Abstract: - In the healthcare sector, the lack of assets visibility leads to a myriad of operations inefficiencies; affecting possibly patient safety. Radio frequency identification (RFID) represents a highly promising technology for material management in asset-intensive sectors such as healthcare. Even though RFID is proclaimed as a breakthrough technology for asset tracking; its adoption and implementation in healthcare have been hindered by many factors. This paper presents the results from a detailed longitudinal field research and documents the prevailing issues related to RFID implementation in a hospital setting.

Key-Words: - RFID implementation; mobile asset management; key performance indicators; healthcare.

1 Introduction
The number one priority for healthcare systems is to ensure prompt and safe care delivery to patients. In order to do so, they need to have access to necessary human, material, informational and financial resources at the point-of-care. However, management, synchronization and alignment of diverse flows necessary to effectively operate healthcare systems are very complex. In an effort to address the core mission of healthcare organizations and reduce the occurrence and impacts of medical errors, a more advanced use of information technology (IT) has been suggested [1], [2], [3].

In spite of the global widespread of IT in many vertical markets, healthcare has traditionally lagged behind other service industries when it comes to implementing innovative technologies [4], [5], [6]. However, the implementation of several IT applications, including applications for digitizing medical records and clinical data, have generated documented benefits [7], such as the reduction of operating costs, the improvement of operational efficiencies and increased productivity [8]. In the US, healthcare investments in IT could result in cost savings in the order of $140 billion a year by 2014 [9]. Innovations in the field of mobile technologies are opening new opportunities to overcome some of the current pressures faced by healthcare and their applications have therefore grown considerably. In particular, RFID, a wireless automatic identification technology, is rising as the “next disruptive innovation in healthcare” [5] as it generates several potential benefits including the improvement of patient safety [6], [7], [8]. The healthcare sector is becoming an important market niche for RFID implementations with a wide range of applications from patient identification, medication management, specimens’ identification and newborns identification [9], [10], [11], [12]. In particular, a lot of interest is given to the area of material and asset management which is becoming the mainstream application of RFID in healthcare facilities [13]. Despite the importance given to RFID in this sector, there is a lack in knowledge with respect to the issues related to RFID implementation. We therefore aim to bridge this gap.

This paper is organized as follows. In the next section, we present a brief overview of RFID and its implementation in healthcare while the third section analyses the context. Section 4 provides essential information on the methodological approach. Results are presented and discussed in section 5 whereas section 6 presents some concluding observations.

2 Technical context: RFID technology
RFID is considered one of the “hottest” Automatic Identification technologies (AIDC) due to its particular capabilities to track and trace in real-time objects across the extended supply chain. Various
technologies fall under the AIDC family, including optical recognition, biometrics, card technology, contact memory technology, bar coding and RFID. The latter allows unique “item-level” identification and ensures the availability of real-time information on single physical objects or persons.

The term RFID refers to a set of technologies that uses radio waves to transmit information. An RFID system consists of multiple components including RFID tags, RFID readers, and the RFID middleware. RFID tags have a chip and an antenna that allows data communication to readers via electromagnetic radio waves. Tags can be passive, semi-passive, and active. Passive tags do not have a power source; thus, depend on RFID reader’s electromagnetic field to trigger signal transmission. Active tags have an internal power source used for signal transmission. In the healthcare environment, different RFID technologies play complementing roles. For instance, active RFID are more likely to be used for tracking mobile medical equipment [13], whereas passive tags may be often seen attached to medications and laboratories specimens [10].

**RFID readers** are responsible for information retrieval and acquisition and therefore allow the information flow between the tags and the host system by means of the RFID middleware. Readers’ antennas emit and receive radio signals that activate the tags and capture the data stored in them. The RFID middleware is responsible for key functions including filtering, processing and routing information gathered through readers [14]. The middleware corresponds to the link between the components of RFID systems and the existing enterprise application systems, such as hospital information system (HIS), and patient management systems in healthcare settings.

