality gains (using DataMatrix as carrier technology):

- patient safety improvements
  - increased patient safety (reduced risk of adverse drug reactions)
  - improved compliance with best practices in intensive unit medication administration
  - capacity to respond quickly and efficiently to a medication recall

Other gains:

- clinical governance improvements
  - increased accuracy and reliability of documentation extending from medication dissension to patient administration
- improved staff and patient understanding of use and merit of RFID technologies
- supports modern and innovative image of the hospital

3.3.5 University Hospital Geneva (CH): Working garment tracing & computerising chemotherapy

In 1995, the four Geneva-based university hospitals merged to become the University Hospitals of Geneva (HUG), a consortium of hospitals spread across five campuses with more than 30 ambulatory facilities, comprising more than 2,000 beds, 5,000 care providers, over 47,000 admissions and 780,000 outpatients' visits each year. HUG provides the complete range of inpatient to outpatient services, from primary to tertiary facilities. HUG is the major healthcare facility for Geneva and the bordering region of France.

Two applications were reviewed. First, an RFID-based garment tracking application (1995-2008). Second, an RFID-based application for chemotherapy procedures.

Garment tracking RFID application (1995-2008)

The merger in 1995 confronted HUG with a specific logistical problem, the management of working garment within and across the newly merged hospitals. To address this challenge it adopted and gradually elaborated an RFID-based garment tracking application (1995-2008). This RFID-enabled systems manages daily collection, ironing and redistribution of garments across 4 sites, 7 distributors, distribute 28,000 garments per week.

Application costs

No baselines and application evolution outcome data was available for this application. On the basis of in-depth interviews, an overall budget of roughly €2.1m (distributors 60percent, laundry 40percent) was estimated; according to rough estimates, approximately 10percent of the costs were RFID-specific implementation and maintenance costs.

Application benefits

The overall ROI period for this application was suggested to stand at 1.5 to 3 years (automatic distributors), and to be primarily attributable to savings in full-time employees (FTEs). The largest source of this saving occurred through the replacement of all garment distribution kiosks or semi-automated systems at HUG by automated systems. In addition, the automated system allowed for a 24/7 laundry service – much appreciated by staff and patients. The specific monetary or FTE equivalent of this saving category is, however, unknown.

Efficiency gains:

- reduced garment stock, resulting in up to 30percent reduction in garment capital outlays
- improved purchase management capacity
- ability to invest in two-piece clothing, increasing staff and patient satisfaction.
- 24/7 availability

Other gains:

- Improved quality of services (in particular 24/7 availability) realised through this RFID-enabled application (in combination with RFID enabled staff batches) supported a positive image of RFID at HUG.

RFID-supported chemotherapy for patient safety

Chemotherapy is a highly complex and high-risk process that involves numerous actors and critically depends on accurate, reliable, timely and fast information. In 2004, HUG decided to reengineer the chain of processes involved in chemotherapy and to fully electronically capture the chemotherapy process from prescription to administration and commissioning of chemotherapy preparation. The intention was to use RFID in combination with existing barcodes to computerise the complete process of chemotherapy. The applications aimed to improve patient safety by gaining better visibility in key processes and ensuring the “5 rights”: right patient, right medication, right time, right dose, and right route.

The pilot was split into two pilot phases: (1) centralisation of the preparation of all chemotherapies administered and integration into the e-prescription process; (2) the medication administration and commissioning process at the patient’s bedside (‘last mile’).

Application costs

No comprehensive overview of costs could be established. On the basis of our interviews, the following estimates were brought forward – cost estimates mainly focus on phase 2 of the unsuccessful RFID pilot and where possible also include costs for the successful DataMatrix solution.

Implementation costs:

  - investment budget: €50,000 (DataMatrix solution: €0)
  - hardware costs: €8,940
  - training to nurses: 1 hour

- Maintenance costs: annual operating costs: €24,000 (DataMatrix: €6,300)

Application benefits

Benefits realised in phase 1 of the project (for phases see above): The prescription process improved in terms of transparency and readability. In the pharmacy, it has allowed for better management of raw substances, better traceability to increased safety and standardisation of the operators’ work. Clear benefits have been derived thanks to the standardisation, completeness and readability of treatment directives. The importance of the quality of the information was well recognised and the tools did offer a significant improvement. However, formalisation and validation of all processes, including each protocol, required considerable time investments, especially by oncologists. The initial project aiming to support the prescription and production of chemotherapies had been successfully deployed and is well accepted by its users. The e-prescription process has been fully operational since 2007 at pharmacy level and fully functional in the oncology department, the first department that made the effort to define and set up protocols.

Expected benefits of phase 2 of the project (not realised through RFID): The second phase of the project aimed at RFID-enabled bedside validation of the administration of medications to patients. It only reached development phase and was only used in a pilot ward. It failed because of the experienced technical limitations of RFID (eg low reliability, availability of suitable readers, WiFi roaming, power management, poor printing, insufficient reading rates, low user acceptance). Overall the many small problems encountered made the overall process less safe. A solution was found in developing a printed DataMatrix application. This new solution is considered a success. Out of the eight medical departments administering chemotherapies, currently only the oncology department has fully implemented the DataMatrix solution, two other departments, specialised in some specific kind of pathologies, eg gastro-oncology will implement the DataMatrix solution in the near future. In total, these three departments will cover more than 50percent of all chemotherapies administered at HUG.

Quality gains (using DataMatrix as carrier technology):

- significant improvements in patient safety: facilitating better documentation in the patient record, eliminating handwritten orders, introducing controls and support during prescription, eliminating multiple retranscription, production and administration levels, etc.
- For nurses, the application helps to validate administration, provides support and increases confidence in the administration process.

3.3.6 Wayne Memorial Hospital (USA): real time asset location and management

Wayne Memorial Hospital is a 316-bed facility based in Goldsboro, N.C., which served as a beta site for the development of an RFID-based real time asset management solution. The application is focused on the hospital-wide tracking & management of portable assets & equipment and had as objective to aid WMH staff in keeping tabs on the location and status of tagged assts, including: infusion pumps, diagnostics machines, blood warmers, and computers on wheels, wheelchairs and other equipment; and to enable WMH management to make better-informed capital investment and asset utilization decisions. At present, the application - "RadarFind" - is predominantly used by clinical engineers, environmental services staff, nurses (including nurse supervisors and clinical administrators), central sterile staff and the WMH VP of Operations.

Application costs

The annual implementation and maintenance costs associated with “RadarFind” are shown in Appendix C. Total fixed cost of implementation of hardware, software and training; are $273600. Variable implementation costs amount to $25,925. Operational fixed costs of software and backups are estimated at $25,000; and annual variable operational costs – including labour are $20,860.

Application benefits

This RFID-based RTLS asset management solutions delivers a wide range of efficiency gains – most sizably in terms of forgone capital outlays and labour costs (see

Table 1 Application benefits (1), Wayne Memorial Hospital (USA)3 and Table 2 Application benefits (2), Wayne Memorial Hospital (USA)4 below), but it also has the capacity to improve quality although available data does not support the hypothesis that this is its primary use.

Efficiency gains:

Table 1 gives a summary of the capital expense and operational cost savings WMH realized in fiscal year 2007 using "RadarFind". Annual operating savings arise from cost avoidance for external partly service contracts and maintenance on the 53 pumps which were not purchased. The calculation does not include any time spent by CED on the maintenance of the IV pumps. This is partially to compensate for the fact that saved time is spent on "RadarFind" maintenance and running.

Table 1 Application benefits (1), Wayne Memorial Hospital (USA)

Realized capital expense reductions	327,147
Reduction in infusion pump purchases	303,147
Capital purchase savings	*276,235*
Annual operating cost savings	*26,912*
Reduction of bladder scanners	24,000

Source: WMH.

Table 2 Application benefits (2), Wayne Memorial Hospital (USA)

	PRE	measure	POST	Measure	Change
Wheelchair transports					
Time needed to respond to a nurse call for patient transport within WMH	40	min on av. per patient	15	min max per patient	63percent (25 min) time saved per patient transpo
Wheelchair location time (WLT)	25	min on av. per chair	10	min max per chair	60percent (15 min) time saved per wheelchair location
Annual cost of WLT *	$110,705	without "RadarFind"	$44,282	With "RadarFind"	60percent ($66,423) annual cost avoidance - wheelchair location
Wheelchair inventory					
Wheelchair round-up	16	hr/mo	1.25	hr/mo	92percent (14.75 hr) tim saved per month
Equipment inventory & cataloguing for servicing	12	Hr/mo	5	min/week	97percent (11.7 hr) time saved per month
Annual wheelchair inventory labour charges	5,958	FY'06	2,630	FY'07	56percent ($3,328) annu budget saving
Wheelchair purchase budget					
Annual capital expense budget	26,000	FY'06	13,000	FY'07	50percent reduction in capital expenses due to better repair, closer management of useful lif and avoiding waive-replacement

Additional efficiency benefits that have been associated with the system are:

- 50percent reduction in labour costs spent on locating beds (associated with staff time utilization improvement, and more time available for PM on other equipment)
- nurse satisfaction's with amount of non-care-specific tasks that need to be done, and its impact on nurse turnaround rates (to be monetised, including cost of new hires training)
- asset loss avoidance ($3,000 for IV pumps, $500 for wheelchairs)
- the elimination of asset hording decreases the clutter WMH was experiencing, hence preventing potential safety threat conditions.

Quality gains:

- improved patient safety (via better preventive maintenance of assets and infection control - with preventive maintenance improvement of all types of portable equipment from 96percent to 100percent)
- change in patient safety adverse events associated with 20 to 30 min delay of patient care (due to inability to locate a needed asset)
- change in patient satisfaction associated with faster transport of patients within the hospital
- improved infection control capabilities (hypothetically, through the ability to more effectively locate and monitor equipment that has come in contact with patients carrying antibiotic-resistant organisms
- Increased management control through the availability of a reliable and highly-beneficial management support tool (via the different user application software functions WMH helped develop).

Other gains:

- improved regulatory compliance (eg with Joint Commission standards for equipment preventive maintenance) and hospital accreditation. This brings benefits from a litigation point of view as well (avoided liability claims).

3.3.7 Royal Alexandria Hospital (UK): Real time asset location

The Royal Alexandra Hospital is a relatively large district general hospital that is part of NHS Greater Glasgow and Clyde, and is situated in Paisley. It serves a population of about 200,000 people from across Renfrewshire with a mix of urban and rural populations. The hospital provides a range of services including inpatient beds, general medical and surgical services, trauma and emergency surgery centre, HDU, medicine for the elderly, maternity hospital, Panda Children's Centre and Accident & Emergency.

The Royal Alexandra Hospital had an identified need to reduce staff time (clinicians and technicians both) in locating medical devices both for immediate clinical use and for Planned Preventative Maintenance. In response to these challenges, in May 2007 RAH adopted an RFID-based real time asset management technology. The application is used at present only by clinical technicians – to locate equipment (currently only IV pumps) for preventive maintenance, and covers predominantly IV pumps along with other key movable assets.

Application costs

The cost figures for Royal Alexandria Hospital are more detailed then in other cases (see cost summaries in Appendix C). Total implementation costs have been estimated at £210,350 with an annual maintenance cost of £35,600.

Application benefits

Unfortunately no outcome evaluation for the system has been carried out thus far and no detailed information on the benefits of this RFID system is available. However, it is reasonable to assume that the staff's increased productivity and improved equipment utilisation do imply improved efficiency in the delivery of care as with the same resources more patients and/or tests are served and performed.

Efficiency gains:

- Increased staff productivity (reduction of time clinical staff spends trying to locate portable medical devices)
- Improved equipment utilisation

Quality gains:

- More nurse time to spend with patients
- potential life-saving benefits of being able to locate devices quickly and efficiently
- Items serviced when required (improved preventive maintenance goals)
- Reduce risk of faulty devices:

Other gains:

- Ability to take advantage of additional applications such as telemetry, providing information on temperature and other environmental conditions; motion sensors that notify when a device is being used; alarms when devices are moved out of a defined zone; anti-tamper technology that alerts if a tag is removed from a device; and call button technology that can be used in a patient emergency or for maintenance notification.

3.4 Summary

Unfortunately, as the case summaries indicate, there is a general scarcity of data on the costs and benefits associated with the applications, generally attributable to the low priority placed on *ex-ante* and *ex-post* evaluations.

For both costs and outcomes, the logical process is to first identify, then measure and finally assign a value. Currently, most of the problems of evaluation healthcare RFID applications are mainly in the measurement and valuation stage as rigorous cost and outcome evaluations are not implemented. While partially applicable to the US, this appears to be a particularly severe problem for all of the European case studies which were conducted. Once data for the actual measurement and valuation of the costs and benefits of RFID solutions starts to be collected, a full economic analysis (CBA) of the impacts of RFID technology adoption on a wider scale will be possible. This is an issue that funding organisations need to take up as a requirement perhaps for funding any related research or pilot implementation.

Even though a CBA and cross-case analysis was not possible, there are conclusions that we can draw from the collective of the above presented cases:

- Applications in care delivery are having more implementation problems than in logistics; especially where they are deployed in critical treatments and processes.
- Implementation and the running costs vary significantly between cases and applications
- Benefits are also variable, although these are highly dependent on the degree to which the RFID application was successfully introduced into the organisation and was used to innovate rather than automate existing processes
- To be able to determine the added value and RoI of technology investments, healthcare institutions – particularly in Europe – need to apply better monitoring practices of cost and benefit data against a pre-investment baseline

Overall, current partial evidence suggests that there is apparent potential for realizing economic benefits in addition to improving the delivery of care when RFID applications are successfully adopted in a healthcare setting. However, without serious and committed efforts to document and to derive the relevant evidence in an undisputed way this potential may not be realized.

CHAPTER 4

Identifying the most promising RFID applications in healthcare

The previous sections of the report have examined the benefits associated with the use of RFID and identified potential barriers to their full implementation. In terms of benefits, it is important to emphasise that the identified benefits go beyond the mere financial return of investments through the calculation of their net present value or medium and long term cost savings. They also encompass specific elements such as workflow management, operational management and patient safety. Barriers, instead, involve specific technical issues such as interference, battery-power, legal issues such as privacy and security concerns, and general operational liability.

A first identification of most promising applications was made through the Delphi survey on the basis of their potential to:

1. save costs
2. improve quality of care

Subsequently, a more nuanced test was applied through expert interviews and case studies to identify five critical functionalities of RFID that make it the most suitable technology for a number of specific tasks and applications. This assessment will reveal what the critical issues are that determine the potential for success and failure of RFID applications in healthcare.

4.1 Overview of Delphi findings on the most promising RFID applications

The following paragraphs provide an overview of the analysis of the Delphi survey aimed at uncovering the most promising applications of RFID. As discussed later on, it is evident from an examination of the expert responses during the two rounds that healthcare delivery organisations' use of RFID tools and services are expected to lead to cost savings in terms of better operational management while improving the general quality of the healthcare service to patients. The Delphi report in Appendix B presents the detailed list of the applications that are most likely to reduce cost. The leading application is "asset tracking and tracing for expiration date and restocking". This can lead to general operational savings in terms of better workflow and supply chain management, like a number of other applications related to assets which are clearly seen as having the highest potential for cost reduction. RFID applications associated with patients are also relevant here, especially where they are concerned with error prevention.

In assessing the ability to improve quality of care the Delphi results point squarely at applications involving patients as those with the highest potential. Only one top-ten entry for staff and one for asset-related applications is noted. The number one application area to improve quality of care is 'patient identification to avoid wrong drug dose/time/procedure'.

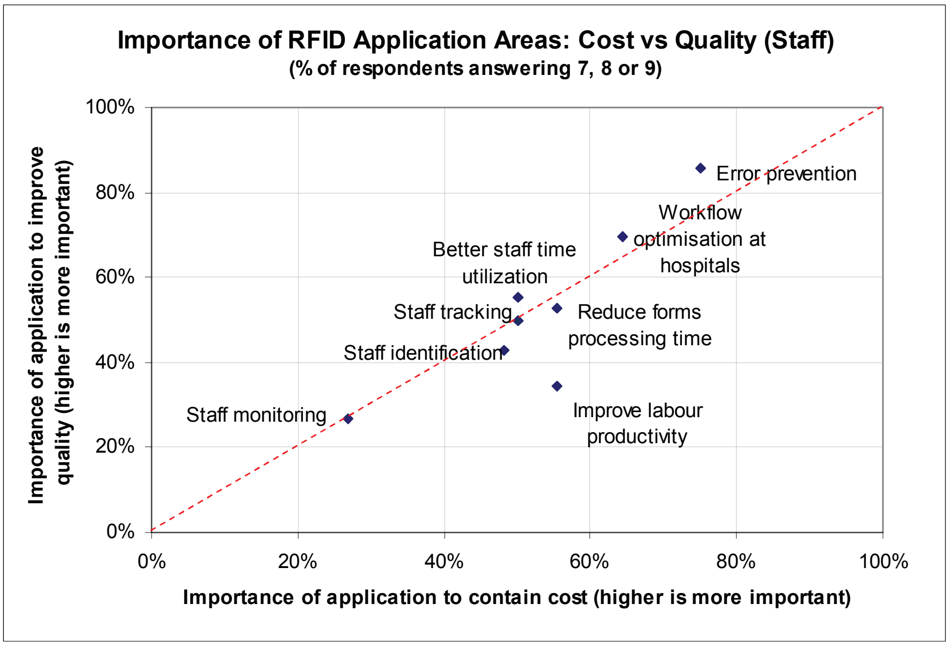
The following paragraphs provide a more detailed analysis according to three different categories: staff, patients and assets.

4.1.1 Applications relating to staff

The analysis of the Delphi results allow for a more detailed understanding of the general relationships between the importance of RFID for containing operational costs associated to staff management versus their role in improving general quality of service delivery. Figure 7 shows for each area the percentage of Delphi respondents – those who indicated that they felt these applications where important – giving a high rating for quality (vertical axis) and cost (horizontal axis).

The figure indicates that RFID applications allow for cost savings by improving labour productivity while, as previously indicated, error prevention appears to be of (slightly) higher importance to improve quality than to contain cost. Still, experts do not see staff monitoring via RFID as very beneficial. This last point, nevertheless, may be justified primarily with a potential sense of discomfort among staff to be constantly tracked. It is also possible to relate this to the potential limited knowledge of RFID technology by healthcare staff.

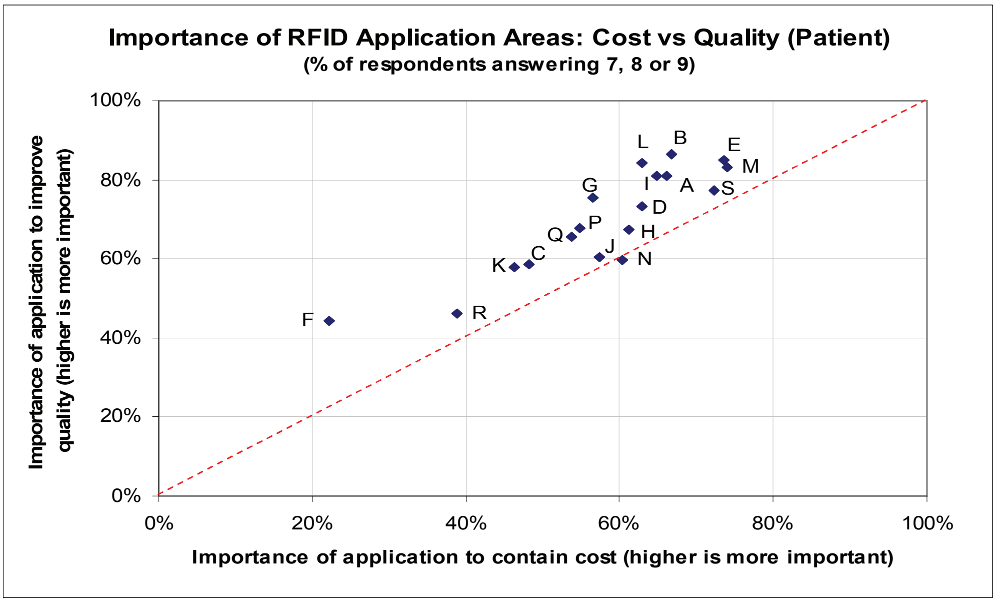
Figure 7 The importance of RFID applications: Cost versus Quality (staff)



4.1.2 Applications related to patients

When it comes to patients, the results are significantly different as RFID tools are seen as improving service quality more than achieving general cost savings. Figure 8 shows, in fact, that for all but one application related to patients (patient tracking and tracing at hospitals for monitoring patient flow), respondents thought RFID have higher importance for improving quality compared to containing costs (ie all dots are situated above the 45-degree line).

