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Using Survey Data to Design a RFID Centric Service System for Hospitals

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The continuous growth of health care services expenses urges U.S. government to take actions. The adoption of Information Technology, and especially RFID (Radio Frequency IDentification) allow hospitals to re-engineer their processes in order to reduce costs, maintaining the same level of service to the patients. Information technology represents a core element of the service itself; therefore a service design approach is believed to improve the adoption rate of RFID in hospitals. The main goal of the present study is to propose an RFID based service platform for hospitals, which is consistent with a service science driven design approach. A survey of 33 California based hospitals has been used to identify the user requirements of the hospitals. Later, a business process re-engineering for hospitals is proposed. Firstly the different actors involved in the health care services, along with their relationships in terms of information flows, are identified. This leads us to identify the various operations in a hospital setting that have a potential to be streamlined by introducing RFID technology. Having introduced these operations, we theorize a customizable RFID service, which can be implemented sequentially by each hospital according to its individual conditions such that it suits them most.

Key words: service system design; survey; California based hospitals; radio frequency identification, RFID
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1. Background

1.1 A Services' Approach to Health Care

The continuous growth of the service sector in today's economies both in terms of Gross Domestic Product (GDP) (Chesbrough and Spohrer 2007) and employment (Karmarkar 2004) has recently led academics and practitioners towards a "science of services", an emerging interdisciplinary field aiming at applying rigorous approaches for the study, design and implementation of service systems (Spohrer *et al.* 2007, Maglio and Spohrer 2008).

Among services, health care accounts a high percentage of GDP in many industrial countries: in the most advanced European countries health expenses in 2007 were between 8.0 and 11.0 percent of the GDP, whereas in the United State they have reached the 16.0% in 2007 (OECD 2009). According to NCHC (2009) U.S. health spending is expected to reach \$2.5 trillion in 2009 (17.6% of GDP) and \$ 4.4 trillion in 2018 (more than 20% of GDP). As for the U.S., the combination of the aging of the Baby Boomers (the U.S. citizens born between 1946 and 1964) and the increase in life expectancy are considered to be the main factors leading to the continuous rise of health expenses (AHA and First Consulting Group 2007). Reducing the cost and improving the efficiency of the U.S. health care system is among the priorities of the government, which have been widely discussed in the recent health care reform debate on publicly funded health care.

The systemic rationalization proposed by the government is not the only way to improve the efficiency of health care. A great improvement can also be gained at the single facility level, by (re)-designing the services and consequently (re)-engineering the processes of hospitals.

Nevertheless, a scientific approach to services design, especially in health care, is extremely recent. 'Design scholars' have emphasized the necessity of users participation in designing the services (Cottam and Leadbeater 2004) and the usefulness of developing user cases in order to understand service requirements (Thackara 2007). On the other hand, 'Operations research and Operations management scholars' have mainly focused their research effort to the application of 'Lean Thinking' to the specific case of activities programming in the operating blocks (Kuo *et al.* 2003, Guinet *et al.* 2003, Jebali *et al.* 2005, Pandit *et al.* 2007). Their studies tackle only marginally the greater topic of managing the various processes related to patients, which is the core of the health care services.

1.2 Information Technology and Health Care Services

In recent years, there have been many research efforts to identify factors and practices indicating how technological innovation may support companies in creating a competitive advantage. For example, Tidd *et al.* (2001) argued that the possible contribution of innovation to create competitive advantages ranges from the continuous assessment of the cost/performance ratio, as in the case of incremental innovation, to the establishment of completely new competitive rules, as in the case of disruptive innovation. Incremental innovation is therefore believed to improve or maintain the same level of performance (e.g. customer service) by reducing the cost, as emphasized by Operations Management scholars (Hill 2005).

Information and Communication Technology (ICT) is one of the most important and fast growing innovations that provide companies with a wide range of opportunities to improve efficiency and effectiveness and even gain competitive advantage (Porter and Millar 1985, Mata *et al.* 1995). Health care lags behind other industries in adopting Information and Communication Technology by as much as 10-15 years (Goldschmidt 2005). The current administration of U.S. is planning to significantly invest to fund the modernization of the ICT health care system, with the goal of reducing the spiraling costs of health care and the drastic amount of paperwork and bureaucracy in medicine, which are making health care unavailable for a significant population of the United States (WINMEC 2009). The recent trend of the growing adoption of ICT in health care is highlighted by the American Hospitals Association survey on U.S. based hospitals (AHA 2008). This survey shows that Electronic Health Record or EHR (a system that integrates electronically originated and maintained patient-level clinical health information, derived from multiple sources, into one point of access) is implemented or in implementation by 68% of the hospitals. The same survey shows that Computer Physicians Order Systems (CPOE), which allows physicians to electronically order medication, tests and consultation, is implemented or in implementation by 27% of the hospitals. The most part of the hospitals started the adoption of these ICT solutions only in recent years.

Technology, and more specifically Information and Communication Technology, represents a core element in Service Systems along with people and value propositions (Maglio and Spohrer 2008). Qiu (2006) underlines that not only the research and development of ICT is a service by itself but also when ICT helps enterprises streamline their business processes, it essentially functions as a knowledge service. In the present paper, we consider ICT in the second perspective, as a core element of the health care service itself.

1.3 RFID Technology as an Innovation Driver for Health Care

Among the Information and Communication Technologies, a growing interest for Radio Frequency Identification (RFID) in hospitals comes from the possibility of obtaining improvements in terms of efficiency, quality of health care treatment and errors reduction (Correa *et al.* 2007, Thuemmler *et al.* 2007). Tzeng *et al.* (2007) suggest that RFID has an enormous business value for hospitals, based on the following drivers: more effective communications among staff, increased asset utilization, enhancement of the patient-care process, better participation of the patients in care process and better visibility on the workflow.

Radio-frequency identification (RFID) is a method of identifying unique items using radio waves. Typically, a reader communicates with a tag, which holds digital information in a microchip (RFID Journal 2002, Staples 2006). An RFID system in order to work needs to use a Middleware, a software that acts as an interface between the reader and the organizations' information systems (Prabhu *et al.* 2006, Su *et al.* 2007). RFID for hospitals has risen to public attention especially for social concern about the privacy of the information tracked (Fishkin and Lundell 2005).

The use of RFID technology in the health care market is on rise. The global market of RFID tags and systems in the health care sector will increase steadily from \$ 90 million in 2006 to \$ 2.1 billion by 2016 (IDTechEx 2006). RFID solutions have primarily been implemented in emergency departments and surgical centers, where medical equipments should be located quickly and there are large volumes of patients and heightened risk of medical errors (Chen *et al.* 2008, Fisher and Monahan 2008).