### 3 RFID adoption in healthcare

Healthcare facilities turn to RFID in order to better manage assets, to improve inventory management, to prevent newborn abductions, to ensure optimal patient medication management and avoid errors, to keep mentally impaired patients from walking away unnoticed, to track and match blood for transfusions, to track counterfeit medicines in pharmaceuticals supply, or to improve business processes and workflows, and the list goes on [6,7,13].

Several case studies have been reported in the literature: For instance, Wang et al. [12] present results from an RFID feasibility project at a Taiwanese hospital to combat SARS; Kannry et al. [15] describe a study at a US hospital designed to measure the effectiveness of using RFID for bed management; Janz et al. [16] report on results from a “proof of application” and outline that RFID can provide timely business intelligence for healthcare, hence optimistically impacting the quality of care delivered. Furthermore, some simulations have also been carried out to measure the value of RFID in this sector [17].

In addition to the above mentioned empirically based articles, some conceptual papers have been published and include among others the work of Ngai et al. [18] that proposes the architecture for an RFID-based healthcare management system that is intended to reinforce patient and medication safety, improve inventory management of pharmaceuticals, patient identification and hospital tracking processes. Moreover, Kumar et al. [6] suggest a three-stage implementation approach for RFID adoption in healthcare environments, while Tzeng et al. [19] offers a framework for evaluating the business value of RFID technology within healthcare activities.

Though many papers point to numerous potential benefits of RFID applications in healthcare (Table 1), there is still an important knowledge gap regarding the prevailing issues raised by the implementation of RFID applications in healthcare organizations and the actual measurable and realized benefits generated by such implementation.

#### 3.1 Finding value of RFID adoptions

IT is perceived as an enabler for the improvement of care delivery and operational efficiencies, the reduction of organizational expenses, and the achievement of competitive advantage [20]. However, creating business value from IT investments remains a great concern and represents a prominent inhibitor factor for their adoption, particularly when adopting emergent technologies such as RFID.

As demonstrated in Table 1, the prospective benefits of RFID comprise a wide range of **tangible benefits**, and a great deal of **unquantifiable benefits**, making a holistic assessment of its economical profitability a difficult task [8]. The business case behind RFID implementation is in some cases very hard to demonstrate. Many have the perception that RFID is too expensive to deploy [15] since the actual cost of RFID integration is not only limited to hardware (e.g. tags and readers) and software components of
the RFID system, in fact, the true investment goes well beyond that.

Among the potential benefits that RFID can offer to healthcare organizations, let us mention the improved visibility and management of critical mobile assets, the elimination of non-value added activities and the emergence of intelligent processes [13], the reduction of clinical staff frustration, and the improvement of organizational climate and work conditions [8] and the improvement of patient satisfaction and security [21].

Table 1: Potential RFID benefits in healthcare

<table>
<thead>
<tr>
<th>Benefit type</th>
<th>Benefits</th>
<th>References</th>
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<tbody>
<tr>
<td><strong>DIRECT / TANGIBLE</strong></td>
<td>- Increased patient safety</td>
<td>[6-9,11]</td>
</tr>
<tr>
<td></td>
<td>- Improved patient identification and location in case of health crisis</td>
<td>[12]</td>
</tr>
<tr>
<td></td>
<td>- Enhanced clinical services quality</td>
<td>[6,7,21]</td>
</tr>
<tr>
<td></td>
<td>- Cost savings</td>
<td>[6,7,16]</td>
</tr>
<tr>
<td></td>
<td>- Improved asset visibility, and utilization</td>
<td>[6,7,13]</td>
</tr>
<tr>
<td></td>
<td>- Improved inventory management</td>
<td>[6,13]</td>
</tr>
<tr>
<td></td>
<td>- Improve drug management and administration</td>
<td>[7,13]</td>
</tr>
<tr>
<td></td>
<td>- Improved healthcare supply chain</td>
<td>[7]</td>
</tr>
<tr>
<td><strong>INDIRECT / INTANGIBLE</strong></td>
<td>- Improved business process and workflows</td>
<td>[6,13,16,19,21]</td>
</tr>
<tr>
<td></td>
<td>- Improved information flow and visibility</td>
<td>[13]</td>
</tr>
<tr>
<td></td>
<td>- Reduced clinical staff frustration</td>
<td>[13]</td>
</tr>
<tr>
<td></td>
<td>- Gained competitive advantage</td>
<td>[21]</td>
</tr>
</tbody>
</table>

4 Methodology

RFID implementation in healthcare cannot yet be grounded in theory and remains under investigated [15, 18, 19]. As the overall research objective here is to gain a better understanding of RFID implementation in healthcare organizations, the research design clearly falls in the realms of exploratory research. The research was conducted over two years at one hospital (hereinafter referred to as "hospital A").