Figure 8 The importance of RFID applications: Cost versus Quality (patients)



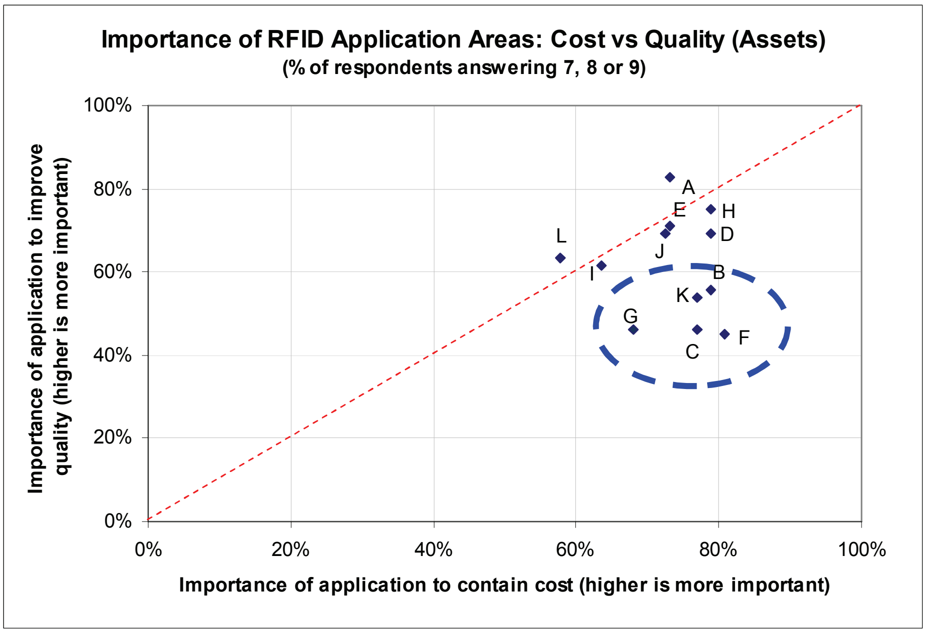
Legend:

A	Accurate patient identification
B	Accurate patient identification for medication safety
C	Critical information to the patient
D	Dementia patients tracking and tracing in out patient
E	Eliminate wrong patient wrong procedure surgery
F	Implanted RFID carrying medical record
G	Infant identification hospitals to forego mismatching
H	Infant tracking and tracing hospitals for security to forgo theft
I	Intelligent medication monitoring for elderly at home
J	Interventions automated care pathways procedures audit management
K	Monitoring tracking of patient location
L	Patient identification for blood transfusion
M	Patient identification to avoid wrong drug dose time procedure
N	Patient tracking and tracing hospitals for monitoring patient flow
P	Patient tracking to ensure safety access control dementia psych
Q	Portable current and comprehensive health records
R	RFID ingested or implanted to provide real time information on health indicators and vital signs
S	Tracking of drugs supplies and procedures performed on each patient

4.1.3 Applications related to assets

Another promising area for RFID applications is general asset management. However, different from the previous results, the evidence indicates that these applications can both lead to cost savings and improvement in quality of care. In the first case, these tools are expected to achieve operational savings by improving inventory utilisation and management, as well as general asset tracking and access. Improvements in quality of care are expected instead through the use of RFID for the management of sensitive medical instruments and materials/substances such as blood bags and tissue.

Figure 9 The importance of RFID applications: Cost versus Quality (assets)



Legend:

A	Asset identification blood bags identification hospitals OR to ensure blood type matching
B	Asset tracking
C	Asset tracking and tracing for access control and inventory shrinkage decrease
D	Asset tracking and tracing for expiration date and restocking
E	Asset tracking and tracing to avoid procedure delays
F	Inventory management
G	Inventory utilisation
H	Maintenance of medical equipment
I	Materials tracking to avoid left ins
J	Medicine tracking
K	Real time inventory count and location tracking
L	Tissue Bank operations

After this summary of Delphi results, the next paragraphs will provide a deeper assessment, combining the results of all analytical steps in the project: literature review, Delphi survey, interviews, and case studies.

4.2 Most promising RFID applications in healthcare

A comprehensive overview of all the evidence collected during the study leads to the identification of the following four domains where it would be possible to see the promising applications of RFID in healthcare delivery:

- Tracking of
    - assets
    - people (mostly patients)
- Identification of patients
- Automatic data collection and transfer
- Sensing for monitoring of patients

4.2.1 Tracking of assets and patients

RFID technologies can help in tracing the movement of either individuals or objects, or both. In the case of individuals, RFID-enabled tracking can provide an individual's location in real-time or their movement through critical choke points such as entry/exit in/from designated areas. This feature is specifically relevant in cases of patients with specific illnesses such as dementia or when it is necessary to feed information back to relatives without involving professional staff to communicate the whereabouts of a patient.

RFID technologies also provide promising applications in tracking medical tools and instruments such as, for example, surgery tools or wheelchairs. . This is in itself not new since it is a direct extension of their use in industries with complex supply chains such as shipping, manufacturing and retail. An interesting case is the "RadarFind" solution implemented by Wayne Memorial Hospital. This RFID-enabled application is predominantly used by medical and support staff to keep tabs on the location and status of tagged assets, including: infusion pumps, diagnostics machines, blood warmers, and computers on wheels, wheelchairs and other equipment. The ability to easily and quickly locate an infusion pump at the time of its need in patient care (and also at the time of maintenance) is a clear benefit to the patient and the care provider who would otherwise be left waiting until this item was found after a (lengthy) search.

RFID can furthermore improve the overall inventory management of a hospital provided that they are integrated with a supply management software application. This integration can lead to a number of critical improvements.

- Availability of data about current stocks can ameliorate the overall planning and the move towards a more just-in-time supply chain management.
- This can lead to accurate procurement processes and, more importantly, more structured cash flow management.
- It can also allow for the rapid identification of specific tools that may present a safety hazard, are being recalled by the manufacturer, or are required in an emergency situation.

- RFID applications can improve the management associated with the overall workflow of medical instruments starting from their initial procurement to their final use and dismissal.

4.2.2 Identification of patients

Identification and authentication of patients are promising areas for use of RFID. Assuming that the association between a patient and a reader is done correctly, RFID can improve accuracy in patient identification leading to several benefits. The reason why patient identification can be a problem in many healthcare settings is due to the fact that the dominant mechanism in many settings for identifying a patient relies on hand-written wristbands which can be illegible or be prone to spelling errors, or both. Thus, the benefit of RFID-enabled patient identification is the potential to:

- improve patient safety by reducing incidents such as, for example, errors in drugs, doses, times, or even procedures when the root cause of such adverse events is 'wrong patient'. Thanks to RFID applications, medical staff are put in a position to access precise information about the patient and link the individual to a specific drug or treatment; it is also possible to imagine the possibility of the use of RFID for auto-ID enabled medication
- improve authentication and matching between patients, as in the case of a secure electronic hand-shake between mother and new born babies to prevent and/or reduce potential cases of mismatching.

The evidence has pointed to the added value of RFID technologies, in particular RFID active tags, in providing better identification and authentication functionalities compared with regular barcodes. The latter, in fact, are passive tools with no intelligence in them which means that they can allow just a yes/no identification and authentication process but are not able to provide addition information (unless the reader is linked to a hospital information infrastructure). By contrast, active RFID tags have intelligence in them. Therefore, they can be provided with enough storage capabilities to contain data (eg medical record) which is beyond a mere number or symbol.

4.2.3 Automatic data collection & transfer

A third promising application refers to the automatic data collection and transfer. Automation is an important feature that can lead to a reduction in form processing time and related human errors. For example, it is possible that specific drugs and equipment are automatically ordered from suppliers when a certain minimum level is reached. In this case, medical staff does not have to allocate time for processing forms or potentially make mistakes if this activity is done in an emergency situation. Contrary to the previous benefit, this case is directly related to the necessity of having RFID readers and antennas integrated with the clinical research information system of a hospital or other healthcare delivery organisation.

These integrated systems can be distinguished by their complex constellation of capabilities. One of these capabilities is the rapid assembly of information from different sources. Another capability is the automatic initiation of a data-mining process that covers all relevant information sources (linked by integrated system) – information sources that are often created for that specific healthcare institution. In this context of automated system integration, particular attention should be directed to the use of RFID to enhance procurement efficiency, as already discussed in the previous section. For example, one might consider how RFID-enabled data collection on medical devices or drugs at the hospital site (or other healthcare setting) can be automatically sent in electronic form to a preferred supplier that can then respond by returning an electronic invoice for payment. Notably, automatic data collection and transfer for the purpose of inventory management is just one specific aspect of the most promising benefits originating from RFID.

Finally, expert interviews and case studies have also indicated the promising use of RFID applications for automatic:

- medication commission: this requires that a specific hospital unit, for example intensive care, has a system that integrates information concerning drug dosage, drug dispensing, and individual patient medical data in order to allow the automatic transmission of a prescription order by an ICU staff to the pharmacy
- medication preparation: this application may also be extended to include order-to-delivery of prescriptions, thereby providing new visibility at the end-point of care ie the patient's bedside.

4.2.4 Sensing for patient monitoring

Sensing is the fourth promising RFID-enabling functionality which we identified. In particular, sensing is a promising functionality of RFID in the context of diagnosing patient conditions because RFID-enabled data collection can provide real-time information on individual health indicators. However, this feature of RFID technology needs to be considered as a component part of an evolving set of e-health applications. These may include situations where hospitals or other care delivery organisations can manage devices from a distance required for sensing and standardise interfaces to support better plug and play interconnectivity. These sensing functionalities also contribute to the asset tracking feature of RFID, as discussed above, as well as to repair status and general software patching levels.

RFID sensing functionalities are not just associated with patient monitoring. The collected evidence has highlighted the use of RFID's sensing feature in terms of the specific issue of compliance monitoring. For example, it is possible to use RFID-enabled staff identity cards to check staff compliance with basic hygiene rules such as washing hands. A second specific issue is the contribution of the sensing functionality to overall system access security, in particular by staff according to their role in the institution. As previously noted, RFID active tags can be part of an overarching identity and access management solution that regulates staff entrance to specific areas.

4.3 Critical conditions for transforming RFID promises in reality

Having identified the most promising areas for their use, this section provides general thoughts on the main factors that need to be taken into strong consideration for the successful implementations of RFID systems.

The previous section has provided a detailed analysis of the evidence collected by the project overview via the case studies, the Delphi survey, and expert interviews. The analysis has concluded that the implementation of RFID by healthcare delivery organisations can lead to operational benefits in terms of patient safety and asset management. However, the same analysis has emphasised that the achievement of benefits requires overcoming a set of potential barriers. In particular, it has been highlighted that the use of RFID in care delivery leads organisations to several implementation issues. The same cannot be said of their use for critical assessment and general supply management.

The evidence, in addition, has not provided a definitive conclusion on the impact of costs for the implementation of RFID. In fact, the case studies have provided mixed results. It is evident, therefore, that this aspect needs to be assessed on case-by-case basis. Still, a precise assessment requires healthcare delivery organisations to collect quantitative evidence of the situation prior to the implementation of an RFID system. The lack of these data does not allow for a precise *ex post* assessment of the benefits generated with the introduction of RFID.

RFID are instruments or tools whose success is not only dependent on technical performance. Their success is directly related to the strategic support and commitment of senior management and operational involvement of all stakeholders who are to use the system. The latter condition is needed since the development and implementation of RFID system are often part of a stronger willingness of a healthcare delivery organisation to innovate its internal organisation and operational processes. This innovation, nevertheless, can only happen if all medical staff expected to use the RFID system is directly engaged in the identification of the required functionalities, its design and final testing prior to its release.

The hype cycle associated with the use of RFID is over. Initially, hospitals and other healthcare delivery organisations had decided to join the RFID hype cycle as part of an effort to become more innovative. However, as clearly identified in the case studies, the actual use of the tools has produced mixed results. Senior management commitment is essential, since the introduction of RFID within healthcare delivery organisations can have an impact on established overall organisational and operational processes. Their development and implementation, moreover, can face a set of technical difficulties such as their integration with pre-existing technical infrastructures or closed systems, interference with other instruments and general limited performance. Strong senior commitment, therefore, is required to make sure that these technical obstacles are either anticipated during the design phase or overcome with appropriate technical turnarounds. Senior management commitment is needed to maintain evolving RFID implementation in line with the expected objectives.

Senior management commitment is also required to foster the engagement of all stakeholders and actors who are to use or benefit from the introduction of RFID tools and instruments. The direct engagement of healthcare staff is specifically required when the RFID system is to support patient-centric activities. In particular, their engagement is required when the system requirements and functionalities are identified and their potential impact on the remaining organisational and technical infrastructure is defined. It is also needed when RFID is compared with more consolidated technologies such as DataMatrix, barcodes, or WiFi-supported tools.

This engagement is also required when the RFID system is going through the various test phases and is in the process of being released and delivered. Healthcare staff can indicate to the development team functionality changes so as to ensure that the new RFID system supports specific operational activities. However, engagement is also required since the introduction of an RFID system, as with any IT system, is expected to change the current situation. In this context, healthcare operators may be forced to resist this change unless they directly see specific benefits for their day-to-day activities. Continuous engagement and senior management support are the two elements that can overcome resistance to the introduction of new systems, including innovative ones such as those related to RFID.

Senior management support and stakeholder engagement are also needed to overcome specific cost issues associated with the introduction of RFID systems. As clearly indicated by the collected evidence, the *a priori* quantification of the overall costs associated to the implementation of an RFID-enabled technological infrastructure is a complex undertaking. It requires that healthcare organisations have the necessary data to simulate the direct and indirect costs associated to the implementation of the new RFID system. These data are also needed to define different development and implementation scenarios, especially when a complex hardware/software selection is undertaken. However, data collection is not restricted to the design phases. After the implementation and release of a RFID system, healthcare organisations are expected to define data collection processes for the quantification of the benefits associated to the new system. They can also use this data to identify potential operational bottlenecks that require the introduction of new RFID-enabled corrective actions. The strategic objective of these activities is to make sure that a healthcare organisation is in a position to extract maximum operational and organisational value for their investment on innovative solutions, such as those centred on RFID.

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APPENDICES

Appendix A: List of interviewees

As part of the evidence collection, RAND Europe staff has interviewed the following experts:

Thomas A. Bradshaw, VP of Operations, Wayne Memorial Hospital (WMH)

Jason Britton, CSci, Principal Clinical Scientist, St. James' Hospital, Leeds, UK; (formerly Clinical Scientist, Royal Alexandra Hospital, Renfrewshire, UK)

Vincent Carrasco, Chef Medical Officer, RadarFind

Bill Crounse, Senior Director, Worldwide Health, Microsoft

Roberto Birago, CEO, SICED System Integrator (Treviglio)

Guenther Braun, HCS Consultants

John T. Collins, Director, Engineering and Compliance, American Society for Healthcare Engineering, USA

Rolf Dahm, n-tier

Massimo Damiani, CEO Softwork, RFID Solution provider (Treviglio)

Jonah Frolich, MPH, Senior program officer, Better Chronic Disease Care program, California HealthCare Foundation

Ross Folland, Head of Product Development, Safe Patient Systems, Lincoln House, Brimingham Heartlands Hospital, Birmingham

Tobias Goetz, SAP Sales (Jena)

Michael Hartmann, Head of pharmacy Universitaets Klinikum Jena

Stephen Miles, Chair, MIT Enterprise Forum RFID SIG, Research Affiliate, MIT Auto-ID Labs, USA

Dr. Björn Kabisch, Head of research and development; project manager Universitaets Klinikum Jena

Peer Laslo, SAP, Key account manager Audto-ID (Jena)

Christian Lovis, Director of Clinical Information Unit, Service of Medical Informatics

Heinrich Oehlmann, EHIBCC

Deven McGraw, Director, Health Privacy Project, Center for Democracy & Technology

David Morgan FRCS, Founding director, Safe Surgery Systems Limited, Lincoln House, Brimingham Heartlands Hospital, Birmingham

Dawn Norris, Chef Clinical Nurse 2nd Floor, WMH

Nurse, Day Surgery Ward, Heartlands Hospital, Birmingham

Dave O'Neil, JD, MPH Senior program officer, Innovations for the Underserved program California HealthCare Foundation

Kevin Rustill, Head of Testing & Quality, Safe Patient Systems, Lincoln House, Brimingham Heartlands Hospital, Birmingham

Gerard Scriba, Professor of Pharmaceutical Chemistry, Department of Pharmaceutical Chemistry, Universitaets Klinikum Jena

Lara Srivastava, ITU, New Initiatives Programme Manager with the Strategy and Policy Unit (SPU)

Stéphane Spahni, project manager at SIM

Patrick Solier, Administrator DEX, Deputy manager, responsible for accounting and financial management, technical projects and informatics for department of logistics (retired - Geneva)

Martine Velkeniers, Mobility Solutions Marketing Manager, Marketing/CMO, Cisco Systems Inc.

Appendix B: Delphi methodology and results

METHODOLOGY

A Delphi exercise to elicit expert opinion

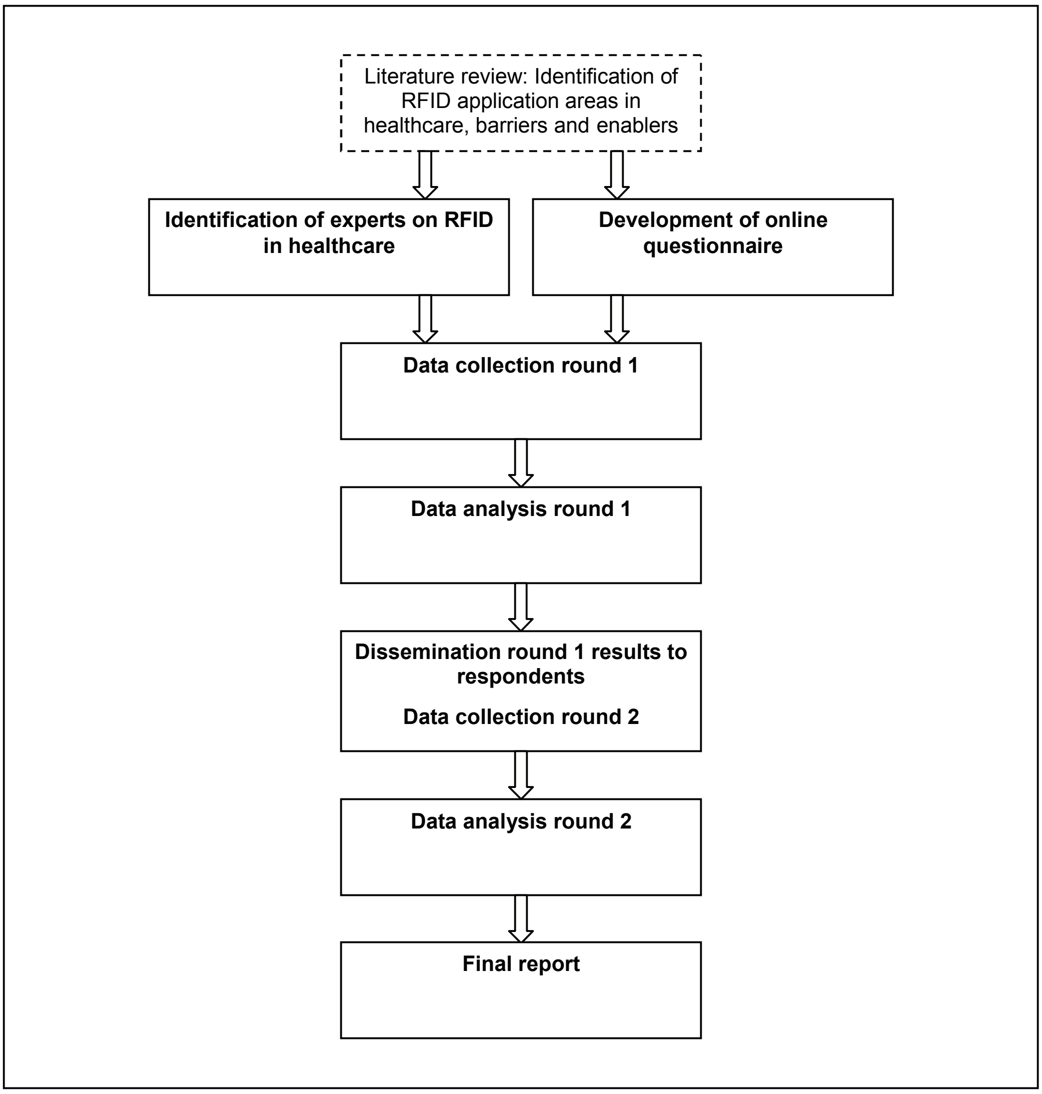
To prioritise application areas for RFID in healthcare and barriers and enablers, we used a two-stage Delphi process (Brown, 1968), in which we asked experts to rate the importance of application areas, barriers and enablers on a nine-point scale. We will explain the specific application of this method in our study in further detail below.