Nevertheless, the demand for RFID technology in the health care sector has not been strong as was initially predicted despite RFID's many benefits, such as improved management of assets, drugs and patients and reduced

number of medical errors (BearingPoint, 2006). Difficulty in integrating data with hospitals not standardized IT infrastructure is one of the reason explaining that the adoption is slower than initially predicted (IDTechEx 2006, AHA 2008). Recent academic literature is also exploring the process of adoption of such technology. Chen *et al.* (2008), via interviews of doctors and caregivers, identify good interoperability between tags and readers, advantages of the technology over the bar-code and good prior experiences with the technology as key drivers for the continued use of RFID technology in the emergency room. Fisher and Mohan (2008), via interviews with technical hospital staff members, physicians and nursing, highlight that RFID projects implies a Business Process Reengineering activity that needs to rethink the organization of the personnel, and how its work is managed and evaluated. A strict involvement of CEOs and administrators of hospital is therefore suggested. Moreover, Janz *et al.* (2005) suggest that the presence of champions is a critical success factor for the implementation of RFID technology. Lee and Shim (2007), via an empirical survey of hospitals managers, mainly CIOs, proved that the presence of champions (usually C-level managers) is one of the main factors driving the adoption of the technology.

2. Goals and steps for designing the service system for hospitals

As reviewed in the previous paragraph, ICT and especially RFID can be considered among the innovations that allow hospitals to gain efficiency in their processes while maintaining or even improving the service level, making therefore health care accessible to more people. Nevertheless, as pointed out before, the adoption of this technological solution is quite low. This fact can also be attributed to the lack of a scientific methodology that can help hospitals to re-design their processes after the technology adoption, as pointed out by Cottam and Leadbeater (2004) and Thackara (2007). Therefore the main goal of the present study is to propose an RFID based service platform for hospitals, which is consistent with a service science driven design approach.

With this regard, Bullinger *et al.* (2003) have proposed a service development approach, articulated in the following steps: (1) Idea generation; (2) Requirements analysis; (3) Concept development; (4) Implementation; (5) Market launch; (6) Post-launch review. The present article focus on the steps (2), (3) and (4) of Bullinger *et al.* model, since they can be considered the most critical ones from a 'design methodology' point of view. Moreover, step (1) has been partially described in Section 1.3., whereas steps (5) and (6) are more related to recurrent business operations than scientific research. According to previous literature, the three steps analyzed in the present paper have been re-named **User requirements identification** (Cottam and Leadbeater 2004, Thackara 2007), **Business process management or re-engineering** (Qiu 2009), and **Guidelines for implementation**. These steps constitute the 'building blocks' of the service science driven design approach used in this paper.

Identifying **User requirements** is a fundamental activity in service design (Karmarkar 2004). As for health care, the development of user cases (Thackara 2007) and the users participation in designing services (Cottam and Leadbeater 2004) have been emphasized. In previous studies focusing on service design, case studies methodology (Yin 2008) had been used, also with specific reference to RFID adoption (Qiu 2007, Fosso Wamba *et al.* 2008). Structured surveys have been used in order to understand the RFID adoption process (Lee and Shim, 2007) but also in service design literature, for example to measure service development competence (Menor and Roth 2007). Nevertheless, in the knowledge of the authors, surveys had not been widely used as a methodology to investigate user requirements. Survey data, which represents a random sample, can be representative of the population studied and can be manipulated with statistical tools. For this reason, surveys usually leads to results which are more representative and generalizable than the ones that can be obtained with case studies, since the latter focus exclusively on specific scenarios (Forza 2002) Nevertheless, survey methodology is more structured than case studies and is only applicable when the phenomenon analyzed has been already widely studied, as it is the case of RFID, where it has been possible to put forth a questionnaire based on previous literature. A survey of 33 California based hospitals administrators has been carried out in order to understand the user requirements of an RFID based service platform (Paragraph 3). The survey investigates four main points: the current service systems adopted in the sector; the kinds of applications requested by the users; the reasons for implementing and the factors impeding the adoption.

The **Business Process Management or Re-engineering** step can be further broken down in the activities as follows (Morelli 2007):

- Identification of the **actors involved** in the definition of the service.
- Codification of the **service blueprint**, i.e. the map of the sequence of events in a service and its essential functions (Shostack 1982, Shostack 1984). Design orienting scenarios (Morelli 2007) and workflow models (Qiu 2009) are two of the techniques proposed for this activity in previous studies.

- Representation of the service, which should include the **platform of the service system** proposed: people, material flow and information flow (Morelli 2007).

In the present paper, the Business Process Management or Re-engineering step has been carried out on the basis of face-to-face interviews with CIOs involved in current action research projects with the WINMEC consortium (Paragraph 4). From a formal point of view, both case studies and action research seem suitable methodologies to be applied to this step (Qiu 2007, Fosso Wamba *et al.* 2008).

The last step, **Guidelines for implementation**, takes into account technical and organizational issues in order to achieve an effective implementation of the solution (Paragraph 5).

3. Users Requirements Identification

The survey methodology has been chosen in order to identify the user requirements of an RFID based service platform. The survey has been directed to California based hospitals, which represents the 'target market' for the research activities of WINMEC-UCLA. The respondents identified were CEOs, because as high-level managers they are aware of the needs of their organizations, and as highlighted by Lee and Shim (2007) and Balocco *et al.* (2009), they often play a pivotal role in the adoption of Mobile and Wireless technologies such RFID. The survey investigates four main points: the current service systems adopted in the sector; the kinds of RFID service systems requested by the users; the reasons for implementing RFID and the factors impeding RFID adoption.

The survey methodology has been organized into the steps as follows (Forza 2002):

1. **Questionnaire design.** The relevant literature on the topic was instrumental to prepare a first draft of the questionnaire. Since the questionnaire was targeted to CEOs, not-technical language has been used. A certain degree of overlapping between the questions has been adopted in order to check contrasting or inconsistent information. Ten relevant experts (CIOs and CEOs of hospitals, researchers and academics) participated to a meeting held in October 2007 at UCLA in order to check the comprehensibility of the questionnaire and verify its appropriateness for a web-based survey. Experts highlight potential difficulties for respondents in retrieving quantitative information and ambiguities in our questions. Feedbacks from prospective respondents required changes to approximately 10% of the questionnaire. The final questionnaire contained 23 questions, organized into the following six sections: organization description, degree of Information Technologies adoption, knowledge of RFID and its implementation plan, main data on RFID projects in implementation (if applicable), reasons for implementing RFID, factors impeding RFID adoption. Likert scales (five point scales asking the respondent how much he does agree with a statement, Forza 2002) were used for the last two sections whereas the other ones used multiple-choice items. Respondents could insert their comments in every section of the questionnaire.
2. **Sample definition.** The survey was addressed to California hospitals, which represent the 'target market' for the research activities of WINMEC-UCLA. The California Hospital Association (CalHealth 2008) identifies 382 hospitals in California. Among them, it has been possible, through hospitals web sites or phone calls, to identify 350 CEOs (since sometimes a CEO administrates more than one hospital).
3. **Preparation of the mailing list.** The CEOs contacts that have been used for the survey have been found on the web. Some of the contacts have been also drawn from attendants to UCLA-WINMEC conferences. The response rate was almost the same for the two categories.
4. **Contact strategy.** An e-mail invitation to participate in the survey had been sent in November 2007 to the 350 CEOs identified, explaining the purpose of the initiative. Respondents were allowed to answer to the question directly within the invitation e-mail or by connecting to a web site.
5. **Survey tool.** The web-based survey has been implemented on UCLA servers with the open source survey application Lime Survey 1.53 (Limesurvey 2008). The web-based survey allowed us to automate the sending of e-mails and reminders and the collection of the data.
6. **Survey administration.** In order to improve the response rate, three e-mail reminders have been sent to the 350 CEOs. The total number of questionnaires received was 33, with a response rate of 9.4%. The response rate is satisfying for a web-based survey (Klassen & Jacobs 2001), especially if we consider that respondents are top executives. CEOs have been followed up by phone only in case of missing data, inconsistencies or anomalies.