With some 180 medical specialists and approximately 30 medical units, hospital A is nearly 100% Wi-Fi and has adopted medical information systems. In order to manage assets inventory, maintenance and repair, the hospital relies on various enterprise applications, and uses a barcoding. Hospital management demonstrated interest in the implementation of an RFID-based mobile asset tracking system to improve the management of critical medical devices.

In order to allow triangulation and strengthen the validity of the results [22], multiple sources of evidence were analyzed:

1) analysis of internal documents such as clinical and non-clinical procedures and directives;
2) multiple on-site observations;
3) panel studies (same focus groups over a period) and semi-structured on-site interviews over multiple points in time (two year period);
4) continuous analysis of the data generated by RFID tags and the corresponding information from the asset tracking system.

The research design therefore combined both unobtrusive and obtrusive data collection methods that generated large amounts of qualitative and quantitative data. For instance, the quantitative data provided by the RFID-based mobile asset tracking system (1317 tags readings) corresponds to a rather efficient and unobtrusive data collection method to assess the value of the RFID-based mobile asset tracking system. On the other hand, the obtrusive data collection methods such as the semi-structured interviews and the focus groups allowed the researchers to gain additional insights into the existing legacy systems, the needs and requirements for the future RFID system, and the priorities and divergent issues prevailing at each stage of the RFID implementation process from the perspective of the different groups of participants and stakeholders. The thirty one (31) participants represent key managers, professionals, medical and non-medical staff as well as technical specialists from nine (9) organizations (Table 2).

Table 2: Profile of participants

<table>
<thead>
<tr>
<th>Entities</th>
<th>Type of participants</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top-management</td>
<td>- Hospital director</td>
<td>1</td>
</tr>
<tr>
<td>Medical technical</td>
<td>- Manager</td>
<td>3</td>
</tr>
<tr>
<td>department</td>
<td>- Biomedical engineers</td>
<td></td>
</tr>
<tr>
<td>Medical units</td>
<td>- Manager for ward A &amp; B</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>- Team manager for other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- medical wards</td>
<td></td>
</tr>
<tr>
<td>Hospital A</td>
<td>- Team manager for other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- medical wards</td>
<td></td>
</tr>
<tr>
<td>ICT departments</td>
<td>- Manager - automation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>- Manager- ICT</td>
<td></td>
</tr>
<tr>
<td>Central storage room</td>
<td>- Technical expert</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>- Supervisor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Clerk</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Hospital association</td>
<td>Chairman</td>
<td>1</td>
</tr>
<tr>
<td>Four TPs</td>
<td>Top managers, technical experts and</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>professionals from TPs (technological</td>
<td></td>
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<tr>
<td></td>
<td>partners)</td>
<td></td>
</tr>
<tr>
<td>UBRC</td>
<td>Director of UBRC (University-based research center)</td>
<td>1</td>
</tr>
<tr>
<td>Two universities</td>
<td>Professors and PhD candidates</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>
5. Results and discussion
Results from the case study are presented in a linear manner following five consecutive phases, namely pre-feasibility, feasibility, RFID scenario building and validation, implementation in a real-life setting, and benefits assessment, although iterations between these phases have occurred. These five phases are in line with the implementation model recently proposed by [23].

5.1 Pre-feasibility
The main objectives that could be derived from an RFID-enabled mobile asset management system were discussed in the first focus group. Consensus on the hospital needs concerning critical assets was rapidly reached on the following objectives:

1. Need to improve real-time monitoring and management of mobile assets;
2. Need to reduce delays in patient care;
3. Need to improve productivity and efficiency by reducing the time hospital staff spends in locating misplaced assets;
4. Need to improve communication and decisions activities by keeping up-to-date equipment status on maintenance, sterilization, decontamination, etc.;
5. Need to reduce overbuying, unnecessary rentals, and under-utilization of hospital assets;
6. Need to eliminate costly replacement of lost or stolen medical equipment.