The Delphi method is a widely used method to obtain forecasts using expert opinion in a structured way. It was developed by Helmer, Dalkey and Rescher in the 1960s and used initially in defence community at the RAND Corporation. Later on, the method was used in many other fields as well, notably healthcare.

Since RFID applications in healthcare are only in their infancy, the prioritisation of these naturally involves a certain degree of forecasting ie at the current moment we cannot easily prioritise these using historical evidence as such evidence is not widespread. This problem is obviously not unique to RFID, but equally true for technological innovations in general.

Figure A shows the different steps in our research approach. The first step in this approach was part of our previous deliverable (Vilamovska et al., 2008) and we will therefore not discuss this step in this report. We will discuss the other steps in the remainder of this chapter.

Figure A Schematic overview of study approach



Sample and respondent characteristics

We established a convenience sample of 116 experts and stakeholders regarding the application of RFID in healthcare or in general. People were eligible for inclusion if they were a (co-)author of at least one publication that was part of our literature review, were affiliated with an organisation or company involved in the production or implementation of RFID technology, or were affiliated with an organisation providing healthcare and involved in the implementation if RFID technology.

Of the 116 experts we identified, 59 responded to the first round of our online questionnaire (50.8 percent response rate). Of those 59, 19 responded to the second round as well (16.3 percent response rate). Based on their (primary) organisational affiliation, we categorised respondents as representing ‘academia’, ‘providers (of healthcare)’, ‘industry’, and ‘other’.

Table A shows the number of respondents in the first round (first row) and second round (second row). The last column of the third row shows that overall 32 percent of the first round respondents responded to the second round as well. However, this percentage does not appear to be constant across the four groups of respondents. In particular, the percentage is about twice as high for respondents from academia (47 percent), compared to the other three groups (varying between 21 and 29 percent). As a result, academics are over-represented in the second round, compared to the first round, and make up nearly half of the respondents to the second round (as shown in the bottom two rows).

Table A: Number of respondents in the first and second round by category

	Academia	Provider	Industry	Other	Total
1st round	19	9	17	14	59
2nd round	9	2	5	3	19
Response 2nd round as % of 1st round response	47%	22%	29%	21%	32%
1st round (% of total number of 1st round respondents)	32%	15%	29%	24%	100%
2nd round (% of total number of 2nd round respondents)	47%	11%	26%	16%	100%

Online Questionnaire

Our questionnaire comprised 3 sections: 'Application areas', 'enablers' and 'barriers'. Within the first section (Application areas), we asked the following question:

> *Q1. In your opinion, on a scale of 1-9, how important is each of the following application areas for RFID to contain cost and improve the quality of healthcare?*

We then listed a series of 38 application areas, divided into three sections: Staff (8 application areas), Patients (18 application areas) and Assets (12 application areas). We provided instructions on the anchoring of the 9-point response scale as follows:

> 1 – very unimportant
>
> 5 – neither important nor unimportant
>
> 9 – very important

Because we asked the respondents to rate the importance of each application area both with respect to containing cost and with respect to improving quality, the total number of items in the first section was 76.

Within the second section (Enablers), we asked the following question:

> *Q2. In your opinion, on a scale of 1-9, how important is each of the following enablers to facilitate wide-scale RFID implementation in healthcare?*

We then listed 8 enablers (identified in our previous literature review, Vilamovska et al, 2008), and gave respondents instructions on the anchoring of the scale, identical to the previous section. Within the third section (Barriers), we asked the following two questions:

Q3. In your opinion, on a scale of 1-9, how important is each of the following obstacles to wide-scale RFID implementation in healthcare?

Q4. In your opinion, on a scale of 1-9, how difficult is it to overcome each of the following obstacles to wide-scale RFID implementation in healthcare??

We then listed 12 barriers (identified in our previous literature review, Vilamovska et al, 2008) for each of those two questions. For Q3, we used the same anchoring on the nine-point scale as in the previous sections. However, for Q4, we used the following anchoring:

1 – very hard to overcome obstacle

9 – very easy to overcome obstacle

We used the online survey tool SelectSurvey.net available from ClassApps (www.classapps.com), and presented each of the 3 application areas (staff, patients, assets) on separate screens, also separately for ‘cost’ and ‘quality’. We also presented Q2-Q4 on separate screens. In addition, each of the 38 application areas was hyperlinked to a pop-up window in which a short explanation and/or example was offered, to ensure a common understanding across the respondents.

Data collection

We collected data in two rounds, as follows:

Round 1

In the first round, we sent invitations by email to the 116 experts in our sample. The invitations were sent out on 31 July 2008. In the email, respondents were requested to visit the survey website (by clicking the corresponding link provided in the email), and enter a unique username and password (also provided in the email). Respondents could then start to fill out the questionnaire by simply ticking a number of boxes. They were allowed to temporarily suspend answering the questionnaire, and could re-login at a later date, using the same username and password provided in the email invitation.

After three weeks, we started to send several reminders by email, and also followed up by telephone. Data collection for the first round officially ended on 9 September 2008.

Round 2

In the second round, we sent each respondent to the first round an email with a personalised PDF document attached. In this document, each respondent could see for each item on the questionnaire a comprehensive amount of information obtained in the first round, as shown in the example in Figure B:

- column 1: his/her own response (ie a rating between 1 and 9)
- column 2: the median response across all other participants
- column 3: the 25th percentile across all participants
- column 4: the 75th percentile across all participants

- column 5-13: the number of responses (frequency) for each of the nine response options

Figure B Example of information provided in second round of the Delphi process

	Response	Median	25th Percentile	75th Percentile	1	2	3	4	5	6	7	8	9
Workflow optimisation at hospitals	5	7	6	8	2	2	2	0	5	10	11	13	12

Respondents were encouraged to change their response in case it diverged from the rest of the group, although this was not mandatory if they felt strongly about their original answer. In order to make any changes they had to re-login to the online survey tool and make the desired changes, after which they had to click the 'done' button to record the changes. Respondents were also allowed to email any changes directly (descriptively), after which a member of the research team would record the change in the data. Finally, we also asked respondents who preferred to not make any changes at all, to inform us about this, as this would allow us to distinguish these respondents from any non-respondents to the second round.

We also allowed respondents in the second to provide qualitative feedback (written comments) regarding their answers or changes therein. The second round data collection started on 29 October 2008 and ended on 2 December 2008. Unfortunately, the response rate to the second round was substantially lower than to the first round, even though we made similar efforts as in the first round to follow up non-respondents by telephone. We noticed a general fatigue and lack of interest among non-respondents in the second round, in part due to the (perceived) substantial amount of time involved to complete the task.

Data analysis

Due to the low response rate in the second round, we used only the data obtained in the first round as the main dataset for our analysis. Thus, the findings reported in later sections are all based on the data collected during the first round, and findings based on the data collected during the second round are discussed separately in the final section. Due to the very low number of respondents (fewer than ten) providing written comments, and the very diverse nature of these comments, we were not able to use these comments in any of our analyses.

In the results that follow we either summarize ratings across respondents by showing the average or frequencies. In the latter case, for clarity of presentation, we do not show the frequencies of responses for each of the nine (1-9) response options separately, but rather show frequencies across bins of three adjacent response options, as follows:

- response options 7, 8 or 9 ("important")
- response options 4, 5 or 6 ("importance unclear")

- response options 1, 2 or 3 (“unimportant”)

By binning the responses it is inevitable that some information will get lost, but we gain a lot in terms of visual presentation and ability to summarize the data in a convenient format.

In most cases we tested whether responses differed by respondent group (academics, providers, industry, and ‘other’). We used a 95percent level of confidence ($p<0.05$) as our cut-off point for describing a difference in average ratings between respondent groups as ‘statistically significant’.

All analyses were conducted using the R language and environment for statistical computing (R Development Core Team, 2008), and all figures were prepared using Microsoft® Excel 2003.

DELPHI RESULTS: most important areas of application

Table B shows that the most important areas for RFID application to contain cost primarily relate to assets, with ‘asset tracking and tracing for expiration date and restocking’ as the number one application area. Applications related to patients only start to appear at the 7th place, and for applications related to staff only one top-ten entry exist (‘error prevention’).

Table B: Ten most important application areas of RFID in healthcare to contain cost

Rank	Area	Application	Average rating
1	assets	Asset tracking and tracing for expiration date and restocking	7.4
2	assets	Asset tracking	7.4
3	assets	Maintenance of medical equipment	7.3
4	assets	Asset identification / blood bags identification at hospitals or to ensure blood type matching	7.3
5	assets	Inventory management	7.3
6	assets	Asset tracking and tracing for access control and inventory shrinkage decrease	7.3
7	patients	Patient identification to avoid wrong drug dose/time/procedure	7.2
8	patients	Eliminate wrong patient/wrong procedure surgery	7.1
9	patients	Accurate patient identification for medication safety	7.1
10	staff	Error prevention (e g via SurgiChip)	7.1

Table C reveals a very different picture for the importance of RFID in healthcare to improve quality. Now almost all areas for application relate to patients, with only one top-ten entry for staff- and asset-related applications. The number one application area to improve quality of care is ‘patient identification to avoid wrong drug dose/time/procedure’.

Table C: Ten most important application areas of RFID in healthcare to improve quality

Rank	Area	Application	Average rating
1	patients	Patient identification to avoid wrong drug dose/time/procedure	7.9
2	patients	Accurate patient identification for medication safety	7.8
3	assets	Asset identification/blood bags identification at hospitals or to ensure blood type matching	7.8
4	patients	Patient identification for blood transfusion	7.7
5	staff	Error prevention (e g via SurgiChip)	7.7
6	patients	Eliminate wrong patient / wrong procedure surgery	7.7
7	patients	Accurate patient identification	7.5
8	patients	Intelligent medication monitoring for elderly at home	7.5
9	patients	Infant identification at hospitals to forego mismatching	7.3
10	patients	Dementia patients tracking and tracing in/outpatient	7.3

DELPHI RESULTS: RFID applications related to staff

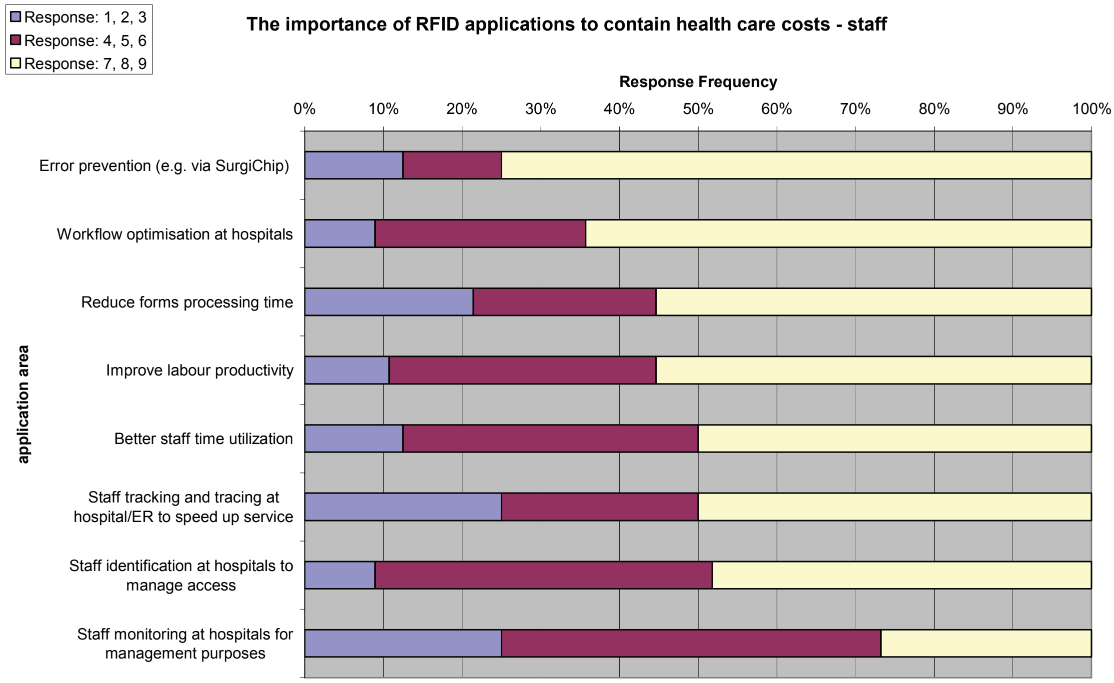
Containing cost

Figure C shows the distribution of responses to the question “How important is each of the following application areas of RFID in healthcare to contain healthcare costs?” The figure shows that for all but two application areas, more than 50percent of the respondents rated the importance as 7, 8 or 9 (yellow-coloured bars; the two exceptions are application areas related to staff monitoring and identification at the bottom of the figure). Similarly, only a minority of respondents (varying between approximately 10percent and 25percent) sees these application areas as unimportant to contain cost.

The area perceived as most important to contain cost in healthcare through RFID is error prevention (rated by 75percent of respondents as 7, 8 or 9), followed by workflow optimisation and the reduction in processing time of forms.

Another category worth mentioning is “staff tracking and tracing at the hospital or ER to speed up service”. For this category, it seems expert opinion diverges, as we find substantial numbers of respondents for both the “unimportant” (1, 2, 3) and the “important” category (7, 8, 9).

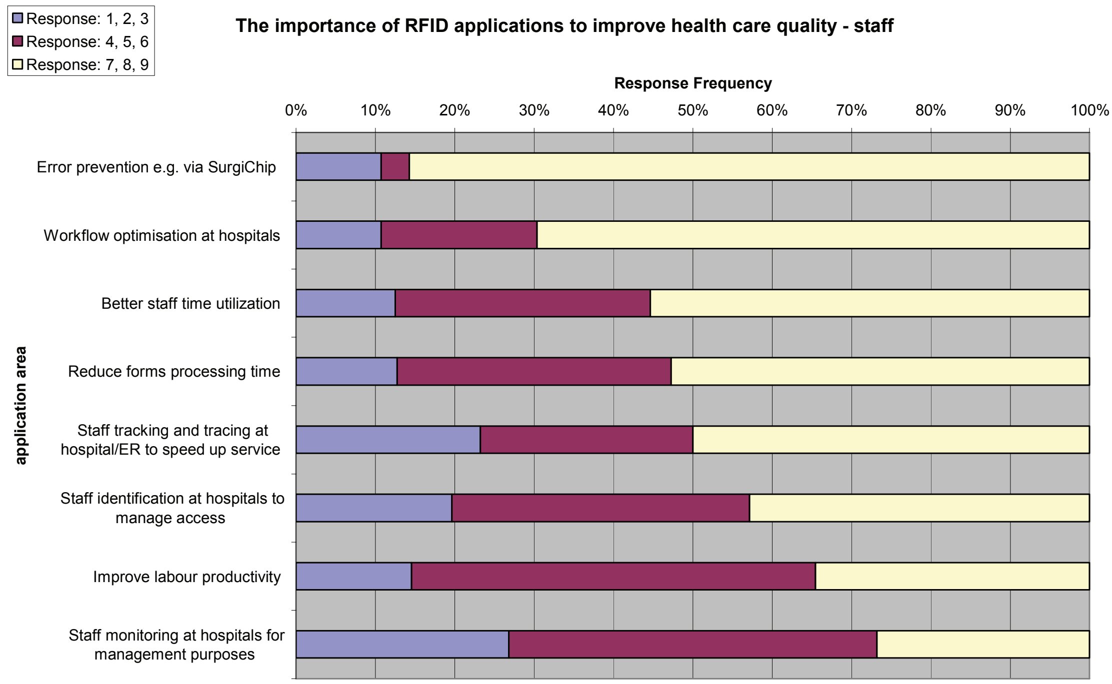
Figure C The importance of RFID applications to contain healthcare costs (staff)



Improving quality

Figure D shows responses to the same application areas, but now with respect to the importance of these areas to improve quality. As in the previous figure, the experts seem to rate the importance of the majority of these RFID application areas high (7, 8 or 9; yellow bars). Error prevention (85percent), workflow optimisation (70percent), and better staff time utilization (55percent) saw the highest percentage respondents assigning 7, 8 or 9, and can thus be considered the most important application areas of RFID in healthcare to improve quality.

Figure D The importance of RFID applications to improve healthcare quality (staff)

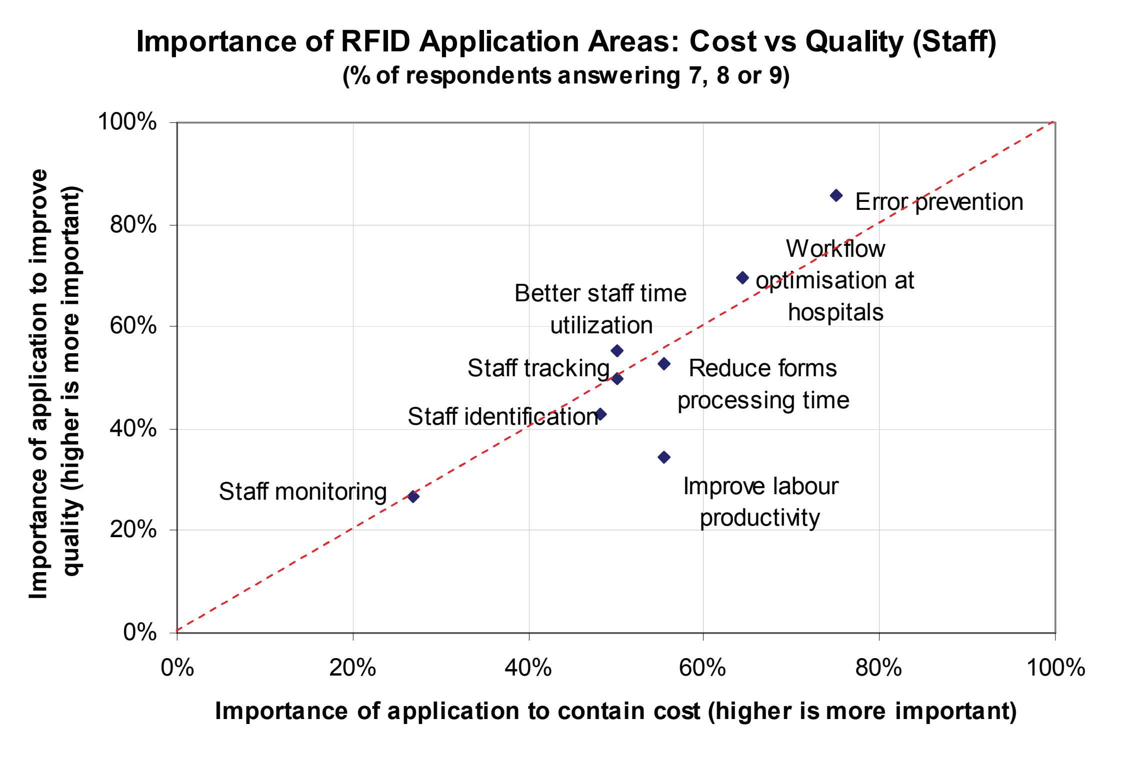


Cost versus quality

To better understand the importance of these application areas for containing cost relative to improving quality, Figure E shows for each area the percentage of respondents who assigned 7, 8, or 9 (ie the yellow bars in Figure C and Figure D) combined for quality (vertical axis) and cost (horizontal axis). For application areas lying on the (dotted red) 45-degree line, an equal percentage of respondents rated the importance of this area 7, 8, or 9 for both cost and quality. For example, Staff monitoring is of equal (un)importance with respect to improving quality and containing cost. The more interesting cases are those further diverging from the 45-degree line: The results suggest that RFID applications to improve labour productivity appear to be of higher importance to contain cost than to improve quality, whereas error prevention appears to be of (slightly) higher importance to improve quality than to contain cost.