The sample includes the opinions of 33 CEOs of U.S. based hospitals. Among the hospitals surveyed, 7 are implementing RFID projects, for a total expenditure of \$ 5.6 million. IDTechEx (2006) assess that the world hospitals expenditures in RFID amounts at \$ 100 million in 2007. As most of the projects were completed within about 3 years, the sample would therefore be in the region of 1.9% of the hospitals global expenditure in RFID. As

for the size of the hospitals surveyed, the largest group (15; 45.5% of the sample) has between 200 and 499 beds, followed by hospitals that have between 100 and 199 beds (8; 24.2%) and hospitals with less than 99 beds and hospitals with more than 500 beds (5; 15.2 for both). Among the hospitals surveyed 19 (57.6%) are private and 14 (42.4%) are public. Only 3 hospitals are profit (9.1%) and 30 are not profit (90.9%). The most part of the hospitals surveyed are urban (24; 72.7% of the sample) whereas 9 (27.3%) are rural. Finally, the most part of the hospitals are teaching (20, 60.6%) whereas 12 are non-teaching (12; 36.4%).

3.1 Current service systems adopted in the sector

The survey investigated the rate of adoption of service systems such Electronic Health Record (EHR), Computer Physicians Order Entry Systems (CPOE), Radiology Information Systems (IS), Pharmacy IS, Laboratory IS, Administration IS and (AHA, 2008). The results are depicted in Table 1.

Table 1 Service Systems Adopted in California based Hospitals

	Fully Implemented	Implementing	Not implementing	Total
EHR (Electronic Health Record)	13; 39.4%	12; 36.4%	8; 24.2%	33; 100%
CPOE (Computer Physicians Order Entry)	10; 30.3%	10; 30.3%	13; 39.4%	33; 100%
Laboratory IS	27; 81.8%	2; 6.1%	4; 12.1%	33; 100%
Radiology IS	28; 84.8%	2; 6.1%	3; 9.1%	33; 100%
Pharmacy IS	28; 84.8%	3; 9.1%	2; 6.1%	33; 100%
Administration IS	25; 75.8%	3; 9.1%	5; 15.2%	33; 100%
Radio Frequency Identification	2; 6.1%	5; 15.2%	26; 78.8%	33; 100%

RFID is in implementation or adopted by 7 of the hospitals surveyed, i.e. 21.2 % of the sample, that is consistently higher than the average rate of adoption of the technology for U.S. hospitals (12%, according to AHA, 2008). However, only 2 hospitals have fully implemented the solution. Almost half of the respondents (15; 45,5%) are taking the technology into consideration. Finally 6 CEOs (18,2% of the sample) declared to not know RFID technology.

Hospitals where RFID is implemented or in implementation usually have a good level of adoption of the most advanced service systems (i.e. EHR and CPOE). The integration between RFID and these technological solutions should thus be taken into consideration in the definition of an RFID based service system.

Cost of the investment is a critical factor slowing down the adoption of all these solutions, especially for small and rural hospitals, and should also be taken into account in the RFID based service system. For example, one of the respondents commented: "Our hospital is a rural, primary care center. The bottom line is not positive. Everything of this nature must be purchased on grants. Grants go to bigger facilities – Our hospital will buy when the \$\$\$ begin to roll to rural."

3.2 Kinds of RFID Service Systems Requested by the Users

On the basis of the literature available on the topic (Table 2), we put forth a simple and clear classification of RFID service systems, which includes the categories as follows: **systems with RFID on assets** (e.g. medical equipments, drugs, etc.), **systems with RFID on people** (e.g. patients, medical staff, etc.), **systems with RFID on assets and people integrated**, which usually enhance the care treatment process.

Table 2 Kinds of RFID Service Systems

RFID on asset	- RFID on medical equipments in order to track them and better manage the inventory (Panagiotis & Ria 2006, Fisher & Monahan 2008).
	- RFID on medical equipments in order to locate them quickly when it is necessary (Britton 2007, Chen <i>et al.</i> 2008).
	- RFID on documents and patient charts in order to archive and retrieve them easily (IDTechEx 2006)
	- RFID on biological sample in order to archive and manage them electronically: e.g. on blood bag (Tzeng <i>et al.</i> 2008) or on specimen (Prabhu <i>et al.</i> 2008).
	- RFID on therapeutic devices (pacemakers, cochlear implants, etc.) in order to interactive status reading and monitoring (Masters & Michael 2007).
	- RFID on materials that have been in contact with patients in order to track them in case of infectious disease: e.g. on laundry, rented textile (IDTechEx 2006) or on waste (Tzeng <i>et al.</i> 2008).
	- RFID on drugs that enable hospitals to check if they are counterfeited (Thompson 2004, Panagiotis & Ria 2006).
	- ...
RFID on people	- RFID tags on wrist bands in order to univocally identify the patients (Poston <i>et al.</i> 2007, Thuemmler <i>et al.</i> 2007, Chen <i>et al.</i> 2008, Fisher & Monahan 2008).
	- RFID tags on wrist bands in order to univocally identify the victims of a disaster, e.g. in the case of Hurricane Katrina (Gadh & Prabhu 2006).
	- RFID tags on wrist band in order to track the process time of each exam performed by the patient (Janz <i>et al.</i> 2005).
	- RFID tags on wrist bands in order to locate the movements of patients with impaired cognitive function (e.g. Alzheimer's) (Panagiotis & Ria 2006) or children in order to avoid baby snatching (Tzeng <i>et al.</i> 2008).
	- RFID tags integrated with sensors in order to automatically monitor patients' vital sings and exigencies (Malan <i>et al.</i> 2004, Chen <i>et al.</i> , 2008, Tzeng <i>et al.</i> 2008).
	- RFID tags integrated with biosensors implanted in patients, which can transmit source information as well as biological data (Masters and Michael 2007).
	- RFID tags on personnel badges of for access control (Tzeng <i>et al.</i> 2008).
	- RFID tags on medical staff badges in order to collect data on workflow and inefficiencies in current hospital operations (Panagiotis & Ria 2006, Fisher & Monahan 2008).
	- Tracking the movements of medical staff, patients and visitors in order to check which people have been in contact with people affected by infectious diseases such as SARS (Panagiotis & Ria 2006, Tzeng <i>et al.</i> 2008).
	- ...
RFID on asset and people integrate	- RFID embedded in patient wrist bands and drugs in order to associate the correct medication to the therapy of the patient (Fisher & Monahan 2008)
	- RFID embedded in patient wrist bands and physical documents in order to associate the patient to his medical treatment (Tzeng <i>et al.</i> 2008)
	- ...

The survey showed that 22 respondents are interested in RFID: 15 hospitals administrators are considering the technology, 5 are implementing the technology and 2 have already implemented the technology. Those respondents, who are considering or implementing RFID, have been asked to detail which kinds of RFID service systems (RFID on assets, RFID on people, RFID on assets and people integrated) are considering or adopting.