Mainly, the overriding concern expressed by participants deals with the improvement of the quality of healthcare services, either directly as noted from objective 2 or indirectly as implied by objectives 1, 3 and 4. Cost effectiveness objectives, namely objectives 5 and 6 are placed in second rank.

The development of strategic alliances among technological and non-technical partners proved to be based on their respective competences, resources and strengths. Technology partners’ readiness was the factor that contributed the most to the hospital’s decision to go ahead with the RFID project. As all participants aimed to minimize financial and time investments in the RFID-based project, they agreed to limit the scope of the project to one type of mobile assets and three hospital units.

Participants from the hospital felt that infusion pumps would be particularly pertinent and rather strategic for hospital A. The main problems with the infusion pumps at hospital A relate to the fact that they are continually misplaced, or hoarded around the hospital; rendering them very difficult to find and restock. According to hospital participants, lack of visibility on location and status results in continual shortage of infusion pumps which, in turn, entails several significant drawbacks, including consuming staff time on unnecessary equipment search, delaying care delivery, and postponing maintenance and repair activities.

The decision was also easily reached to limit the RFID project to i) two medical wards (Ward A and Ward B) where the availability of infusion pumps is considered critical, and ii) the central storage unit, which is responsible for infusion pump’s warehousing activities, including the distribution of pumps to wards and their restocking from wards. Given the actual lack of visibility on pumps location; clerks cannot comply with medical unit’s demands due to repeatedly pumps stock-outs.

5.2 Feasibility
Asset management related to infusion pumps covers five broad activities: procurement, warehousing, usage (point of care), maintenance and repair, and, final disposal or recycling. However, participants retained only warehousing and usage to be targeted by the RFID pilot project. Activities such “maintenance and repair”, and “disposal and recycling” although implied by the previously agreed objective were discarded. Strong arguments were made by team leaders to focus on the clinical dimension of the pilot project. Cleavage between administrative perspective and the clinical perspective became apparent.

Once the focus on warehousing and usage activities was agreed upon, prevailing importance was given by participants to two aspects: i) the assessment of the actual operational inefficiencies and, ii), the requirements of the RFID application to overcome these inefficiencies. “AS IS” business processes were mapped and validated with key personnel to ensure reliability of the data collected from on-site observations and the semi-structured interviews. Existing processes were analyzed in order to find areas of opportunity for improvement such eliminating unnecessary manual activities or duplications. Several operational inefficiencies affecting hospital A’s mobile asset management were then identified. These inefficiencies such as recurrent inventory shortages at central storage room, service delays since infusion pumps are unavailable on demand, asset sub-utilization, wasted staff time searching for equipment, were caused by the lack of visibility on equipment location and the
presence of information “silos” among hospital services.

Further, consensus was reached to retain a RFID solution that allows the identification, location, and tracking which would resolve to a certain level some of the above mentioned inefficiencies and would directly resolve issues concerning lack of equipment location visibility. Hence, technological feasibility of the RFID future implementation was carried out with the technological partners and the university-based researchers who worked closely with the IT and technical staff at hospital A. Opportunities and constraints in the selected zones (wards A and B, central storage room) were examined. Participants agreed that for the scope of the pilot project visibility at a ward level will be sufficient, meaning that only the information of whether or not a specific infusion pump is inside ward A or B at a given time will be available. Finally, particular consideration was given to the selection of a "scalable solution" that would permit to use the foreseen RFID infrastructure in order to improve management of other mobile asset, as well as for additional applications according to the eventual needs of hospital A.

5.3 RFID scenario building and validation
Scenarios integrating RFID technologies were modeled using a drill-down approach with Aris Toolset and were validated in an iterative manner with participants. Once scenarios were built, a gap analysis between the “AS IS” situation and the “TO BE” situation was performed for all activities pertaining to warehousing and usage.