Still, most application areas are fairly close to the 45-degree line, suggesting that the importance of RFID applications with respect to patients in general does not differ much with respect to containing cost versus improving quality.

Figure E The importance of RFID applications: Cost versus Quality (staff, ratings of 7, 8 or 9)



Because Figure E is based on only the upper end of the distribution of responses (ie, ratings of 7, 8 or 9), it is useful to contrast this figure with a similar figure based on the lower end of the distribution. Figure F is similar to Figure E, except that it shows the percentage of respondents answering 1, 2, 3 or 4[15], identifying respondents who thought the application area was less or more *un*important to contain cost and/or improve quality.

Figure F is consistent with Figure E in the sense that all application areas are close to the 45-degree (dotted red) line, suggesting that the importance of RFID applications with respect to patients in general does not differ much with respect to containing cost versus improving quality.

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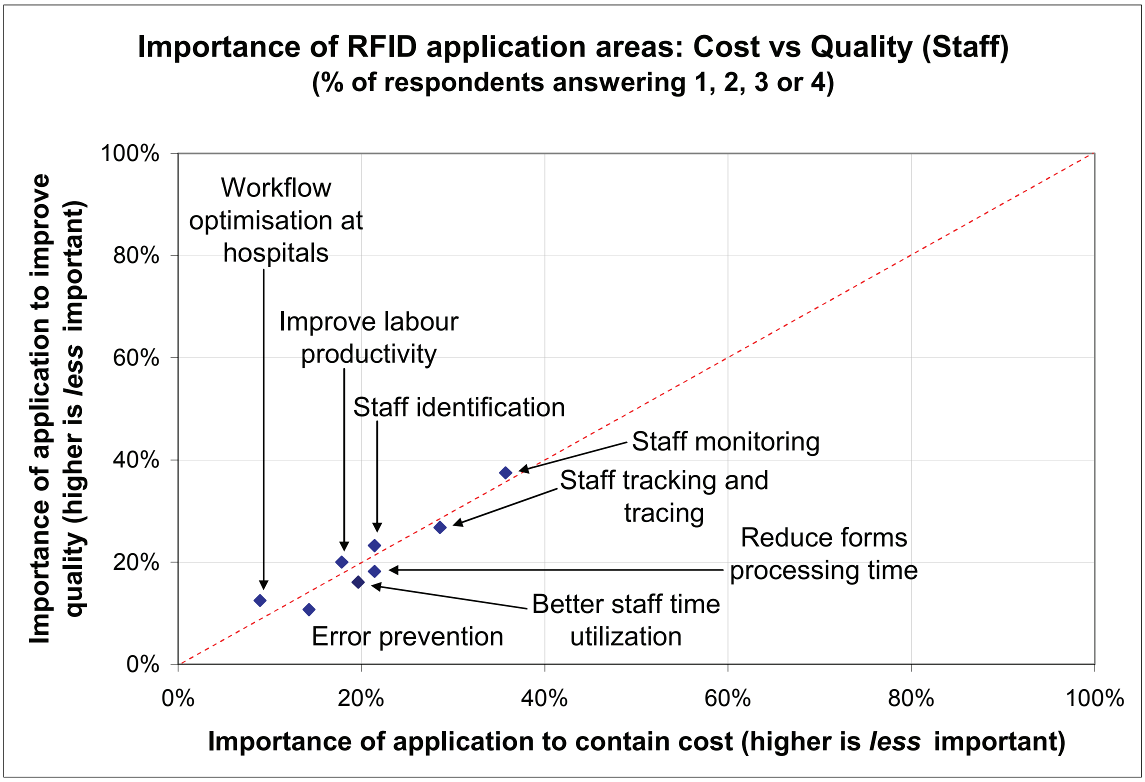
[15] Excluding the '4' response option here would have made the figure consistent with Figure and Figure . However, since the number of respondents that chose response options 1-3 was already low, we decided to add the '4' response option in order to obtain greater variation across the different application areas, and hence a more informative picture.

Figure F The importance of RFID applications: Cost versus Quality (staff, ratings of 1, 2, 3 or 4)



Differences between respondent groups

An important question is to what extent these ratings differ across the four different groups of experts included in our sample: Academics, Industry, Providers and Other. Table D shows the average of the responses (1-9) by application area and respondent group. Because the number of respondents in some categories (in particular providers) is fairly small, we now look at the average (ie using all responses), rather than only focusing on the percentage of respondents answering 7, 8 or 9 (as before). The bottom row of Table D shows for each respondent group the average across all application areas. It is clear that the differences between the groups based on these averages is very small, as they are all very close to each other (varying from 5.9 to 6.4). Looking at the ranking within each respondent group, it also appears that rankings are largely preserved across different respondent categories, with occasional interchanges of adjacent areas (eg "workflow optimisation" and "error prevention" for academic respondents), and larger differences. As an example of these larger differences, it is interesting to note that respondents associated with the industry seem to judge reductions in forms processing time as substantially less important compared to other respondent groups, given that these respondents would rank this area as 7th, compared to the 4th place ranking this area would receive when taking all respondents into account.

To detect whether any of the differences between these 4 groups where statistically significant, we conducted t-tests for differences in means for each area and for each of the possible six two-way combinations of respondent groups (eg academia vs. provider, academia vs. industry, academia vs. other, provider vs. industry, provider vs. other, and industry vs. other)[16]. These tests revealed that the only two differences significant at the 95percent confidence level were the differences between the ratings for "error prevention" between academia (average rating of 6.9) and providers (average rating of 8.2), and between industry (average rating of 6.8) and providers. A third difference was significant at the 90percent confidence level, which was "workflow optimisation" between academia (average rating of 7.3) and other (average rating of 5.9).

Table D: Average ratings by application area and respondent group, with respect to the importance of RFID applications to contain cost (staff)

Application area	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Error prevention e g via SurgiChip	7.1	6.9	8.2	6.8	6.7
Workflow optimisation at hospitals	6.8	7.3	7.1	6.9	5.9
Improve labour productivity	6.4	6.5	6.6	6.7	5.8
Reduce forms processing time	6.4	6.7	6.7	5.9	6.2
Better staff time utilization	6.2	6.3	6.0	6.8	5.5
Staff identification at hospitals to manage access	6.1	5.9	6.2	6.3	6.2
Staff tracking and tracing at hospital/ER to speed up service	5.8	5.4	5.4	6.2	6.0
Staff monitoring at hospitals for management purposes	5.1	4.6	5.3	5.6	4.9
Average across all areas	*6.2*	*6.2*	*6.4*	*6.4*	*5.9*

The bottom row of Table D shows that average ratings for the importance of RFID applications with respect to improving quality do not differ much across the four respondent categories. Here as well, the rank order across the different respondent groups is largely preserved, with some interesting deviations though. For example, providers ranked "better staff time utilization" lower (7th) compared to the overall ranking (4th). When testing for differences, we found the difference between providers and other for "workflow optimisation at hospitals" to be statistically significant at the 95percent level.

[16] Note that these tests do not just test for the difference in the percentage of respondents who answered 7, 8, or 9, but rather test for the difference in the average rating (thus including any rating between 1 and 9).

Table E: Average ratings by application area and respondent group, with respect to the importance of RFID applications to improve quality (staff)

Application area	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Error prevention e g via SurgiChip	7.7	8.2	8.2	7.6	6.7
Workflow optimisation at hospitals	6.7	6.7	7.7	6.9	5.6
Reduce forms processing time	6.3	6.7	7.1	6.0	5.5
Better staff time utilization	6.2	6.7	5.2	6.1	6.0
Staff tracking and tracing hospital ER to speed up service	5.9	5.9	5.8	5.9	6.1
Improve labour productivity	5.8	6.2	5.4	5.8	5.4
Staff identification hospitals to manage access	5.7	5.7	5.7	5.8	5.8
Staff monitoring hospitals for management purposes	5.0	4.9	4.8	5.3	4.7
Average across all areas	*6.2*	*6.4*	*6.2*	*6.2*	*5.7*

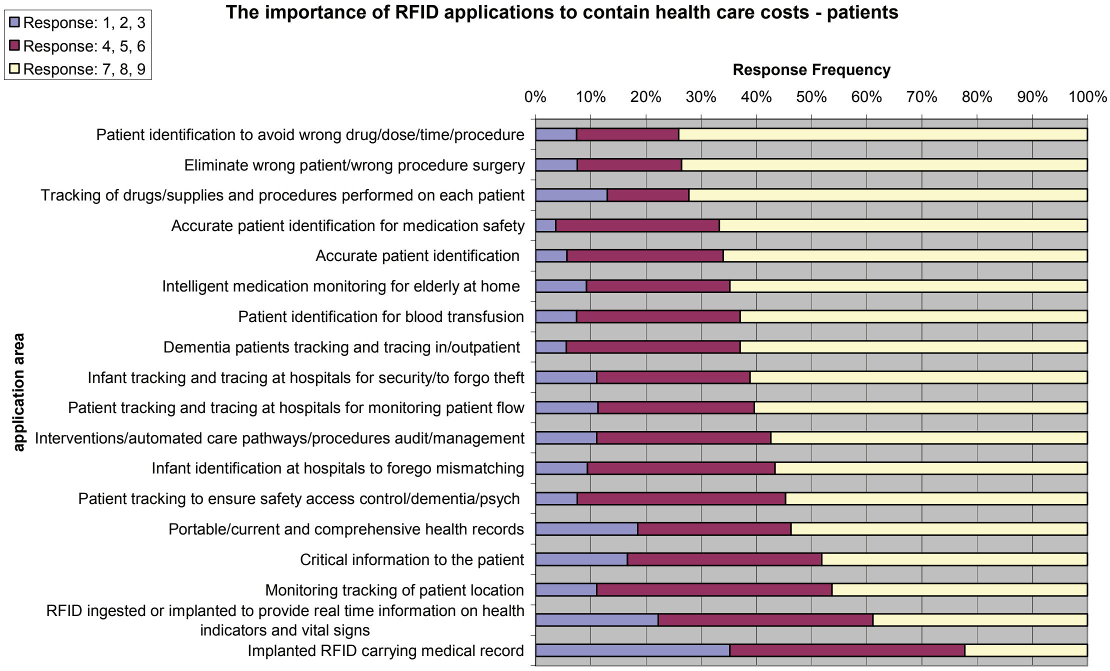
DELPHI RESULTS: RFID applications related to patients

After considering the importance of RFID for containing cost and improving quality in areas related to staff, we now turn our focus to areas related to patients.

Containing cost

Figure G shows the perceived importance for various RFID applications related to patients to contain healthcare costs. On average respondents are again very positive about the importance: For 14 out of the 18 application areas, more than 50percent of respondents assigned 7, 8 or 9, whereas for all but two areas less than 20percent of respondents assigned 1, 2 or 3. The top-3 most important areas (based on the number of respondents assigning 7, 8 or 9) are: the identification of patients to avoid wrong drug/dose/time/procedure; elimination of wrong patient/wrong procedure surgery; and the tracking of drugs/supplies and procedures performed on each patient.

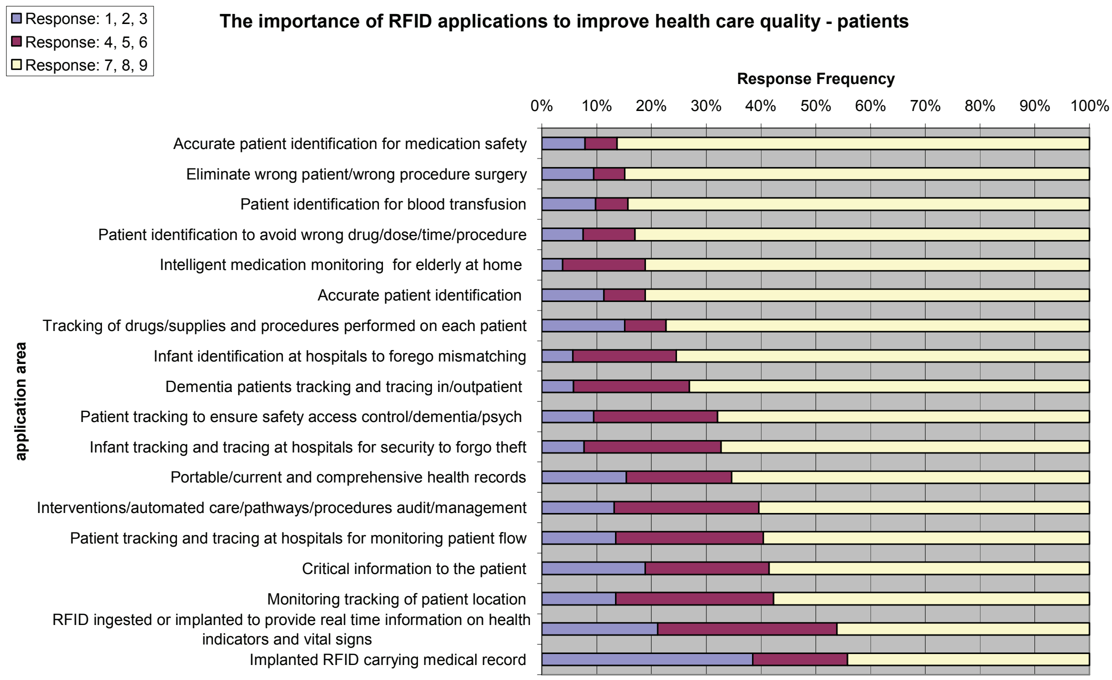
Figure G The importance of RFID applications to contain healthcare costs (patients)



Improving quality

A similar picture emerges for the importance of RFID applications related to patients, to improve quality of care, shown in Figure H.

Figure H The importance of RFID applications to improve quality (patients)



Cost versus quality

Figure I shows that for all but one application related to patients (Patient tracking and tracing at hospitals for monitoring patient flow), respondents thought RFID has higher importance for improving quality compared to containing costs (ie, all dots are situated above the 45-degree line). There appears to be a strong correlation between the importance with respect to improving quality and containing costs, apparent from the fact that all dots are situated *along* the 45-degree line.

A similar picture emerges when looking at the low end of the distribution (ratings 1-4), as shown in Figure J. Now, the majority of application areas is situated below the 45-degree line, indicating that a larger number of respondents thought these RFID application areas to be *un*important to contain cost, as compared to improve quality.

Figure I The importance of RFID applications: Cost versus Quality (patients, ratings of 7, 8 or 9)

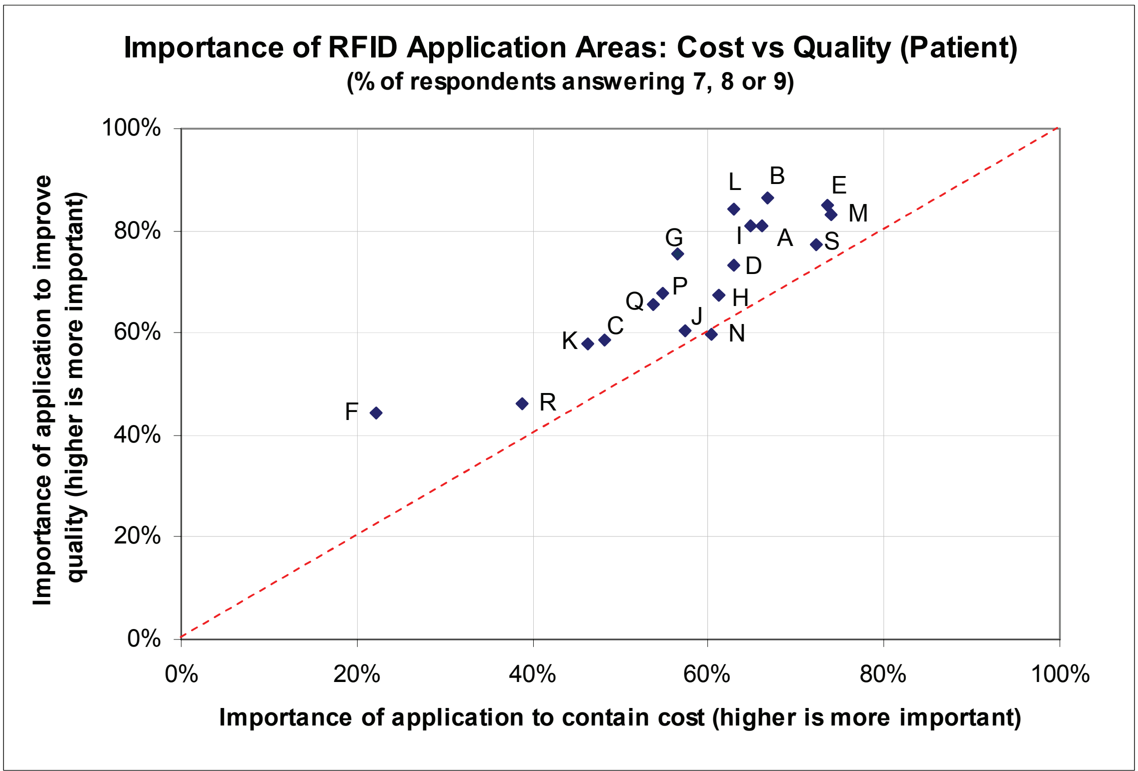
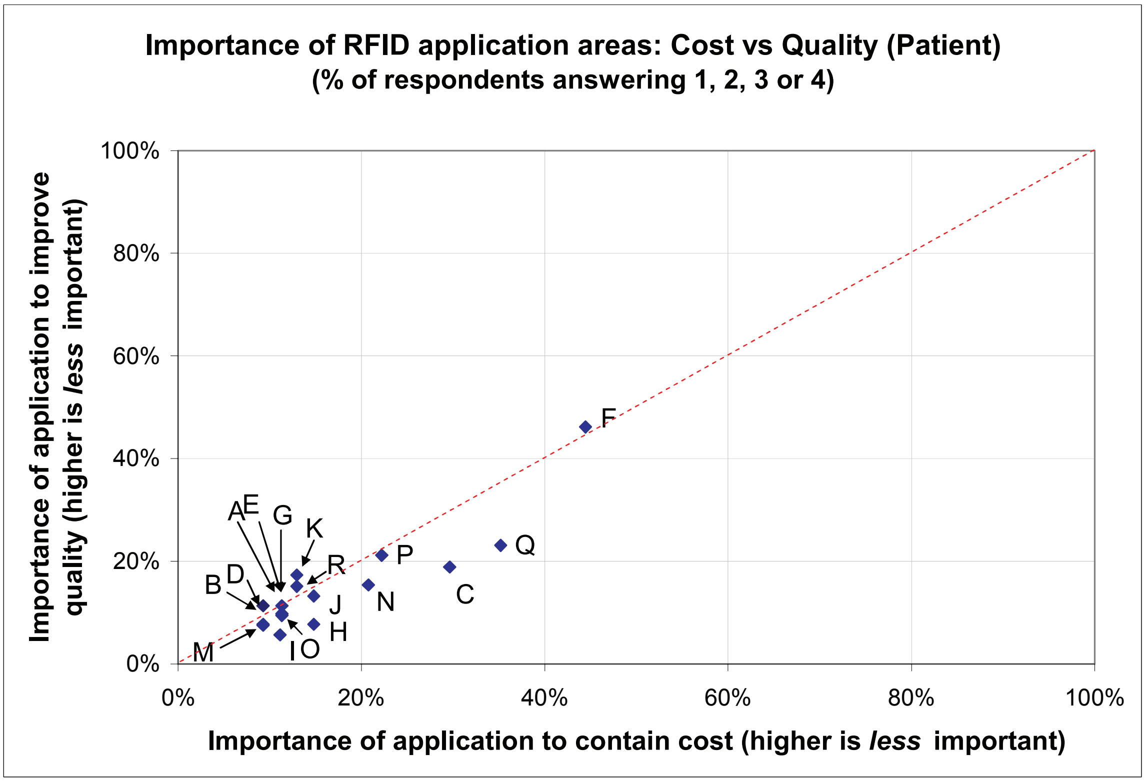


Figure J The importance of RFID applications: Cost versus Quality (patients, ratings of 1, 2, 3 or 4)



Legend:

A	Accurate patient identification
B	Accurate patient identification for medication safety
C	Critical information to the patient
D	Dementia patients tracking and tracing (in/outpatient)
E	Eliminate wrong-patient, wrong procedure surgery
F	Implanted RFID carrying medical record
G	Infant identification @ hospitals to forego mismatching
H	Infant tracking and tracing @hospitals for security/ to forgo theft
I	Intelligent medication monitoring (for elderly at home)
J	Interventions: automated care, pathways, procedures audit, management
K	Monitoring/tracking of patient location
L	Patient identification for blood transfusion
M	Patient identification to avoid wrong drug, dose, time, procedure
N	Patient tracking and tracing @ hospitals for monitoring patient flow
P	Patient tracking to ensure safety/access control (dementia, psych)
Q	Portable, current and comprehensive health records
R	RFID ingested or implanted to provide real-time information on health indicators and vital signs, to monitor and report on the results of surgeries, to regulate the release of medications, telemedicine
S	Tracking of drugs, supplies and procedures performed on each patient

Differences between respondent groups

Table F shows average ratings by respondent groups and application areas. We found no differences in the average ratings between the four groups to be statistically significant, with one exception: Providers rated 'accurate patient identification' of higher importance (8) compared to academia (6.6). As shown at the bottom the overall average (ie across all categories) shows very little difference between the four groups (all are in the range 6.2-6.7).