Therefore it has been possible to classify the respondents interested in RFID service systems into two main groups:

Group 1: Hospitals administrators exploring all the opportunities. The respondents in this cluster are in an early stage of adoption of the technology. They are seeking the solutions in all the three different areas and by acquiring more information in order to understand which one is more suitable for their processes. This group includes the major part of the hospitals administrators surveyed (12 hospitals).

Group 2: Hospitals administrators focused on a specific RFID service system. The respondents in this cluster have already chosen which RFID service system will be suitable to implement (RFID on assets or RFID on people or RFID on assets and people integrated). Some of them are still evaluating the adoption of the technology (3 hospitals); others are implementing (5 hospitals) or have already implemented RFID (2 hospitals). Among the hospitals focused on a specific service system (Group 2, 10 respondents), a further distinction can be drawn on the basis of the specific service system identified. Among the 5 hospitals considering or implementing **RFID on assets**, 4 of them are focusing on medical equipment tracking and one of them on specimen tracking. As for the hospitals focusing on **RFID on people**, 2 of them are focusing on RFID solutions enabling patient tracking, whereas a third organization is implementing a contactless smart card to identify patients, in collaboration with other hospitals. RFID on assets service systems and RFID on people service systems described by the users surveyed are not integrated with other IT applications and their cost ranges from \$ 50,000 to \$ 100,000. As for the 2 hospitals implementing **RFID on assets and people integrated**, their focus is to enhance the whole care treatment process. These two solutions are integrated with EHR and CPOE service systems and the cost of each one is more than \$ 1 million.

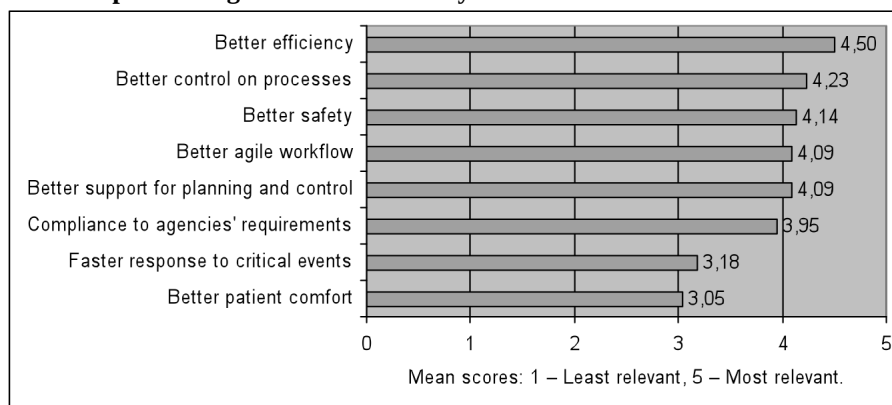
The adoption of RFID service system is more effective when a specific area of application for the technology is defined (e.g. medical equipment tracking, patient tracking). In fact this application has a lower level of complexity and a lower budget if compared with the RFID service system enhancing the whole care treatment process. For this reason, a progressive RFID adoption (during time) is suggested for hospitals. Hospitals should have the possibility to invest in single specific service systems on the basis of their priorities and their funding available. These service systems should be the modules of the overall platforms, compatible with each other and also with other hospitals IT systems.

3.3 Reasons for Implementing RFID

Hospitals administrators that are either considering (16) or are actually implementing RFID technology (6) were asked for the reasons for deploying RFID in their organization on a scale of 1-5, 1 being least relevant and 5 being most relevant. On the basis of previous literature, the main reasons for adopting RFID in hospitals included in the questions were: *Better agile workflow* (Egan & Sandberg 2007, Fisher and Monahan 2008); *Better control on processes* (Janz *et al.* 2005, Fisher and Monahan 2008); *Better efficiency* (Chen *et al.* 2008); *Better patient comfort* (Janz *et al.* 2005, Chang *et al.* 2008); *Better safety* (Varshney 2005, Chao *et al.* 2007, Egan & Sandberg 2007, Chang *et al.* 2008, Fisher & Monahan 2008); *Better support for planning and control* (Janz *et al.* 2005, Panagiotis & Ria 2006); *Compliance to agencies' requirements* (Varshney 2005, Chen *et al.* 2008); *Faster response to critical events* (Varshney 2005, Egan & Sandberg 2007).

The results are depicted in Figure 1. RFID is mainly seen by the CEOs as a technology for automating processes in order to achieve better control (4.23) or better efficiency (4.50). Better safety (4.14) is also one of the reasons with the highest score: the reduction of errors implies thus a direct reduction of legal costs. Reasons related to service level are the ones with the lowest scores: "Faster response to critical events" (3.18) and "Better patient comfort" (3.05).

Figure 1 Reasons for Implementing an RFID Service System



A t-test has been performed in order to assess the significance between the averages of the reasons for implementing between the two different groups of respondents defined in Section 3.2: Group 1: Hospitals

administrators exploring all the opportunities and Group 2: Hospitals administrators focused on a specific service system (Table 3).

Table 3: Reasons for Implementing an RFID Service System

	Mean		t-ratio	p-value
	Group 1	Group 2		
Better efficiency	4.42	4.60	0.7079	0.4872
Better control on processes	4.42	4.00	1.3172	0.2027
Better safety	4.25	4.00	0.6478	0.5245
Better agile workflow	4.33	3.80	1.9374	0.0669
Better support for planning and control	4.00	4.20	0.8827	0.3879
Compliance to agencies' requirements	3.58	4.40	2.7945	0.0112
Faster response to critical events	3.33	3.00	0.9782	0.3396
Better patient comfort	3.42	2.60	2.1795	0.0414

Notes: Group 1, "Hospitals administrators exploring all the opportunities" (n=12); Group 2, "Hospitals administrators focused on a specific service system" (n=10); responses: 1, least relevant; 5, most relevant.

Hospitals administrators focused on a specific service system (Group 2) are characterized by more pragmatism than the hospitals exploring all the opportunities (Group 1). Compared to Group 1, hospitals of Group 2 thus estimate less important reasons for adoption intangible benefits as "Better agile workflow" (significant at 0.1 level) and "Better patient comfort" (significant at 0.05). Moreover, hospitals focused on a solution are willing to adopt RFID in order to be compliant to agencies' requirements more than hospitals exploring all the opportunities (significance at 0.05 level). The results show that the top reason for implementing RFID is in order to increase efficiency. In conclusion, hospitals already focused on a specific solution seem more practical, by marking as top reasons the ones more related with tangible benefits (efficiency and safety) whereas the hospitals still "exploring all the opportunities" are still considering the reasons related to more intangible benefits (agile workflow, patient comfort). These elements will be taken into account in the proposed solution.

3.4 Factors Impeding RFID Adoption

Hospitals administrators that are either considering (16), actually implementing RFID technology (6) and not interested at all in the technology (6) were asked for the factors impeding RFID adoption in their organization on a scale of 1-5, 1 being least relevant and 5 being most relevant. On the basis of previous literature, the main factors impeding RFID adoption in hospitals included in the questions were: *Use of Bar-code* (Bureau *et al.* 2008, Chen *et al.* 2008); *Cost* (Janz *et al.* 2005, Varhsney 2005) *Difficulty in foreseeing benefits* (Egan & Sandberg 2007); *Difficulty in integrating RFID with IT* (Janz *et al.* 2005, Thuemmler *et al.* 2007, Chen *et al.* 2008, Fisher and Monahan 2008); *Difficulty in redesigning the workflow* (Egan & Sandberg 2007, Fisher and Monahan 2008); *Interference with other equipment* (Janz *et al.* 2005, Varshney 2005, Britton 2007); *Lack of funding* (Janz *et al.* 2005, Fisher and Monahan 2008); *Lack of standards* (Koroneos 2006); *Not a priority* (Janz *et al.* 2005, Lee & Shim 2007).

The results are depicted in Figure 2. The factors with the highest scores are mostly economical: "Lack of funding" (4.29) and "Cost (4.21). Bar-code (3.25) is also seen as a technology that can be adopted in substitution of RFID: therefore hospitals are taking into consideration only simple RFID solutions. Interference with other medical equipment (2.57) does not seem a real problem for the hospitals surveyed.

Figure 2: Factors Impeding Adoption of an RFID Service System

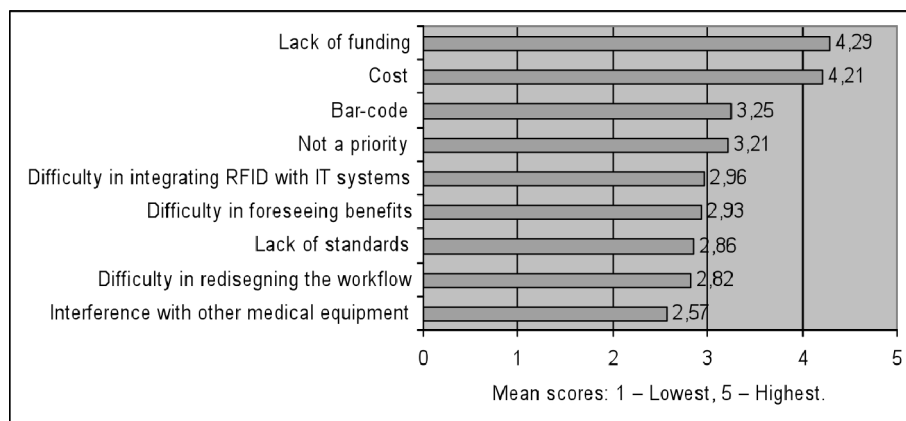


Table 4 breaks the results of the factors impeding adoption for three groups: “Hospitals administrators exploring all the opportunities” (Group 1 – 12 respondents), “Hospitals administrators focused on a specific service system” (Group 2 – 10 respondents) and “Hospitals administrators not considering at all the technology” (Group 3 – 6 respondents). Also in this case, a t-test has been performed in order to assess the significance between the means of the three groups.

Table 4: Factors Impeding Adoption of an RFID Service System.

	Mean			Gr. 1 vs. Gr. 2		Gr. 1 vs. Gr. 3		Gr. 2 vs. Gr. 3	
	Gr. 1	Gr. 2	Gr. 3	t-ratio	p-val.	t-ratio	p-val.	t-ratio	p-val.
Lack of funding	4,50	3,90	4,50	1,9917	0,0602	0,0000	1,0000	1,5000	0,1558
Cost	4,58	3,70	4,33	2,7797	0,0116	0,8000	0,4354	1,3571	0,1962
Bar-code	3,33	2,70	4,00	1,6155	0,1219	1,1732	0,2579	3,3096	0,0052
Not a priority	3,25	2,40	4,50	1,3925	0,1791	2,1442	0,0477	1,3354	0,2030
Difficulty in integrating RFID with IT	3,33	2,30	3,33	1,9458	0,0659	0,0000	1,0000	2,9898	0,0097
Difficulty in foreseeing benefits	2,58	3,10	3,33	1,0232	0,3184	1,4884	0,1561	0,3586	0,7253
Lack of standards	2,75	2,30	4,00	0,9942	0,3320	2,3408	0,0325	3,0698	0,0083
Difficulty in redesigning the workflow	2,67	2,70	3,33	0,0700	0,9449	1,1371	0,2723	1,2520	0,2311
Interference with other equipment	2,67	2,40	2,67	0,5166	0,6111	0,0000	1,0000	0,3809	0,7090

Notes: Group 1, “Hospitals administrators exploring all the opportunities” (n=12); Group 2, “Hospitals administrators focused on a specific service system” (n=10); Group 3 “Hospitals administrators not considering at all the technology” (n=6); responses: 1, lowest; 5, highest.

Hospitals focused on a specific service system (Group 2) are less concerned about the economical issues of RFID implementation than hospitals exploring all the opportunities (Group 1): for “Lack of funding” the significance is at 0.1 level and for “Cost” the significance is at 0.05 level since they might have already investigated how to finance the investment and also because in the majority of the cases (RFID on assets and RFID on people) the cost of investment is inferior than \$100.000. Moreover, once hospitals are focused on the implementation of a specific solution (Group 2) find that the integration of RFID with other IT systems is less complicated than as it is perceived by hospitals in an earlier phase of adoption (significant at 0.1 with Group 1 and at 0.05 with Group 3). Bar code seems to lead hospitals to not consider RFID technology (the difference between Group 2 and Group 3 is significant at 0.05 level). Also “Not a priority” and “Lack of standards” represent relevant barriers in the phase of consideration of the technology, whereas are less relevant once the hospitals are more seriously exploring all the opportunities related to RFID (the differences between Group 2 and Group 3 are significant at 0.05 level).

4. Business Process Management or Re-engineering

In this section we will first introduce the operation of a hospital as a service. The different identities involved in the overall operation of a hospital (such as personnel, pharmacy, blood bank, patients etc) will be reviewed. Then we discuss the interaction between these different identities. This will then lead to defining the different components of a hospital that would primarily use RFID technology. Later, we will discuss how a customizable RFID system can be installed in a hospital. The installation of the RFID system would be designed to be gradual and sequential. This was encouraged by the hesitation shown by hospitals in the above section due to various reasons such as lack of funding and costs, steep learning curve of the technology, etc. As the hospital management realizes the impact of the initial adoption, they can take the decision of the adoption of additional capabilities.

4.1 Identification of the Actors Involved

In this section, we introduce and discuss all the relevant actors that are involved and have a stake in a hospital setup. The relationship of each one of these actors with the hospital is discussed.

The primary actors involved in every hospital are the staff (the doctors, nurses, administrative personell, hospital pharmacist etc.) and the customer (patient and/or his family). Each type of staff in a hospital will need a different kind of access to the data in the hospital. The doctors and nurses treating a particular patient will need to access the Electronic Health Record (EHR) of the patient. On the other hand, the administration personnel might need on the recent hospital activity of other staff etc. This would require storing all the information into a main database in the hospital. The database would have further have compartmental sub-sections to store different types of data such as patient files, staff records etc.