Table F: Average ratings by application area and respondent group, with respect to the importance of RFID applications to contain cost (patients)

Application area	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Patient identification to avoid wrong drug dose time procedure	7.2	7.2	7.5	7.4	6.8
Eliminate wrong patient wrong procedure surgery	7.1	7.2	7.4	6.9	7.1
Accurate patient identification for medication safety	7.1	7.0	7.8	7.1	6.8
Tracking of drugs supplies and procedures performed on each patient	7.0	7.4	6.5	7.2	6.6
Intelligent medication monitoring for elderly at home	6.9	7.2	7.5	6.5	6.8
Accurate patient identification	6.9	6.6	8.0	7.0	6.7
Patient identification for blood transfusion	6.9	7.1	7.4	6.7	6.5
Dementia patients tracking and tracing in out patient	6.8	7.1	6.3	6.8	6.5
Infant tracking and tracing hospitals for security to forgo theft	6.7	6.9	6.8	6.3	6.8
Infant identification hospitals to forego mismatching	6.6	6.8	6.8	6.3	6.8
Patient tracking to ensure safety access control dementia psych	6.6	7.1	5.8	6.6	6.4
Interventions automated care pathways procedures audit management	6.4	6.8	5.5	6.3	6.7
Patient tracking and tracing hospitals for monitoring patient flow	6.4	7.1	5.1	6.5	6.3
Portable current and comprehensive health records	6.3	6.4	5.5	6.1	6.7
Monitoring tracking of patient location	6.2	6.8	5.1	6.2	6.1
Critical information to the patient	5.9	5.7	5.6	6.3	6.0
RFID ingested or implanted to provide real time information on health indicators and vital signs	5.5	5.9	4.9	5.3	5.3
Implanted RFID carrying medical record	4.6	4.5	3.0	5.2	4.9
Average across all areas	*6.5*	*6.7*	*6.2*	*6.5*	*6.4*

Table G shows the average scores for the importance of RFID applications related to patients to improve quality of care. The only difference that is significant here is ‘intelligent medication monitoring for elderly at home’, rated as 8.3 on average by providers and as 7.1 by the industry. It appears as if providers have greater expectations from the application of RFID in this area compared to the industry. Overall, it seems the differences in opinion between the four groups is larger for the importance of RFID applications related to patients to improve quality of care. Whereas in Table F the averages at the bottom were all within a fairly narrow range, in Table G they are getting wider. In particular, respondents from academia give consistently higher ratings compared to the average.

Table G: Average ratings by application area and respondent group, with respect to the importance of RFID applications to improve quality (patients)

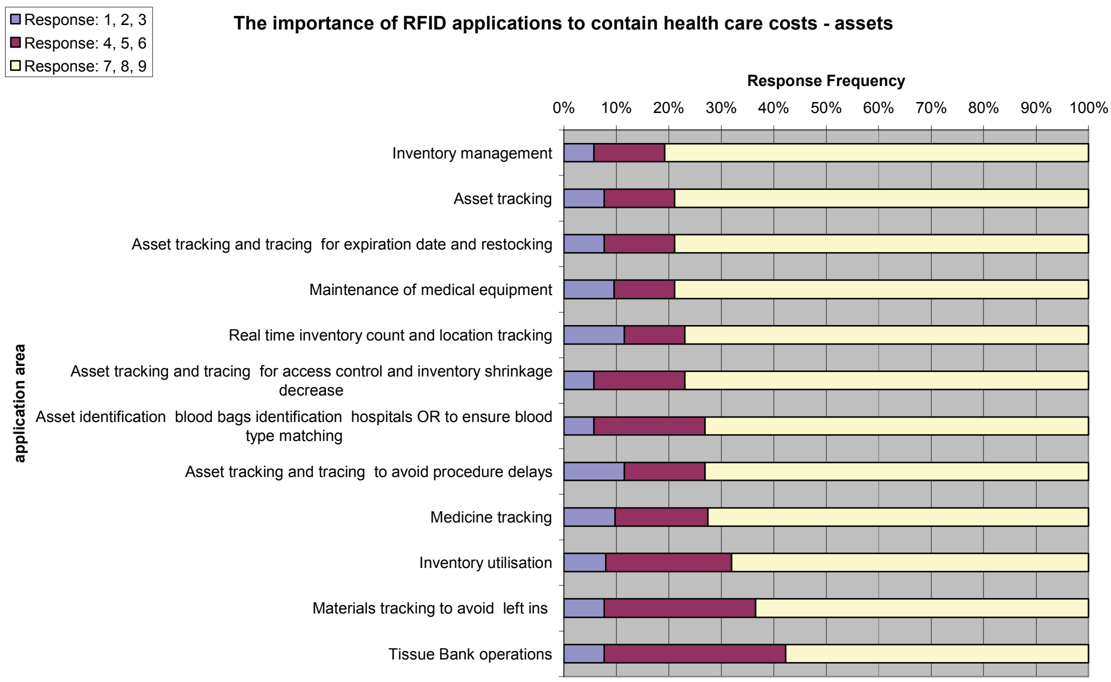
Application area	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Patient identification to avoid wrong drug dose time procedure	7.9	8.3	8.1	7.6	7.4
Accurate patient identification for medication safety	7.8	8.5	8.0	7.5	7.1
Patient identification for blood transfusion	7.7	8.3	8.5	7.4	7.0
Eliminate wrong patient wrong procedure surgery	7.7	8.2	8.1	7.6	6.7
Accurate patient identification	7.5	8.1	8.0	7.3	6.8
Intelligent medication monitoring for elderly at home	7.5	7.9	8.3	7.1	6.8
Infant identification hospitals to forego mismatching	7.3	7.9	7.0	7.1	6.8
Dementia patients tracking and tracing in out patient	7.3	7.5	7.1	7.3	6.9
Tracking of drugs supplies and procedures performed on each patient	7.2	7.9	6.4	7.0	6.9
Infant tracking and tracing hospitals for security to forgo theft	7.0	7.5	6.9	6.8	6.8
Patient tracking to ensure safety access control dementia psych	7.0	7.3	6.8	6.8	6.8
Patient tracking and tracing hospitals for monitoring patient flow	6.5	7.1	5.1	6.5	6.6
Interventions automated care pathways procedures audit management	6.5	6.8	6.1	6.8	5.8
Portable current and comprehensive health records	6.4	7.1	5.9	6.2	6.1
Critical information to the patient	6.4	6.9	5.3	6.7	6.1
Monitoring tracking of patient location	6.3	6.7	5.1	6.6	6.1
RFID ingested or implanted to provide real time information on health indicators and vital signs	5.9	6.9	4.4	5.7	5.8
Implanted RFID carrying medical record	4.9	5.3	3.3	5.9	4.3
Average across all areas	*6.9*	*7.5*	*6.6*	*6.9*	*6.5*

DELPHI RESULTS: RFID applications related to assets

Containing cost

Figure L shows the importance to contain healthcare costs of 12 application areas of RFID with respect to assets. The three most important areas are 'inventory management', 'asset tracking', and 'asset tracking and tracing for expiration date and restocking'. Approximately 80percent of respondents rated these areas with 7, 8 or 9. For all other areas this percentage is greater than 50percent. For all but two areas ('real time inventory count and location tracking' and 'asset tracking and tracing to avoid procedure delays') less than 10percent of the respondents assigned an importance score of 1, 2 or 3.

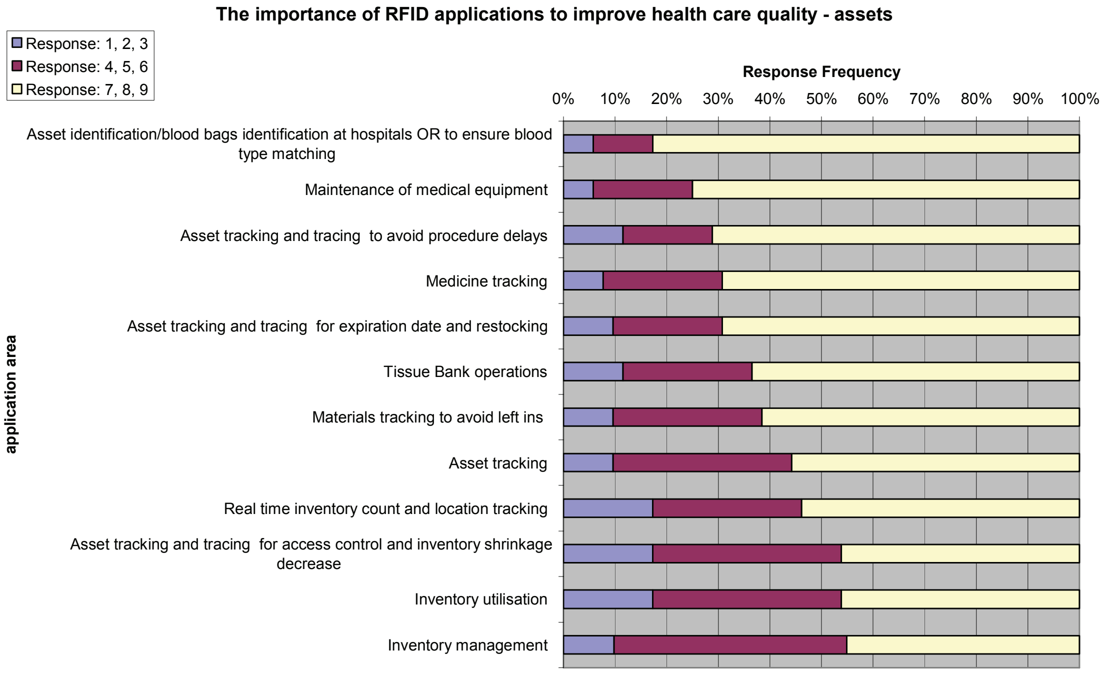
Figure K The importance of RFID applications to contain healthcare costs (assets)



Improving quality

The variation in responses appears to be larger for the importance of these areas with respect to improving quality of care. As Figure M shows, the share of respondents assigning 7, 8 or 9 varies between more than 80percent ('asset identification/blood bags identification at hospitals') to less than 50percent ('inventory management').

Figure L The importance of RFID applications to improve healthcare quality (assets)



Cost versus quality

For all but two application areas related to assets, respondents gave higher ratings for the importance with respect to containing cost compared to improving quality (these areas are represented by dots all lying under the 45-degree line in Figure N). The two exceptions are 'Asset identification / blood bags identification at hospitals' and 'tissue bank operations'. For five areas respondents gave substantially higher scores related to containing cost compared to improving quality. These areas are represented by dots that are farthest away from the 45-degree line:

- Inventory utilisation (G)
- Real-time inventory count and location tracking (K)
- Asset tracking (B)
- Asset tracking and tracing for access control and inventory shrinkage decrease (C)
- Inventory management (F)

Figure M The importance of RFID applications: Cost versus Quality (assets, ratings 7, 8 or 9)

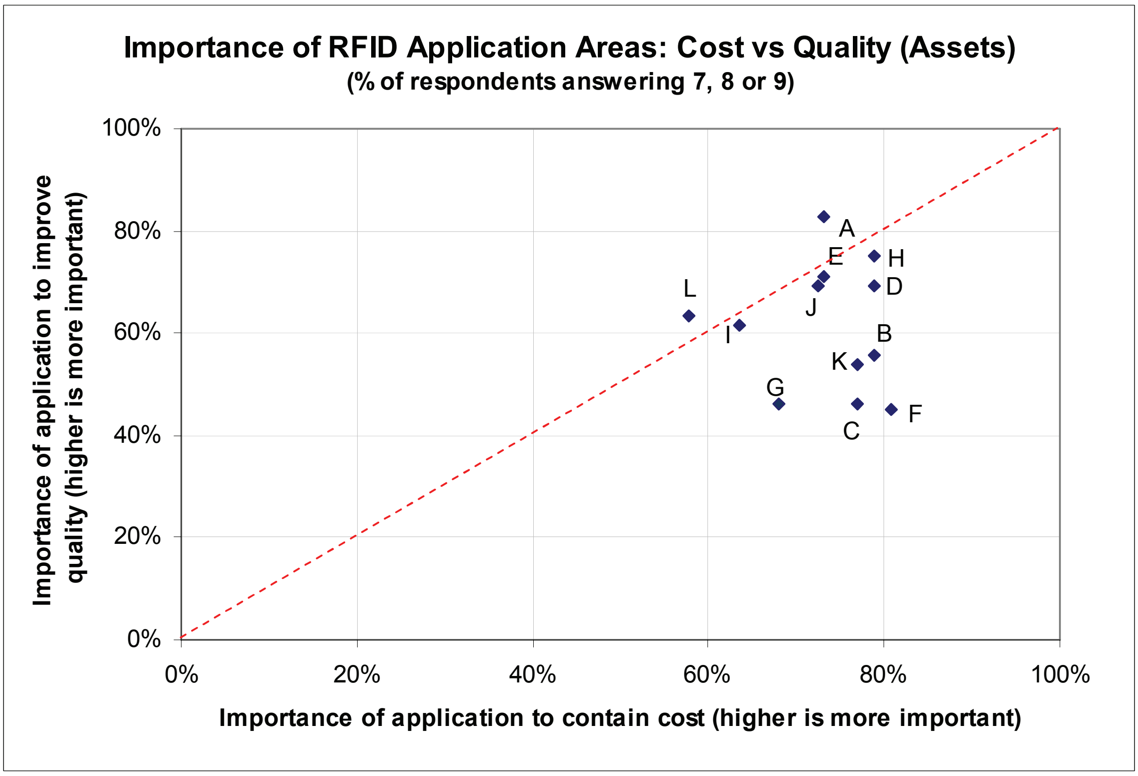
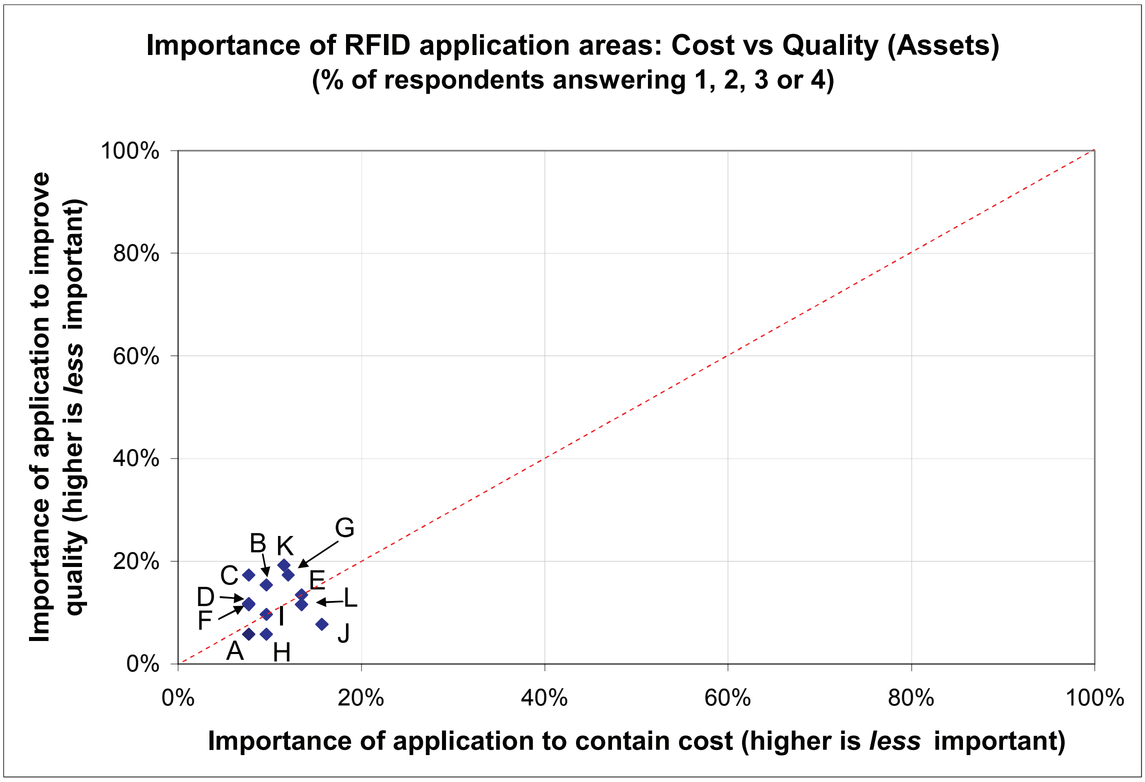


Figure N The importance of RFID applications: Cost versus Quality (assets, ratings 1, 2, 3 or 4)



Legend:

A	Asset identification blood bags identification hospitals OR to ensure blood type matching
B	Asset tracking
C	Asset tracking and tracing for access control and inventory shrinkage decrease
D	Asset tracking and tracing for expiration date and restocking
E	Asset tracking and tracing to avoid procedure delays
F	Inventory management
G	Inventory utilisation
H	Maintenance of medical equipment
I	Materials tracking to avoid left ins
J	Medicine tracking
K	Real time inventory count and location tracking
L	Tissue Bank operations

When looking at the low end of the distribution (ratings 1-4), as shown in Figure N, the majority of application areas is situated above the 45-degree line, indicating that a larger number of respondents thought these RFID application areas to be *un*important to improve quality, as compared to containing cost.

Differences between respondent groups

We found significant differences between respondents groups for the importance of RFID to contain cost for two application areas related to assets: (a) Asset tracking and tracing to avoid procedure delays; and (b) Real time inventory count and location tracking. For the first area, the differences in average ratings were significant for respondents from academia (7.4) and providers (5.4). For the second area, differences were significant between respondents from academia (8.1) and respondents from the industry (6.8); and between respondents from academia and providers (5.6). Table H shows differences between respondent groups have become even larger than in the previous 4 tables. In particular, the difference in overall averages (bottom row) between academics (7.6) and providers (6.2) is striking.

Table H: Average ratings by application area and respondent group, with respect to the importance of RFID applications to contain cost (assets)

Application area	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Asset tracking and tracing for expiration date and restocking	7.4	8.2	7.3	7.0	6.9
Asset tracking	7.4	8.0	6.3	7.6	7.1
Maintenance of medical equipment	7.3	7.6	6.5	7.5	7.2
Asset identification blood bags identification hospitals OR to ensure blood type matching	7.3	7.9	7.8	6.7	6.9
Inventory management	7.3	7.8	6.1	7.4	7.2
Asset tracking and tracing for access control and inventory shrinkage decrease	7.3	7.6	6.4	7.6	6.9
Real time inventory count and location tracking	7.0	8.1	5.6	6.8	6.8
Inventory utilisation	6.9	7.4	5.8	7.3	6.6
Asset tracking and tracing to avoid procedure delays	6.9	7.4	5.4	7.1	7.0
Medicine tracking	6.9	7.5	6.0	6.4	7.4
Materials tracking to avoid left ins	6.8	7.2	6.1	6.7	6.8
Tissue Bank operations	6.5	6.8	5.8	6.4	6.6
Average across all areas	*7.1*	*7.6*	*6.2*	*7.0*	*7.0*

Whereas respondents from academia and providers different in their rating of the importance of 'Real time inventory count and location tracking' for containing cost, they equally differ in their scores for the importance of this application area with respect to improving quality (academics 6.6 vs. providers 3.9). For this same application area, differences are also significant between providers and the industry (6.2) and between providers and 'other' (6.4). A second area where differences were significant is 'materials tracking to avoid left-ins'. For this area the group of 'other' respondents (8.1) is more positive on average compared to providers (5.6) and industry (6.4). Looking at overall averages (bottom row in Table), it appears that providers are substantially more negative (5.7) compared to the other three groups (6.6-7.0) regarding the importance of RFID application areas related to assets for improving quality of care.

Table I: Average ratings by application area and respondent group, with respect to the importance of RFID applications to improve quality (assets)

Application area	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Asset identification blood bags identification hospitals OR to ensure blood type matching	7.8	8.3	8.3	7.4	7.1
Maintenance of medical equipment	7.2	7.4	6.6	7.1	7.5
Medicine tracking	7.0	7.3	6.8	6.7	7.3
Asset tracking and tracing for expiration date and restocking	6.9	7.2	5.9	6.8	7.2
Tissue Bank operations	6.8	7.2	7.0	6.3	7.0
Asset tracking and tracing to avoid procedure delays	6.8	7.2	5.4	6.9	7.3
Materials tracking to avoid left ins	6.8	6.8	5.6	6.4	8.1
Asset tracking	6.4	6.5	5.0	6.8	6.8
Inventory management	6.2	6.2	4.9	6.5	6.6
Real time inventory count and location tracking	6.0	6.6	3.9	6.2	6.4
Asset tracking and tracing for access control and inventory shrinkage decrease	6.0	5.8	5.1	6.1	6.9
Inventory utilisation	6.0	6.1	4.5	6.4	6.3
Average across all areas	*6.7*	*6.9*	*5.7*	*6.6*	*7.0*

DELPHI RESULTS: Barriers and enablers for successful adoption of RFID technology in healthcare

After having discussed the relative importance of RFID application areas in the three previous chapters, we turn to a discussion of the perceived importance of barriers and enablers for successful adoption of RFID technology in healthcare.

Barriers to successful implementation of RFID in healthcare

Obstacles

Figure P shows the percentage of respondents assigning 1, 2 or 3 (blue, least important), 4, 5, 6 (purple) and 7, 8 to 9 (yellow, most important) to the importance of being an obstacle for each of 12 categories. The three most important obstacles for successful implementation are issues concerning 'reliability', 'data integrity' and 'privacy' of RFID applications: 70percent or more rated these categories as 7, 8 or 9. Interestingly, 'tag costs' were perceived as the least important obstacle. Still, all 12 categories are an apparent concern, given that across all categories only a small percentage (10-15percent) assigned a rating of 1, 2 or 3.

Figure O Importance of obstacles to successful application of RFID applications in healthcare

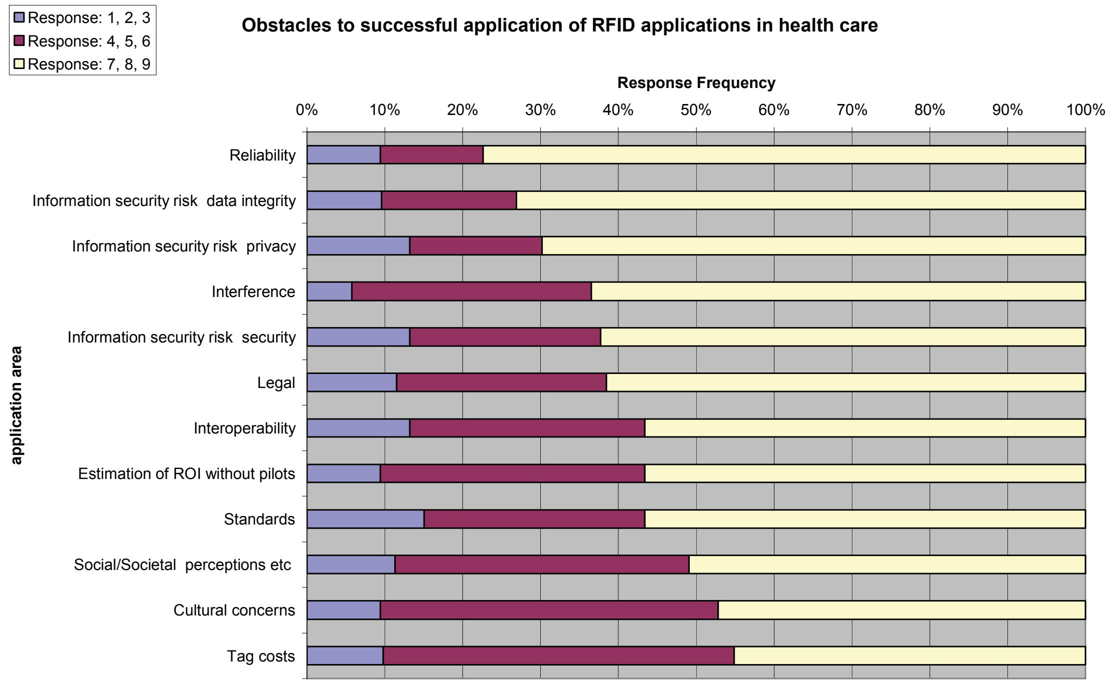


Table J shows how the average ratings varied by respondent group. We did not find any differences in average ratings statistically significant between the four groups of respondents.

Table I: Average ratings by obstacle and respondent group

Obstacle	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Reliability	7.3	7.8	7.1	7.1	7.1
Information security risk data integrity	7.1	7.6	7.4	6.0	7.7
Information security risk privacy	7.0	7.6	6.8	6.4	7.2
Information security risk security	6.9	7.4	6.3	6.3	7.7
Interference	6.8	6.6	6.8	6.6	7.1
Legal	6.6	7.1	5.9	6.1	6.9
Social Societal perceptions etc	6.5	6.8	6.1	6.5	6.3
Standards	6.5	7.2	6.1	6.0	6.3
Interoperability	6.5	7.2	5.8	5.9	6.7
Estimation of ROI without pilots	6.4	6.6	6.8	6.3	5.8
Cultural concerns	6.3	6.6	5.8	6.3	6.2
Tag costs	6.1	6.2	7.0	5.5	6.3
Average across all obstacles	*6.7*	*7.1*	*6.5*	*6.2*	*6.8*

Difficulty of overcoming obstacles

The next figure shows how easy/difficult respondents thought it was to overcome these obstacles. High ratings here indicate that respondents thought the obstacle was easier to overcome, whereas low rates indicate they thought it was harder to overcome. It appears that respondents have very different opinions on this matter, as each of the three parts of each horizontal bar is of substantial size. Eg Slightly more than 35percent of respondents thought data integrity was easy to overcome (assigning 7, 8 or 9), whereas slightly more than 20percent thought is was hard to overcome (assigning 1, 2 or 3). In Figure Q the categories are ordered from top to bottom based on the percentage assigning 7, 8 or 9; However, it is easy to see that this ordering would be very different when ordering by the percentage assigning 1, 2 or 3.

Figure P Difficulty of overcoming obstacles to successful application of RFID applications in healthcare

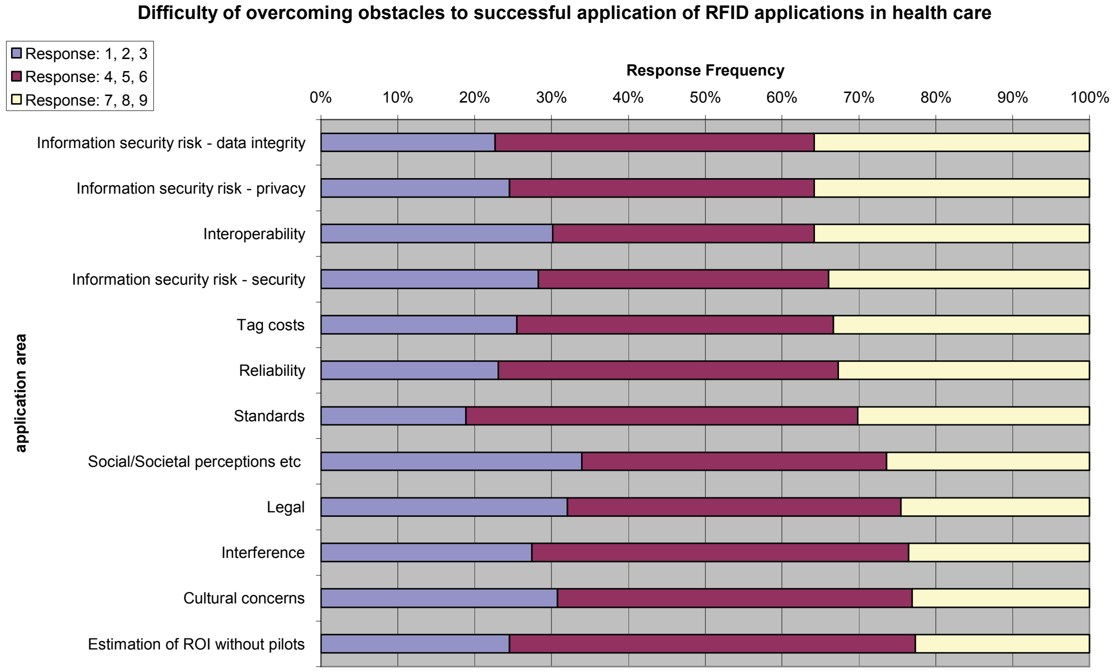


Table K shows ratings of difficulty to overcome the obstacles by respondent group. We found significant differences between some groups for all obstacles related to information security risk. Respondents from the category 'other' rated obstacles related to security (4.2) and privacy (4.1) as harder to overcome compared to the other three respondent groups. Academics thought obstacles related to data integrity (4.9) and privacy (4.8) will be harder to overcome compared to providers (6.1 and 6.9 respectively).

Table K: Average ratings of difficulty of overcoming obstacles

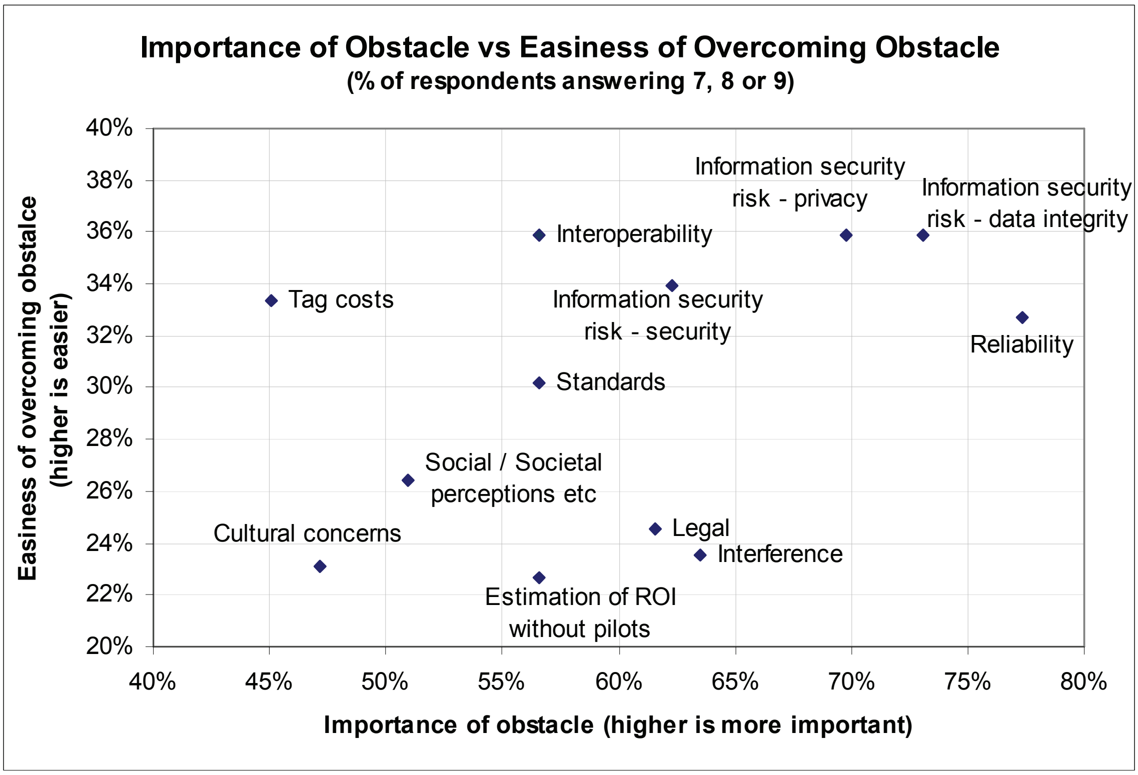
Obstacle	Average rating(*)				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Reliability	5.5	4.9	5.4	5.8	5.8
Standards	5.5	5.5	4.9	5.9	5.1
Tag costs	5.4	5.2	3.8	5.8	6.1
Information security risk privacy	5.3	4.8	6.9	6.1	4.1
Information security risk data integrity	5.3	4.9	6.1	6.0	4.5
Information security risk security	5.3	4.9	6.3	6.1	4.2
Interoperability	5.2	4.9	4.6	6.2	4.8
Estimation of ROI without pilots	5.1	5.1	5.6	4.6	5.3
Interference	4.9	5.2	3.8	4.9	5.5
Legal	4.8	4.4	5.3	5.0	4.8
Cultural concerns	4.8	4.4	5.3	5.0	4.5
Social Societal perceptions etc	4.6	4.4	5.9	4.3	4.6
Average across all obstacles	*5.1*	*4.9*	*5.3*	*5.5*	*4.9*

(*) 1= very hard to overcome obstacle; 9 = very easy to overcome obstacle

As we previously discussed, ranking the difficulty of overcoming these obstacles based on expert opinion is difficult. With this caveat in mind, it can still be useful to consider which obstacles have high importance and are easy to overcome, versus obstacles that have low importance and are difficult to overcome, with the implicit idea that it might be more efficient to spend efforts and resources more on the former rather than the latter category. The relation between importance of obstacles and easiness of overcoming the obstacle is shown in Figure R.

This figure shows that privacy and data integrity are important obstacles that are relatively easier to overcome than most other obstacles. Similarly, cultural concerns and social/societal perceptions are of less importance and relatively harder to overcome. Legal obstacles and obstacles related to interference are of relatively moderate importance and relatively harder to overcome. Finally, tag cost are of low importance but perceived harder to overcome.

Figure Q Importance of obstacles to successful implementation of RFID and easiness to overcome these obstacles



Enablers to successful implementation of RFID in healthcare

Besides *obstacles*, we also asked respondents to rate the relative importance of *enablers* to successful implementation of RFID in healthcare. Figure S shows that it is most important that RFID applications show improvements in patient care and lead to reduced cost; that they are user-friendly and come with clear perceived benefits. Less important enablers (although still rated by more than half of the respondents as important) were broad functionality; government legislation; and falling tag prices.

Figure R Enablers for successful application of RFID applications in healthcare

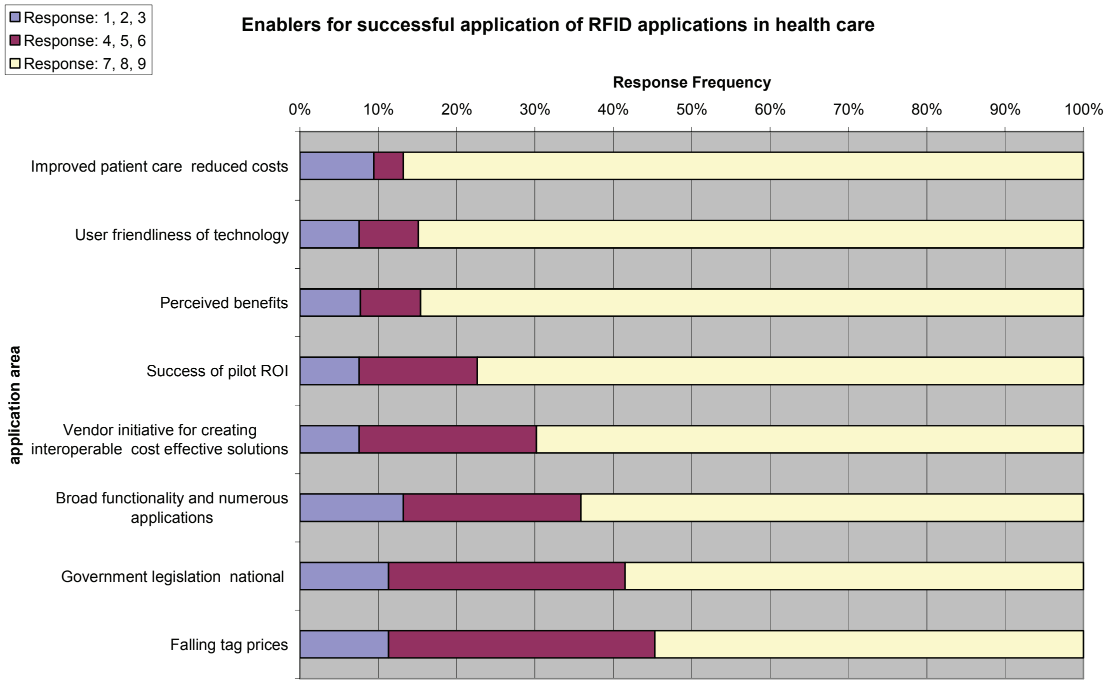


Table L shows average rating of importance across the four respondent groups. We found statistically significant differences between academics and respondents from the industry for two enablers: 'broad functionality' and 'improved patient care / reduced costs'. For both categories academics gave higher ratings compared to the industry. A third difference appeared between industry and providers regarding the user-friendliness of the technology. Interestingly, providers put greater emphasis on the user-friendliness (8.3) as an enabler compared to the industry (6.9). In fact, user-friendliness was perceived as the most important enabler by providers, whereas this was perceived as only the third/fourth-most important enabler by the industry.

Table L: Average ratings by enabler and respondent group

Enabler	Average rating				
	All (n=59)	Academia (n=19)	Provider (n=9)	Industry (n=17)	Other (n=14)
Improved patient care reduced costs	7.7	8.6	8.1	6.9	7.3
Perceived benefits	7.6	7.9	7.8	7.2	7.5
User friendliness of technology	7.5	8.0	8.3	6.9	7.3
Success of pilot ROI	7.4	7.4	8.1	7.3	7.3
Vendor initiative for creating interoperable cost effective solutions	7.0	7.4	6.9	6.7	6.9
Broad functionality and numerous applications	6.7	7.5	6.9	6.0	6.3
Government legislation national	6.6	6.8	6.9	6.4	6.2
Falling tag prices	6.5	6.7	7.5	6.1	6.1
Average across all enablers	*7.1*	*7.5*	*7.5*	*6.7*	*6.8*

DELPHI RESULTS: Results of the second round of ratings

Introduction

This chapter compares the answers to the questionnaire between the first and the second round. Because (unfortunately) only a subset of the respondents to the first round responded to the second round, the use of these responses is somewhat limited. For example, we cannot directly compare the results presented in the previous chapters (based on the first round) to the responses obtained in the second round.

However, what we can do is make such a comparison for the subset of experts who responded to both the first and the second round. The results of this comparison are described in the next section.

Comparing the first and the second round

In this section we identify the most important changes in responses between the first and second round, limiting our analysis to the 19 respondents who answered in both the first and second round.

Table M shows the difference in average ratings between the first and second round, for those 19 respondents who responded to both rounds. The table shows that the revisions made in the second round were largest for the importance of RFID to contain cost as a result of “Better staff time utilisation”, which saw a decrease in its average rating from 7.4 to 7.1 (-0.32), and the importance of RFID to contain cost as a result of “Inventory utilisation”, which saw an increase from 7.5 to 7.8 (+0.31).