The central node in this scenario is the hospital as shown in Figure 4. The EHR of the patient will be collected from the patient and stored. The doctors and nurses would use this data to diagnose the patient's condition. The EHR can also be updated with the doctor's recommendation for the patient's medication. This can be further linked with the pharmacy department, which can re-order the supplies for the medicines order for the patient. Caution would be needed to be exercised to make sure the patient's private medical data is kept discreet at all times.

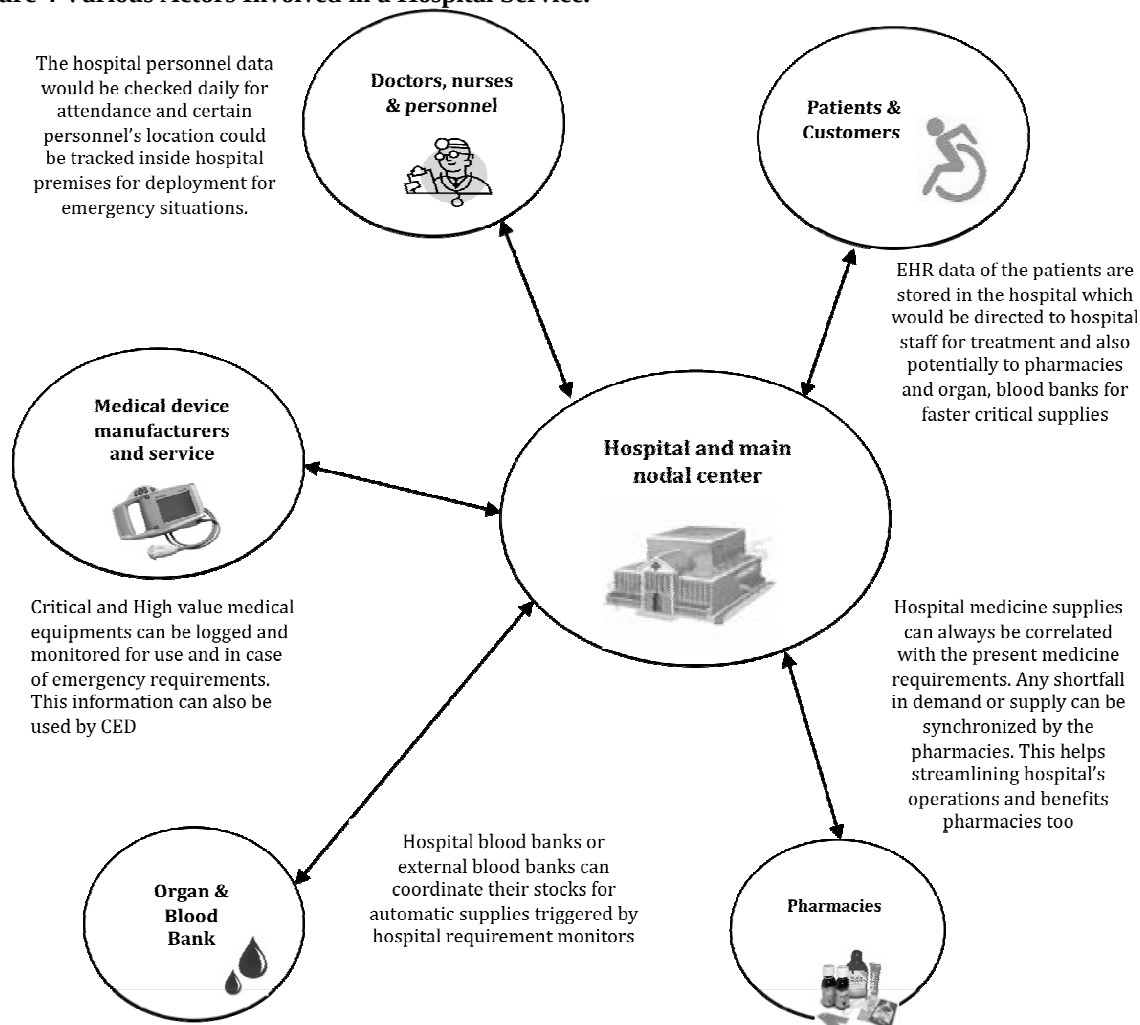
The hospital personnel will access different parts of the database. The doctors and nurses would regularly monitor the patient's EHR data to monitor his progress and if he has any additional requirements. The nurses and doctors could also perform the task of notifying the hospital pharmacist in case a patient needs a particular medicine by performing a request operation etc. The hospital administration however, would need to retrieve data regarding other personnel such as confirming the staff's daily work attendance. They can also assist in locating the doctor's and nurse's location within the hospital premises and alerting them to report in case of any critical situations.

Any hospital contains large number of medical devices. Some of them are small and used for routine health check-ups while some of them are multi million dollar instruments to perform complex surgeries. Each one of these devices needs to be service, or even replaced. This calls for a large Clinical Engineering Department (CED). The CED might be or might not be a part of the hospital. However, every hospital would need such a support system. The relationship between the hospital and the CED can be streamlined where all the data regarding the medical devices and instruments are stored in the database too. This data could be quickly updated if a device was malfunctioning, or needing servicing. The usage of these devices could also be tracked by logging their usage. The CED could use this data to supply critical instruments faster by pin-pointing causes of damage faster etc.

Blood and donated organs are always in demand in large hospitals. Some hospitals have their own blood and organ banks while some order them from banks. Coordinating an update stocks status of local/external blood/organ banks with the hospital could be a good idea as it would result in always sufficient stocks being maintained in a hospital. In case the hospital personnel decide to order blood/an organ for an operation they can simply carry out a request to the blood/organ bank database for supplies. Such a streamlining will save lots of time and could prove crucial in emergencies.

The entire stock of the hospital's pharmacy could also be linked to the database. As discussed above, it would streamline the demand and supply for the patients treatment, speeding up the process.

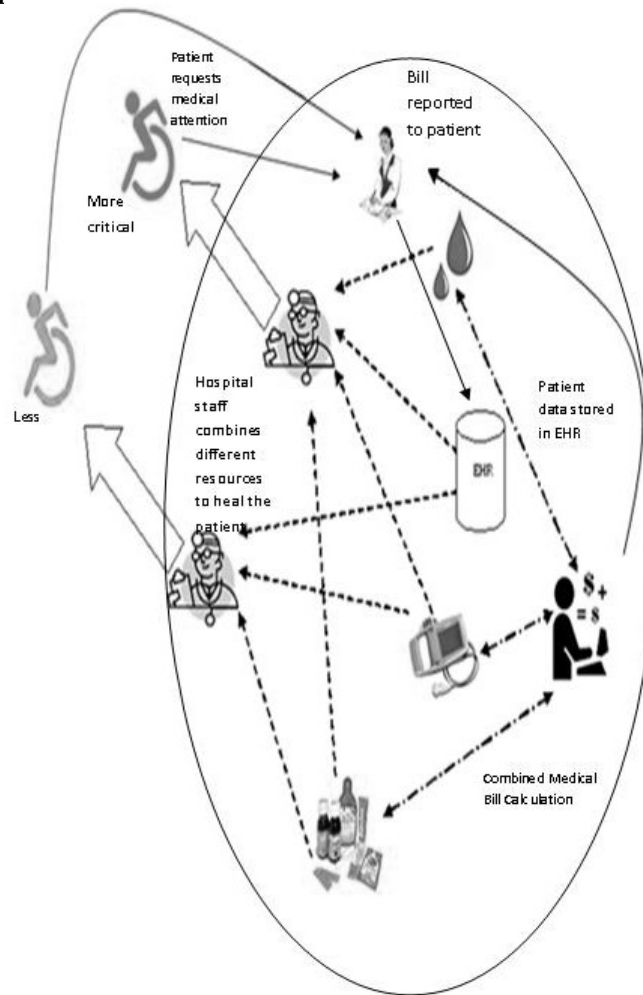
Figure 4 Various Actors Involved in a Hospital Service.