Although for most application areas, the differences are fairly small, the possibility exists that the rankings shown in the previous chapters would change if all respondents would have answered the second round. For example, in Table M, the highest ranking application received an average rating of 7.4, while the tenth highest ranking application area received an average rating of 7.1. Because these averages are so close, a change of 0.1 or 0.2 could potentially change the ranking to some extent. At the same time however, it seems unlikely that the changes would lead to dramatically different results (such as an application area dropping by more than a few ranks).

The latter is especially true when considering the ranking *within* each of the domains. For example, Table M shows a range of 5.1 to 7.1 for the average ratings on the importance of RFID applications related to staff to contain cost. Given such a wide range, and the fact that the vast majority of differences between the first and second round is not larger than +/- 0.11, the changes in expert opinions between the first and second round appear to be marginal.

Table M: Difference between average ratings given in 1st and 2nd round (N=19)

		Application area	Round 1	Round 2	Diffe-rence
Staff	Cost	Better staff time utilization	7.42	7.11	-0.32
Staff	Quality	Staff tracking and tracing @ hospital (ER) to speed up service	6.21	6.00	-0.21
Staff	Quality	Improve labor productivity	6.47	6.32	-0.16
Patients	Cost	Infant identification @ hospitals to forego mismatching	6.84	6.68	-0.16
Staff	Cost	Workflow optimisation at hospitals	7.32	7.21	-0.11
Staff	Cost	Staff monitoring @ hospitals for management purposes	4.95	4.84	-0.11
Patients	Cost	Portable, current and comprehensive health records	6.68	6.58	-0.11
Patients	Cost	RFID ingested or implanted to provide real-time information on health indicators and vital signs, to monitor and report on the results of surgeries, to regulate the release of medications, telemedicine	5.84	5.74	-0.11
Patients	Quality	Portable, current and comprehensive health records	7.11	7.05	-0.06
Staff	Quality	Reduce forms processing time	7.22	7.17	-0.06
Assets	Quality	Inventory management	6.47	6.42	-0.05
Staff	Cost	Error prevention (eg, via SurgiChip)	7.63	7.58	-0.05
Patients	Cost	Patient tracking to ensure safety/access control (dementia, psych)	7.21	7.16	-0.05
Patients	Cost	Monitoring/tracking of patient location	6.95	6.89	-0.05
Patients	Quality	Tracking of drugs, supplies and procedures performed on each patient	7.84	7.79	-0.05
Assets	Cost	Inventory management	7.79	7.74	-0.05
Assets	Cost	Materials tracking to avoid left-ins	7.00	6.95	-0.05
Patients	Cost	Critical information to the patient	6.16	6.11	-0.05
Patients	Quality	Implanted RFID carrying medical record	5.72	5.68	-0.04
Staff	Cost	Reduce forms processing time	7.05	7.05	0.00
Staff	Cost	Improve labour productivity	7.32	7.32	0.00
Staff	Cost	Staff tracking and tracing @ hospital (ER) to speed up service	6.11	6.11	0.00
Staff	Quality	Error prevention (eg, via SurgiChip)	8.47	8.47	0.00
Patients	Cost	Tracking of drugs, supplies and procedures performed on each patient	7.53	7.53	0.00
Patients	Cost	Infant tracking and tracing @hospitals for security/ to forgo theft	7.11	7.11	0.00
Patients	Quality	Patient tracking and tracing @ hospitals for monitoring patient flow	7.47	7.47	0.00
Patients	Quality	Intelligent medication monitoring (for elderly at home)	7.84	7.84	0.00
Patients	Quality	Infant tracking and tracing @hospitals for security/ to forgo theft	7.53	7.53	0.00
Assets	Cost	Asset tracking and tracing: for expiration date and restocking	8.00	8.00	0.00
Assets	Cost	Medicine tracking	7.11	7.11	0.00
Assets	Cost	Real time inventory count and location tracking	7.74	7.74	0.00
Assets	Cost	Asset tracking and tracing: for access control and inventory shrinkage decrease	7.79	7.79	0.00
Assets	Quality	Asset tracking and tracing: for access control and inventory shrinkage decrease	6.37	6.37	0.00
Assets	Quality	Asset tracking	6.89	6.89	0.00
Assets	Quality	Asset identification: blood bags identification @hospitals/OR to ensure blood type matching	8.37	8.37	0.00
Patients	Quality	Patient identification for blood transfusion	8.44	8.47	0.03
Patients	Cost	Eliminate wrong-patient, wrong procedure surgery	7.47	7.53	0.05
Staff	Cost	Staff identification @hospitals to manage access	6.11	6.16	0.05
Patients	Quality	Accurate patient identification<	8.11	8.16	0.05
Patients	Cost	Patient tracking and tracing @ hospitals for monitoring patient flow	7.16	7.21	0.05
Patients	Cost	Implanted RFID carrying medical record	4.95	5.00	0.05

Patients	Quality	Monitoring/tracking of patient location	7.00	7.05	0.05
Patients	Quality	Infant identification @ hospitals to forego mismatching	7.79	7.84	0.05
Patients	Quality	Critical information to the patient	7.37	7.42	0.05
Patients	Quality	Dementia patients tracking and tracing (in/outpatient)	7.79	7.84	0.05
Assets	Cost	Asset tracking and tracing: to avoid procedure delays	7.58	7.63	0.05
Assets	Cost	Tissue Bank operations	7.00	7.05	0.05
Assets	Cost	Maintenance of medical equipment	8.00	8.05	0.05
Assets	Quality	Maintenance of medical equipment	7.63	7.68	0.05
Assets	Quality	Real time inventory count and location tracking	6.95	7.00	0.05
Assets	Quality	Materials tracking to avoid left-ins	7.58	7.63	0.05
Patients	Cost	Patient identification to avoid wrong drug, dose, time, procedure	7.42	7.47	0.05
Patients	Quality	RFID ingested or implanted to provide real-time information on health indicators and vital signs, to monitor and report on the results of surgeries, to regulate the release of medications, telemedicine	6.78	6.83	0.06
Patients	Quality	Accurate patient identification for medication safety	8.42	8.53	0.11
Patients	Quality	Eliminate wrong-patient, wrong procedure surgery	8.42	8.53	0.11
Staff	Quality	Workflow optimisation at hospitals	7.11	7.21	0.11
Staff	Quality	Better staff time utilization	6.84	6.95	0.11
Staff	Quality	Staff monitoring @ hospitals for management purposes	5.47	5.58	0.11
Patients	Cost	Interventions: automated care, pathways, procedures audit, management	6.74	6.84	0.11
Patients	Cost	Intelligent medication monitoring (for elderly at home)	6.95	7.05	0.11
Patients	Cost	Patient identification for blood transfusion	6.95	7.05	0.11
Patients	Cost	Accurate patient identification for medication safety	7.16	7.26	0.11
Patients	Quality	Patient tracking to ensure safety/access control (dementia, psych)	7.63	7.74	0.11
Assets	Cost	Asset identification: blood bags identification @hospitals/OR to ensure blood type matching	7.68	7.79	0.11
Assets	Quality	Asset tracking and tracing: to avoid procedure delays	7.58	7.68	0.11
Assets	Quality	Inventory utilization	6.63	6.74	0.11
Assets	Quality	Medicine tracking	7.58	7.68	0.11
Assets	Quality	Tissue Bank operations	7.32	7.42	0.11
Assets	Quality	Asset tracking and tracing: for expiration date and restocking	7.74	7.84	0.11
Patients	Cost	Dementia patients tracking and tracing (in/outpatient)	6.74	6.89	0.16
Assets	Cost	Asset tracking	8.00	8.16	0.16
Patients	Quality	Patient identification to avoid wrong drug, dose, time, procedure	8.37	8.58	0.21
Patients	Quality	Interventions: automated care, pathways, procedures audit, management	6.84	7.05	0.21
Staff	Quality	Staff identification @hospitals to manage access	5.05	5.32	0.26
Patients	Cost	Accurate patient identification<	7.00	7.26	0.26
Assets	Cost	Inventory utilization	7.47	7.78	0.31

In addition to differences in average ratings, we also examined whether the spread of the ratings had changed between the two rounds. Because respondents were asked to aim for consensus in the second round, our expectation was that ratings would converge at least to some extend in the second round.

To evaluate this hypothesis, we estimated the coefficient of variation (CV), which is defined as:

$$CV(x) = standard\ deviation(x) / mean(x),$$

ie the standard deviation adjusted for changes in the average ratings. We found that for 63 application areas, the coefficient of variation (and thus the spread of responses) indeed declined between the first and second round. It did not change for 6 application areas, and it increased (thus suggesting *less* consensus) for 7 areas (Table N).

To better understand the magnitude of these changes in the coefficient of variation, it is helpful to examine the convergence of ratings for some specific application areas. For example, the largest decline in the coefficient of variation between the first and second round was observed for the importance of RFID to contain cost related to "Staff monitoring at hospitals for management purposes" (first row of Table N). The distribution of responses (1-9) for this application area is shown in Table N, separately for both rounds. The table shows that responses shifted from the tails of the distribution (ie response options "1", "7" and "8") towards the middle (ie response options "5" and "6"), suggesting that opinions converged. Of particular interest in this example is the shift at the upper end of the distribution towards the middle, suggesting that most experts agree that this particular application of RFID is of limited importance to contain healthcare costs.

Interestingly, the two areas with the largest *increase* in the coefficient of variation (thus suggesting divergence of opinions) were both related to Error prevention (eg, via SurgiChip), shown at the bottom of Table N.

Table N: Difference between coefficient of variation of ratings given in 1st and 2nd round (N=19)

		Application area	Round 1 C.V.	Round 2 C.V.	Diffe-rence
Staff	Cost	Staff monitoring @ hospitals for management purposes	0.459	0.366	-0.093
Assets	Cost	Inventory utilisation	0.237	0.150	-0.087
Staff	Cost	Staff tracking and tracing @ hospital (ER) to speed up service	0.405	0.318	-0.087
Staff	Qual	Staff monitoring @ hospitals for management purposes	0.396	0.324	-0.073
Staff	Qual	Better staff time utilization	0.202	0.131	-0.071
Staff	Qual	Staff identification @hospitals to manage access	0.491	0.430	-0.061
Patients	Cost	Accurate patient identification<	0.218	0.158	-0.060
Assets	Cost	Asset tracking	0.191	0.131	-0.060
Staff	Qual	Staff tracking and tracing @ hospital (ER) to speed up service	0.366	0.309	-0.057
Assets	Qual	Asset tracking and tracing: for expiration date and restocking	0.166	0.129	-0.037
Staff	Qual	Reduce forms processing time	0.215	0.181	-0.035
Staff	Qual	Improve labour productivity	0.319	0.284	-0.034
Staff	Cost	Workflow optimisation at hospitals	0.183	0.150	-0.032
Patients	Qual	Interventions: automated care, pathways, procedures audit, management	0.254	0.224	-0.030
Patients	Cost	Intelligent medication monitoring (for elderly at home)	0.278	0.248	-0.030
Patients	Cost	Patient tracking and tracing @ hospitals for monitoring patient flow	0.193	0.164	-0.030
Assets	Qual	Asset tracking and tracing: to avoid procedure delays	0.172	0.144	-0.028

Assets	Qual	Medicine tracking	0.134	0.107	-0.028
Staff	Qual	Workflow optimisation at hospitals	0.229	0.205	-0.025
Patients	Cost	Interventions: automated care, pathways, procedures audit, management	0.247	0.225	-0.022
Patients	Cost	Tracking of drugs, supplies and procedures performed on each patient	0.200	0.179	-0.021
Patients	Cost	Infant identification @ hospitals to forego mismatching	0.235	0.218	-0.017
Assets	Qual	Materials tracking to avoid left-ins	0.269	0.252	-0.017
Patients	Cost	Accurate patient identification for medication safety	0.193	0.177	-0.017
Patients	Qual	Patient identification to avoid wrong drug, dose, time, procedure	0.114	0.098	-0.016
Staff	Cost	Improve labour productivity	0.199	0.183	-0.016
Assets	Qual	Tissue Bank operations	0.228	0.212	-0.016
Patients	Qual	Patient tracking to ensure safety/access control (dementia, psych)	0.176	0.160	-0.016
Assets	Qual	Inventory management	0.249	0.234	-0.015
Patients	Cost	Patient tracking to ensure safety/access control (dementia, psych)	0.229	0.215	-0.014
Assets	Qual	Maintenance of medical equipment	0.170	0.157	-0.014
Patients	Qual	Patient tracking and tracing @ hospitals for monitoring patient flow	0.229	0.216	-0.013
Patients	Qual	Critical information to the patient	0.164	0.151	-0.013
Patients	Cost	Portable, current and comprehensive health records	0.291	0.279	-0.012
Assets	Cost	Maintenance of medical equipment	0.132	0.120	-0.011
Assets	Cost	Tissue Bank operations	0.178	0.167	-0.011
Staff	Cost	Better staff time utilization	0.151	0.140	-0.011
Staff	Cost	Staff identification @hospitals to manage access	0.303	0.293	-0.011
Assets	Qual	Real time inventory count and location tracking	0.201	0.190	-0.010
Patients	Cost	Monitoring/tracking of patient location	0.260	0.251	-0.010
Patients	Qual	Accurate patient identification for medication safety	0.091	0.082	-0.010
Patients	Cost	Infant tracking and tracing @hospitals for security/ to forgo theft	0.248	0.239	-0.009
Patients	Qual	Monitoring/tracking of patient location	0.243	0.234	-0.009
Patients	Qual	Infant identification @ hospitals to forego mismatching	0.158	0.149	-0.009
Assets	Qual	Asset tracking and tracing: for access control and inventory shrinkage decrease	0.315	0.306	-0.009
Patients	Qual	Implanted RFID carrying medical record	0.440	0.431	-0.009
Patients	Cost	Critical information to the patient	0.317	0.308	-0.009
Patients	Qual	Dementia patients tracking and tracing (in/outpatient)	0.169	0.161	-0.008
Patients	Qual	RFID ingested or implanted to provide real-time information on health indicators and vital signs, to monitor and report on the results of surgeries, to regulate the release of medications, telemedicine	0.306	0.298	-0.008
Staff	Cost	Reduce forms processing time	0.297	0.289	-0.008
Assets	Cost	Asset tracking and tracing: to avoid procedure delays	0.212	0.206	-0.007
Patients	Cost	Dementia patients tracking and tracing (in/outpatient)	0.275	0.269	-0.006
Assets	Qual	Inventory utilisation	0.231	0.226	-0.006

Assets	Qual	Asset tracking	0.221	0.216	-0.005
Patients	Cost	RFID ingested or implanted to provide real-time information on health indicators and vital signs, to monitor and report on the results of surgeries, to regulate the release of medications, telemedicine	0.353	0.348	-0.005
Patients	Qual	Accurate patient identification<	0.153	0.149	-0.004
Assets	Cost	Medicine tracking	0.311	0.307	-0.004
Assets	Cost	Inventory management	0.152	0.148	-0.004
Patients	Cost	Patient identification for blood transfusion	0.201	0.198	-0.003
Patients	Qual	Patient identification for blood transfusion	0.109	0.107	-0.002
Patients	Cost	Implanted RFID carrying medical record	0.418	0.416	-0.002
Patients	Cost	Patient identification to avoid wrong drug, dose, time, procedure	0.197	0.196	-0.001
Patients	Qual	Eliminate wrong-patient, wrong procedure surgery	0.107	0.106	-0.001
Patients	Qual	Intelligent medication monitoring (for elderly at home)	0.136	0.136	0.000
Patients	Qual	Infant tracking and tracing @hospitals for security/ to forgo theft	0.185	0.185	0.000
Assets	Cost	Asset tracking and tracing: for expiration date and restocking	0.161	0.161	0.000
Assets	Cost	Real time inventory count and location tracking	0.166	0.166	0.000
Assets	Cost	Asset tracking and tracing: for access control and inventory shrinkage decrease	0.139	0.139	0.000
Assets	Qual	Asset identification: blood bags identification @hospitals/OR to ensure blood type matching	0.114	0.114	0.000
Assets	Cost	Materials tracking to avoid left-ins	0.294	0.294	0.000
Assets	Cost	Asset identification: blood bags identification @hospitals/OR to ensure blood type matching	0.168	0.169	0.001
Patients	Qual	Tracking of drugs, supplies and procedures performed on each patient	0.143	0.146	0.003
Patients	Cost	Eliminate wrong-patient, wrong procedure surgery	0.186	0.190	0.004
Patients	Qual	Portable, current and comprehensive health records	0.198	0.209	0.010
Staff	Qual	Error prevention (eg, via SurgiChip)	0.120	0.144	0.023
Staff	Cost	Error prevention (eg, via SurgiChip)	0.165	0.203	0.038

Table O: Frequency of response options (1-9) for the importance of RFID applications related to "Staff monitoring at hospitals for management purposes" to contain cost

	Frequency of response options (1-9)									
	"1"	"2"	"3"	"4"	"5"	"6"	"7"	"8"	"9"	Total
Round 1	2	2	2	0	3	5	3	2	0	19
Round 2	1	2	2	0	5	7	2	0	0	19

Appendix C: Case Study RFID Application Descriptions

Treviglio Caravaggio Hospital (Italy)

Application: Orthopaedic patient tracing in and between the Emergency Department (ED) and x-ray departments

Primary objective: To understand where patients were in the treatment between the ED and the X-ray department

Hospital context:

- 440 beds and a comprehensive set of ambulatory practices
- newly-built ED department
- 55 000 ED patients annually, on average 3-4 individual treatment per patient
- ED patient volume increasing by 10-12percent annually since 2004
- 200 orthopaedic ED cases each month

The technology:

- active IDENTECT RFID tags, activated upon completion of patient registration with the ED, deactivated when dismissed or admitted to hospital.
- RFID signals are intercepted by 6 Indetec Intelligence Long Range interrogators.
- the system uses the Hospital WLAN
- supporting technical infrastructure is WINDOWS 2000 web server
- the back-end database has been developed using SQL
- middleware functionalities rely on COMPUWARE UNICODE.
- entire system is run through a standard HP server
- back-up by two synchronised disks
- no strong authentication system has been provided and, since the system aims exclusively at patient tracking, currently there is no integration with the hospital central infrastructure.

Partial economic assessment of nurse time saving

Partial economic evaluation of ED orthopaedic patient tracing application at Trevigglio Caravaggio Hospital17

			Scenario 1: ED Nurse spends 12 minutes talking to relatives	Scenario 2: ED Nurse spends 2 minutes talking to relatives	
			Without RFID	With RFID	
Staff Cost	Salary	€ 1,400.0			
	Italian Social Security	€ 1,000.0			
	Indirect ED/Hospital Costs	€ 500.0			
	Total Monthly costs	€ 2,900.0			
	Daily cost	€ 131.8			
	Hourly cost	€ 16.5			
	Minutes	€ 0.3			
COST of Information to Relatives	Cases	200			
	Daily	9			
	Daily cost per case		€ 29.96	€ 4.99	
					Savings
Total Cost	Y2006		€ 10,665.3	€ 1,777.5	€ 8,887.7
	Y2007		€ 10,985.2	€ 1830.9	€ 9,154.4
	Y2008		€ 11,314.8	€ 1,885.8	€ 9,429.0
	Y2009		€ 11,654.2	€ 1,942.4	€ 9,711.9
	Y2010		€ 12,003.9	€ 2,000.6	€ 10,003.2

[17] Assumptions: (i) Length of ED nurse time spent with patient relatives under two scenarios is based on an assumption that if average time spent in X-ray by each patient without the system is 15 minutes, and can be reduced to 5 minutes with it, family-nurse interaction time for the entire episode of acute care can be reduced from 12 minutes to 2 minutes; (ii) Total staff monthly costs include staff salary (monthly salary of a professional ED nurse is based on Italian government statistics; it includes the cost of overtime), social security (social security dues that the hospital has to pay to the government on behalf of the professional ED nurse) and indirect mandatory costs of ED staff nurses needed to pursue his/her tasks (eg professional insurance, equipment). Staff daily cost assumes that a staff nurse works 22 days per month); (iii) Interviews with hospital staff has indicated that the RFID system for orthopaedics is used an average of 200 times per month; (iv) Daily cost per case is based on the cost of staff per minute, minutes each case takes and number of cases per day; (v) The number of cases does not change between scenarios; (vi) Annual total cost is based solely on the daily cost per case and does not include costs associated with the replacement of RFID hardware, software maintenance or staff time needed for patient tagging, information download and system maintenance. 3% annual inflation is assumed when estimating annual total costs.

	Y2011		€ 12,364.0	€ 2,060.7	€ 10,303.3
	Total		€ 44,619.6	€ 5,494.2	37,183.0

Source: Rand Europe

Birmingham, Heartlands Hospital (UK)

Application: Passive pre-OR decision support technology (process management & identification system) using printed RFID wristbands and digital photo identification linked to an electronic pre-operative checklist

Primary objective: To automate the pre-operative process by having a digital operating list, enabled by automated patient recognition, preventing wrong site/side surgeries, increasing hospital efficiency, and decreasing exposure to litigation costs

Hospital context:

- Birmingham Heartlands Hospital is part of the Heart of England NHS Trust – one of highest-performing in the UK; voted Acute Trust of the Year in 2006
- number of surgery patients annually going through BHH: # of patient admissions to ENT at Heartlands over previous 12 months was approx. 800,000 (the denominator for the overall cost of the system over 3 years which is the length of the contract)
- SSS developed to address:
  - never events occurring due to operating list errors and unreliable paper-driven processes);
  - human & litigation costs of patient misidentification to NHS
- SSS implemented in two hospital wards

The technology:

- installed at points of primary patients admission (ED, administration units), where on arrival patient details are sourced from the hospital's Patient Administration System, confirmed by the patient; a digital photo of the patient is taken, placed in the file and a wristband is printed & a patient ID encoded in an RFID tag (or barcode) which clinicians and nursing staff can scan at any point of the patient's pathway; via SSS clinicians, anaesthesiologists and nursing staff are each responsible that various pre-operative checks are carried out; the electronic OR theatre list and patient records are available to all staff on the wards, anaesthesia rooms, operating theatre and recovery rooms; the OR theatre process control also includes visible and audible messages between clinicians and nursing staff, and can record and broadcast expected discharge times (aiding bed management); the automatic logging of per-operative steps supports clinical governance auditing
- SSS is a closed-loop security system, data is Trust-owned and in compliance with NHS governance guidelines
- hardware:
  - single use passive RFID (13.56 MHz) and/or barcode tagged patient wrist band; RFID tags are read/write
  - Zebra RFID/barcode printers

  - webcams
  - fixed and mobile FEIG RFID/barcode scanners
  - PDAs & USB-controlled PCs
- integrates with core systems through SOAP XML Web services or HL7 Messaging; and, works with WiFi compliant networks
- three servers to simplify integration with the hospital information infrastructure:
  - Microsoft Windows server/ VMWare
  - Microsoft internet information server
  - Microsoft SQL 2005 server (storing roughly 500 records per day, 10 to 20 per the 5 wards)
- no interferences between SSS and other equipment were found during its development and piloting; however one of the further directions for SSS developments is to supplement PDAs and handheld scanners with computers on trolleys (as the former two were describes as "not so reliable")

Amsterdam Medical Centre (NL)

Applications:

- Un-scaled pilots of: a) identification/localisation of persons in OR (less than 50percent of staff participated); b) OR materials tracing; c) blood products tracing
- although the three pilots represented different applications they focus on similar processes and patient populations, and rely on a common infrastructure (CapGemini n.d., p. 13).
- government & industry sponsored

Primary objective: The interest of the AMC was primarily focused on questions such as "is this a technology that works", "what can we learn from this technology", and "what is the added value in terms of patient safety"

Context:

- government & industry sponsored pilot
- initial goals to ambitious, not feasible in practice
- staff participation in the pilots was voluntary; staff was tracked at the functional rather than the individual level; on average less than 50percent of the staff working at the site of the pilots wore their RFID badges (CapGemini n.d., p. 40).

Passive and active RFID tags attached to:

- vascular grafts and baskets filled with suture materials
- staff and patients
- blood products (bags with red blood cells and platelets)
- blood plasma (frozen) not possible due to low temperature

The technology:

- For persons and blood products, active tags produce a signal picked up by 'wake-up' antennas situated near certain doorways. As a result, the RFID system registers the time the tag passes the doorway.
- For these reasons materials were scanned by hand when leaving and returning to the storage room and through RFID antennas in the waste disposal room. Because the latter were moved out of the waste disposal room to the hallway (as the result of maintenance work), not all materials were fully tracked (CapGemini n.d., p. 27).
- For blood products it was not possible to use the information on the temperature of the product (measured through RFID tags) as this would require the development of models to relate the room temperature to the registered temperature and the core temperature of the product (CapGemini n.d., p. 27).
- All data were stored in an Oracle database and analyzed through the Movida application developed by Geodan. The latter application allows to link the RFID tag numbers to patient IDs or blood product Ids

CapGemini summary of technology used in pilot

Active RFID technology provided by Avonwood Developments Ltd, United Kingdom

- Avonwood Eureka iD Secure Card Tag for professionals
- Avonwood, Eureka iD Wrist Band Tag Assembly for patients
- Avonwood, Eureka iD Temperature Tag Assemly for blood products
- Avonwood, Eureka iD Reader (LAN) Unit Assembly, 868 MHz
- Avonwood, Eureka iD Wakeup Unit Assembly and Wakeup Antenna, 125 kHz

Passive RFID technology provided by PHI DATA, The Netherlands

- KSW Tempsens tag for blood products
- FEIG Reader for KSW Tempsens tags, 13.56 MHz
- TI/Impinj EPCglobal Gen2 compatible tag for materials
- FEIG Reader for EPCglobal Gen2 tags, 868 MHz
- Handheld scanners: Intermec 700 Series Color mobile computers with IP4 Portable RFID Reader running Oracle Mobile Sensor Edge and Oracle Lite database

Server technology provided by HP The Netherlands

- HP Proliant server with Intel Xeon 3.4GHz 2MB 370/380 G4 Processor running Microsoft Windows Server 2003

Client technology provided by HP The Netherlands

- HP Compaq dc7600 with Intel Pentium4 521 (2.8/800/1M) running Microsoft Windows XP

Database and middleware technology provided by Oracle The Netherlands

- Oracle Database Server (version 10.2.0.10)
- Oracle Application Server (version 10.1.2.0.2)
- Oracle Sensor Edge Server

Application technology provided by Geodan Mobile Solutions, The Netherlands

- Geodan Movida version 1.3.0.23

Source: GapGemini. Gaining solid results with RFID in healthcare.

University Hospital Jena (DE)

Application: Un-scaled pilot of RFID-assisted medication commissioning and medication preparation for patient safety in intensive care

Primary objective: Using the platform's auto-ID infrastructure to identify, track and match medication accurately and in real-time from the hospital's pharmacy until they are administered to patients.

Context:

- modern hospital (build after 2000)
- 4,300 staff, 26 clinics, more than 250,000 patients per year
- Intensive care unit: 72 beds, 100 doctors, 300 employees
- RFID-assisted medication preparation and medication commissioning for intensive care
  - a fully automated unit-dose process
  - RFID assisted medication preparation at bedside (focus on 'last mile')
- pilot scope:
  - 10 rooms of the intensive care unit (~30 patients at one time)
  - RFID tagging of 120 different antibiotics (unit dose)
  - RFID tagging of all drug boxes
  - RFID tagging of transport containers for the automatic transport system
  - RFID tagging of roughly 30percent of ICU patients
  - RFID tagging of ICU medical staff

The technology:

- staff badge: Mifare (13.56 MHz, encrypted, not ISO conform); 13.56 MHz sticky tags (ISO 15693, re-write, passive tags)
- patient wristband, medication, drug boxes and transport containers: 13.56 MHz read/write passive tag (ISO 15693), Dynamics System (distributor)
- pharmacy readers supplied by Deister; Readers IC unit:WPA-2 operable handhelds with integrated web browser (Blackjets Datalogic)
- printers: Zebra R2844Z
- software device management layer: Nofilis
- software business layer: SAP
- interfaces to legacy IT system developed in-house

University Hospital Geneva (CH)

A) RFID-enabled garment tracking application (1995-2008)

Primary objective: Following the merger in 1995, HUG was confronted with a specific logistical problem: how to manage working garment within and across the newly merged hospitals

Context:

- In 1995, the four Geneva-based university hospitals merged to become the University Hospitals of Geneva (HUG), a consortium of hospitals, spread across five campuses with more than 30 ambulatory facilities, comprising more than 2,000 beds, 5,000 care providers, over 47,000 admissions and 780,000 outpatients' visits each year. HUG provides the complete range of inpatient to outpatient services, from primary to tertiary facilities.
- ownership of RFID application planning, development and piloting given to Department of Logistics which is also tasked with laundry service, provision of clothing and household linen, catering, cleaning, transportation, distribution and warehouse, reception and information services
- RFID-enabled systems manages daily collection, ironing and redistribution of garments across four sites, seven distributors, distribute 28,000 garments per week
- hospital is an early technology adopter

The technology[18]:

- staff badge: EM 4150, 125 kHz, read /write tag
- RFID tag garment tag: 13.56 MHz read-only passive tag
- standard software package supplied with equipment
- interfaces to legacy IT system developed in house
- automatic distribution facilities (24/7 service)

B) RFID-supported computerising chemotherapy for patient safety (pilot, replaced by DataMatrix)

Primary objective: To improve patient safety, by matching care giver, patient and medication to ensure the "5 rights": right patient, right medication, right time, right dose, right route.

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[18] Please note that it has been difficult to choose which suppliers or providers to be mentioned or not in this document. For example, tag for employee badge has been provided by EM, but the badge supplier has been Cardintell; the payment solution was developed by Omega Electronic for Selecta; the readers for RFID badges are supplied either by Omega Electronic or by Tyco; Tyco supplied also other equipment and software for access control.

Context:

- chemotherapy is a highly complex and high-risk process involving numerous actors, depending on accurate, reliable, timely and fast information
- in 2004, HUG decided to reengineer the whole chain of processes involved in chemotherapy and to fully electronically capture the chemotherapy process from prescription to administration and commissioning of chemotherapy preparation
- eight HUG departments administer chemotherapies
- the Clinical Information Unit within Service of Medical Informatics (SIM) was charges with the planning, development and piloting of the application; the Oncology Department and the in house pharmacy were the other two key stakeholders
- the intention was to use RFID in combination with existing barcodes to computerise the complete process of chemotherapy
- pilot phase 1: Centralisation of the preparation of all chemotherapies administered and integration into the e-prescription process
- pilot phase 2: Focus on 'last mile': the medication administration and commissioning process at the patient's bedside

The technology:

- staff badge: 125 KHz read/write passive tag; 13.56 MHz sticky tags
- patient wristband: 13.56 MHz read/write passive tag
- medication: 13.56 MHz read/write passive tag
- standard identification: GS1-128 (formerly UCC/EAN)
- identification terminal: RFID-enabled PDA (HP iPaQ), online WLAN
- software package supplied by Nicecomputing (local SME)
- interfaces to legacy IT system developed in house

Wayne Memorial Hospital (USA)

Application: Hospital-wide tracking & management of portable assets & equipment (Real Time Management System)

Primary objective: to aid WMH staff in keeping tabs on the location and status of tagged assts, including: infusion pumps, diagnostics machines, blood warmers, and computers on wheels, wheelchairs and other equipment; and to enable WMH management to make better-informed capital investment and asset utilization decisions

Context:

- 300+ bed hospital in North Carolina, USA
- early technology adopter
- used by technology provider as beta site for "RadarFind" development, and creation of other RFID products
- "RadarFind" is predominantly used by clinical engineers, environmental services staff, nurses (including nurse supervisors and clinical administrators), central sterile staff and the WMH VP of Operations.

The technology:

- Real Time Location Solution
- includes hardware and software only (no middleware)
- application currently reliant on existing power grid for signal transmission
- technology:
  - synchronous multiple-input and multiple-output (MIMO) technology
  - 920 to 928 MHz ISM band
  - Does not operate in or interfere with the 802.11 (WiFi) 2.4 GHz band
  - Frequency-hopping spread spectrum (FHSS) - resistant to interference, secure (difficult to intercept), and can share frequency with other devices in the band
- certification classes: FCC part 15; UL 60950; UL 514-C, and UL 94V-0
- tags
  - available for specific applications - status and non-status tags
  - asset tags: 2.5"L x 1.25"W x (0.8" to 1.15")D
  - safe and ultrasonically welded
  - built-in temperature telemetry
  - tamper-resistant
  - lithium-ion battery (est. 6 year life, 30 second beaconing)

  - custom mounting: super-duty dual adhesive pad, slide-in locking base, plastic and steel mounting straps
- pluggable readers
  - plugs into 120V AC electrical outlets (no Ethernet wiring or IP address required)
  - dimensions: 5" W x 12..3" L x 2.25" D
  - integrated power supply (120V AC 60Hz 1W)
  - does not compromise use of the hospital grade outlet
  - synchronous operation (to minimize data loss and ease scalability)
- collectors
  - controls multiple remote radios for idealized data transmission
  - for WiFi-based - placed in variety of locations (IT closets; nurse's stations)
  - for power-grid based – placed on the power grid, in the IT closets
  - 100BASE-T Ethernet connection
  - requires 1 IP address
  - support for IEEE 802.3af (Power over Ethernet)
  - external power supply is optional
  - dimensions: 6.5" W x 9" W x 2" D
- server
  - fully pre-configured
  - remotely monitored (requires remote access)
  - redundant hard drives and power supplies
  - 1RU standard server rack mounting
- software
  - browser based (no plug-ins required)
  - fully configured with MapView, QuickView, ReportView and AdminView
  - customizable touch screen views

Application costs, Wayne Memorial Hospital (USA)

	Item	Count	Cost/ Item	Total	Who Carries It
Implementation Fixed costs					
Hardware					
	Reader	700	300	$210,000	RadarFind
	Tag	1,000	40	$40,000	RadarFind
	collectors	12	1200 to 1500	$15,600	RadarFind
	Server	1	8,000	$8,000	RadarFind
Software				$0	in bundle
Training				$0	in bundle
Total fixed cost				$273,600	One time cost
Implementation Variable costs					
Labor cost					
	Salaried	1	25% (% time 1st 6 months)	$9,125	WMH (cost 1st 6 months)
	hourly	6 to 8	10% (% time 1st 6 months)	$12,600 - $16,800	WMH (cost 1st 6 months)
Total Variable cost				$21,000 - $25,925 (1st 6 mon.)	WMH (cost 1st 6 months)
TOTAL Implementation costs				$294,600 - $299,525	
Ongoing Fixed Costs					
Software			$25,000	$25,000	WMH Annually
Data backup			$0	$0	WMH Annually
Total Ongoing Fixed Costs				$25,000	WMH Annually
Ongoing Variable costs					
Labor cost	salaried	1	12% (% time monthly)	$8,760 (yearly)	WMH Annually
	hourly	5	5% (% time monthly)	$10,500 (yearly)	WMH Annually
Total Ongoing Annual Labor Cost				$19,260 (yearly)	WMH Annually
Hardware cost	tags	40	$40	$1,600	WMH Annually
Total Ongoing Variable costs				$20,860	WMH Annually
Total Ongoing Annual Costs				$45,860	WMH Annually

Royal Alexandria Hospital (UK)

The application

WiFi tracking system to keep track of and locate portable devices used within the medical block using RFID tags attached to equipment.

Objectives:

Technical staff at the hospital spent a substantial amount of time searching for portable medical devices that needed to be serviced. This involved having to ask ward managers and nursing staff where items were and following the "loan" trail around the hospital.

Additionally, if the devices weren't found, they could not be checked and maintained as often as required. This could then lead to a reduced level of service and increased exposure to risk for patients.

"Our technical staff spent as much as one man-year each year looking for misplaced items." "For practical reasons it was not feasible for us to have a supplier that was not based in the UK."

Nursing staff and healthcare workers also experienced difficulty locating portable devices required to deliver healthcare. Items which were often moved between wards, such as infusion pumps, non-invasive blood pressure monitors and defibrillators, were difficult to locate when needed. Looking for these devices wasted time which could be more productively spent caring for patients.

The Context

- The Royal Alexandra Hospital, part of NHS Greater Glasgow and Clyde, is situated in Paisley
- The hospital serves a population of around 200,000 from a mix of urban and rural areas.
- The hospital provides a range of services including inpatient beds, general medical and surgical services, trauma and emergency surgery centre, HDU, medicine for the elderly, maternity hospital, Panda Children's Centre and Accident & Emergency.

Technology:

Airetrak was appointed to provide a medical device tracking solution that would work with the hospital's new Wireless local area network (wireless LAN).

The Airetrak ResourceView solution transforms the information received from the WiFi tags and wireless network, converts it into meaningful information, and makes it available in an easy-to-access format. The location of devices can be viewed on a web-based portal. This allows users to see in real-time where the items are on a map of the hospital.

It also provides detailed reporting and historical information which is useful when auditing usage and distribution of devices and an easy-to-use administration tool allows users to define zones and to assign WiFi tags to assets.

The WiFi tags provide a host of additional functions:

- Temperature sensors

- Motion sensors
- Alerts and notifications
- Anti-tamper technology
- Call button for emergency
- Bed management

Cost breakdown

Total Application Costs, Royal Alexandra Hospital (UK)

Implementation Costs	£210,350
Total software costs	£44,500
Total hardware costs	£81,900
Total system integration costs	£34,950
Total system integration costs-Internal Staff	£49,000
Annual Maintenance costs	£35,600
Software maintenance contract	£8,900
Hardware costs	£10,700
Internal support and development costs	£16,000

Implementation Costs Break-Down, RAH (UK)

1. SOFTWARE COST				
Software Package	# Units	Description Software Tools	Price per Unit	Total Price
Operating System	1	MS Windows 2003 Server Professional	£1,500	£1,500
Web Server	1	MS Internet Information Server	£0	£0
Airstrike asset tracking, visualisation and enquiry software	1	Resourceview 2.2	£32,000	£32,000
Database software	1	SQL server 2005	£1,000	£1,000
Wireless Control Software	1	Cisco Wireless Control Software 5.0	£10,000	£10,000
Total Software Costs				£44,500

2. HARDWARE COSTS				
Hardware	# Units	Description	Cost per unit	Total Cost
RFID Tag	100	Aeroscout T2/T3 Tags	£53	£5,300
RFID Reader	100	1242 & 1130 CISCO wireless access points	£272	£27,200
RFID Antennas	100	1/4 wave whip antennas supplied by CISCO	£6	£600
Wireless location Appliance	1	2700 Wireless Location Appliance (250 Client Licence)	£10,000	£10,000
Wireless Controller	2	4400 Wireless Local Area Controller (100 Licence Units)	£12,000	£24,000
Communication Switches	5	5 24 Port Power over ethernet switches	£1,200	£6,000
Server/Host Computer	2	Servers for the Wireless Control Software and Airetrak reourceview system	£4,000	£8,000
GE SFP LC Connector SX transceiver	4	Connectors for Power over ethernet switches	£200	£800
Total Hardware Costs				£81,900

3. SYSTEM INTEGRATION COSTS-PROFESSIONAL SERVICES				
Professional Figure	# Days	Professional involvement	Cost per Day	Total Cost
Project Manager	2	External Project manager	£600	£1,200
Senior Architecture Lead	10	Software developer for assett tracking & Visualisation application	£750	£7,500
Consultant Engineer Grade 2	5	Configuration of the CISCO Wireless system	£750	£3,750
Consultant Engineer Grade 3	5	Configuration of the CISCO Wireless system	£500	£2,500
Cabling & Installation for Wireless Access Points	40	Aggregated Costs	£500	£20,000
Total System Integration Costs-PS				£34,950

4. SYSTEM INTEGRATION COSTS-INTERNAL STAFF SERVICES				
Professional Figure	# Days	Professional involvement	Cost per day	Total Cost
Project Manager	50	Principal Clinical Scientist	800	£40,000
Internal Staff-Healthcare professional	5	Clinical Physicist	400	£2,000
Internal Staff-Healthcare professional	5	Medical Physics Technician	400	£2,000
Internal Staff-IT professional	10	Network Infrastructure Professionals	500	£5,000
Internal Staff-IT professional			0	£0
Total System Integration Costs-Internal Staff				£49,000