4.2 Codification of the Service Blueprint

In this section we try to give an idea of the processes occurring in a hospital, which leads the entire service to be run synchronously. A given hospital will have different types of patients requiring varied services. Some patients/customers will have more critical requirements than others. The patient first reports to the front desk representative who admits the patient to the hospital and begins the process by entering her/his medical data. The patient is then administered by the hospital staff (doctors, nurses), which utilizes different resources to treat the patient. The amount of resources devoted to a patient would depend on the criticality of his situation. In Figure 5, the more critical patient requires more services/resources than the less critical patient. The sum of costs of the resources used by the hospital is calculated by the billing service, which is reported back to the front desk representative who receives the payment for the service performed.

Figure 5 Inter-relationship Between the Different Actors



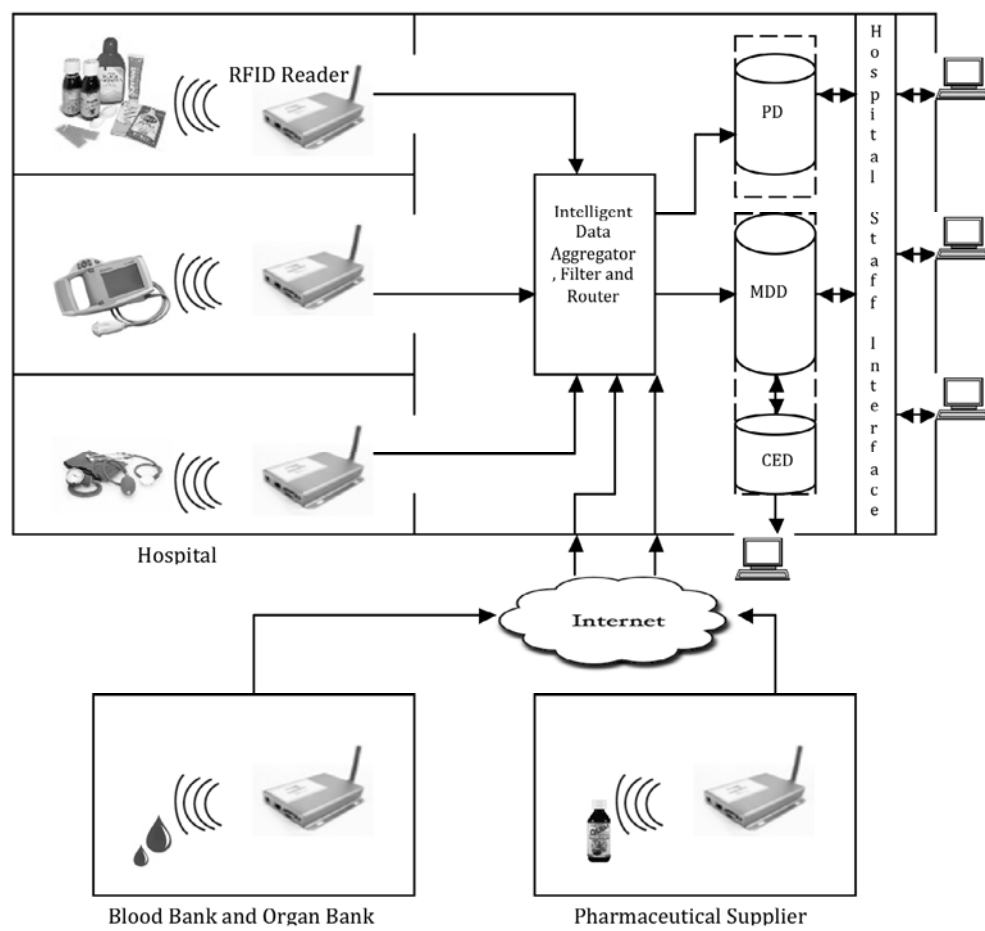
4.3 Service System Platform Proposed

In Figure 6 we have a proposed scalable platform for Asset-tracking in the hospital. The asset-tracking platform has two major components, namely, the Pharmaceutical tracking and Medical Devices tracking. The Medical Devices tracking solution also provides data to the Clinical Engineering Database of the hospital that enables faster repairs of critical hardware by tracking their usage log. In this platform, all the tracking data is first collected by the readers installed throughout the hospital premises. The readers could collect data from tagged medicines or medical devices or tagged blood containers, organs etc, whatever is in the vicinity. All the collected reader data is fed to the centralised intelligent data aggregator, filter and router. This unit will collect all the data flowing from each individual reader and filter it for false reads, multiple reads etc. Once the data has been filtered, it will be channelized to the appropriate database. The information collected from tag medicines, blood containers and spare organs would be stored in the Pharmaceutical database. The reason to club medicines data with blood containers and spare organ data is because the similarity in the RF nature of these items. Blood or spare organs would be retrieved for a patient only on the recommendation of a doctor, similar to medicines. So it makes good sense to store the data together. Also these items have similar composition (organic and water based), which would result in similar tag responses when the RFID reader enquires. The second set of data collected from all the tagged medical devices is sent to the Medical Device Database (MDD). The Medical Device Database is connected to the Clinical Engineering Database (CED), which stores all the repairs and servicing information of the medical devices. The device usage history log can be used in addition to the CED data by the repair engineers for faster malfunction detection. The data stored in MDD and CED is accessible to authorized hospital staff through the Hospital Staff Interface. The Asset tracking platform also has the capability of connecting the hospital-nearest blood banks, organ banks and pharmacy stores with the hospital using the above platform. Every time a particular entity goes low in supply (such as a

particular medicine or organ etc), the hospital staff can order supplies by browsing through the database of supplies in nearby blood banks and pharmacies.

The interested blood banks and pharmacies can be linked up with the hospital using similar RFID readers and by tagging their products. The data path between the blood/organ banks and the pharmacies could be through dedicated lines or through the Internet depending upon the infrastructure present in the hospital and the capital it is willing to invest. As an example, large hospitals might have their own pharmacies and blood banks; however, the small hospitals might not have these facilities and might have to rely on the nearby banks and pharmacies. The data channels between the PD and MDD and the Hospital Staff Interface are bidirectional as these channels carry the request for medicines and devices and then retrieve the associated entries from the database back to the interface for the enquirer. Similarly, the data channel between MDD and CED will be bidirectional, as the CED might routinely need to enquire about the history of usage of a particular medical device to diagnose its health, which would already be stored in the MDD. These databases should be introduced as an improvisation to the already existing records databases of hospitals. As an example, some hospitals might already be having pharmacy records by scanning bar codes on medicines, blood bags etc. In such cases, only the capability of sending and storing RFID data should be added. Due to the high read rate of RFID tags, the database might need to have improved data filtering and streaming capability. A compatibility with pre-existing systems is a must to encourage more organizations to adapt the new technology and can be easily arranged if a progression is made from bar code reading systems to RFID systems.

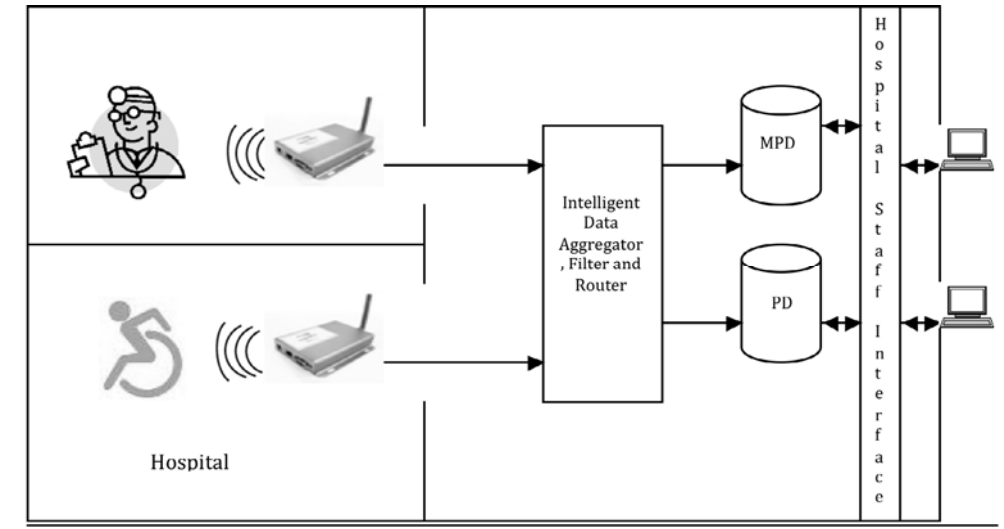
Figure 6 RFID Service Platform for Asset Tracking in a Hospital



In a similar fashion, we have designed a patient and personnel tracking platform (Figure 7). In this scheme, readers set up across the hospital that collect events from the RFID tagged name badges of the hospital personnel and also from the tagged patients. The RFID enabled name badges of the personnel can help in identifying the

presence or absence of personnel in the hospital premises if needed. The RFID personnel data is stored in the Medical Personnel Database (MPD). This database should have the modularity to link up with further applications associated with personnel benefits, employee work environment improvements etc. The RFID tag on patients can be used to ensure that patients get the right kind of assistance according to their location at the hospital. (For instance, if a patient is at the X-ray room, the relevant staff could be notified etc.) . The patient data would be stored in the Patient Database (PD). The patient tracking method can also prove useful for tracking the bed/room of a patient in a large hospital. As in the previous case, the data path is bidirectional between the Hospital Staff Interface and the databases MPD and PD. The patient tracking and the personnel tracking solutions should have the modularity to be separated, as some hospitals might not have the need of one of these systems.

Figure 7 RFID Service Platform for Patient/Personnel Tracking in a Hospital



Finally, the asset tracking and patient/personnel tracking solutions can be combined into a larger customizable system for those organizations who wish to enable a larger RFID based control of their assets and human resources. The customizations would allow them to pick and choose only those sub systems of the platforms discussed above that benefit them the most. Also, as mentioned earlier, each component should be introduced as a backward compatible extension/enhancement to pre-existing systems. This would encourage adaptability which is a main concern amongst new customers.

5. Guidelines for Implementation

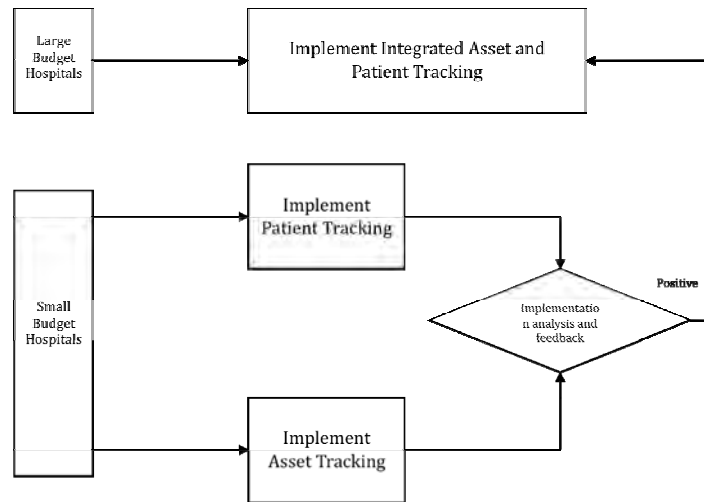
With the initial hesitance shown by many early adopters and planners in implementing RFID based Health care solutions, it is imperative that the RFID Hospital solution is designed in a way that it enables a gradual and sequential adoption of the technology giving the hospital management and staff the time to learn to use it and get used to it rather than getting overwhelmed. A slow gradual approach will also enable the management to monitor the impact the technology has on the operations of the system. It gives them time to gather feedback from the staff and then decide if further implementation, modification etc is necessary.

Based on the above-mentioned philosophy, we define our RFID platform for hospital adoption (Figure 8). The RFID Hospital solutions should be implemented in a sequential process for first time users, especially small hospitals with limited funds. Based on their needs and necessities they can choose between Asset tracking solution (for tracking devices, documents etc) or Patient tracking solution. After the implementation, the set up needs to be analyzed and feedback collected whether, it has improved the operations and economy of the organization. Depending upon the results the management can decide whether they would like to upgrade to or stick to the present system, make certain modifications to it, reject it, or upgrade to an Integrated Asset tracking and patient tracking solution.

The Integrated Asset and patient tracking solution as mentioned above would be offered as an option only to large hospitals or to those hospitals, which have prior experience with either Asset tracking or Patient tracking. The

following diagram displays a flowchart, which demonstrates the gradual implementation of the RFID tracking solutions in large and small budget hospitals.

Figure 8 Flowchart Showing a Sequential Customizable Adoption of the RFID Service for Hospitals



6. Conclusions and further studies

The present study proposes an RFID based service platform for hospitals, which is consistent with a service science driven design approach. The different steps of the service design methodology have been drawn from the literature, whereas the user requirements identification has been innovatively performed with a survey. Future studies should combine more frequently case study methodology with survey methodology in order to define the user requirements.

In the second part of this paper, we first identify and define various players in running a hospital. Their roles in the hospital and their inter-relationship are examined. The results obtained by examining the survey collected from the hospitals are then used as a guiding factor for designing the RFID service for hospital. We first showcase the numerous operations that can be streamlined by introducing RFID technology into them. Then we introduce a sequential customizable adoption technique for the hospitals. This allows different hospitals to optimise the RFID service platform in a way that benefits their operations most. Future studies should focus on action research, in order to empirically identify organizational and technical issues concerning the implementation of the service system proposed.

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