An analysis of the existing processes (AS IS) permitted to identify “pain points” on current process and evaluate opportunity zones within all analyzed processes. For instance, when analyzing activities involved in the “As-is picking” and “As-is distribution” processes, participants determined various not adding value processes that were suitable candidates for improvement such as unnecessary staff movement and equipment manipulation, which add labor time to the distribution process.

Gap analysis of “As-is Processes” and “To-be Processes” permitted to evaluate the capabilities of RFID to increase productivity and quality of operations, validate some of the numerous benefits expected, as well as assess possible technological limitations of RFID-enabled scenarios. Once the “To Be” scenario was agreed upon, technology partners worked closely with hospital A ICT team in order to determine system architecture requirements necessary to support the new processes integrating RFID. All requirements were discussed and agreed upon among technical partners and hospital A designed team. Consensus was easily reached for all decision points pertaining to this third phase.

5.4 Implementation in a real-life setting
During this phase, the “To-be” processes of the retained scenario were reproduced and integrated into real processes at hospital A with the proof of concept running over seven (7) months. As illustrated on Figure 1, the RFID-based asset tracking system as implemented at hospital A included various Wi-Fi access points and exciters, numerous Wi-Fi-based RFID active tags, one tracking engine, and one enterprise tracking software.

![Figure 1. RFID-enabled asset tracking system](image)

Actual deployment of retained scenario included various activities, including general site surveys to verify installation requirements; physical mounting of elements; software configuration and integration; tag-positioning test, programming and activation; test runs by technical experts; system test and system tuning, and tags mounting on infusion pumps.

A system demonstration was given to key participants, including among others the manager for wards A & B, and the technical department manager. Participants were able to see the movement of the tags within the proof of concept zone.
5.5 Benefits assessment

During a seven month period, participants monitored the RFID deployment, and collected and analyzed the unobtrusive data generated by the asset management system in order to substantiate the anticipated benefits of such implementation. Information available through the RFID location system could be used to evaluate medical equipment performance. For instance, the information obtained concerning infusion pumps utilization history and length of usage could be used to measure indicators related to the “usage” activity of medical equipment, including indicators such as equipment utilization rate, number of equipment that are not in used, at a ward, but that replenishment has not taken place, number of equipment been used at a ward at a certain period, as well as total number of equipment requested by a ward, among others.

Various core KPIs related to receiving, put away, picking, distribution, restocking, and usage activities within the context of medical equipment management were analyzed. Being able to measure these metrics is of chief importance for material managers and hospital stakeholders since it will provide them with the necessary information to evaluate the whether their clinical critical assets are utilized, maintained and manage at the levels necessary to ensure operations productivity and well as quality care delivery. However, the relative importance of these KPIs widely differs between the different stakeholders. For instance, the manager of one of the wards stated that “after all, the most crucial objective is to know the location of the infusion pumps”, discarding at the same time the importance of some previously agreed objectives (section 5.1) such as operational issues such as keeping up-to-date equipment status on maintenance, sterilization, or decontamination and administrative issues such as overbuying, unnecessary rentals, under-utilization of hospital assets and elimination of costly replacement of lost or stolen medical equipment.

The analysis of KPIs also revealed that the nurses did not systematically register the status of the infusion pumps that they use. The information on pumps utilization, from the moment it is assigned to the patient to the moment it is not in use any longer, is therefore inadequate in some cases. Nurses and other participants then envisioned a technological solution where the RFID tags would be an integrated element of the medical equipment, so that information could be collected flawlessly.

6. Conclusion

The palpable paucity of established and structured RFID implementation frameworks to guide healthcare managers led us to propose a five-phase implementation model. The results presented in this paper offer valuable insights for top managers in hospitals and IT specialists responsible for RFID implementation.

First, the detailed longitudinal field research allows us to document the prevailing issues related to RFID implementation in a hospital setting. The most significant issues are not technological but are mainly organizational as they seem to arise from the presence of diverging perspectives. The empirical evidence presented in this paper demonstrates a cleavage between the administrative and clinical perspectives but also within the clinical perspective. However, divergences also run deep within each perspective (for instance, nurses vs. doctors) and between the technologists in the hospital (ICT managers, biomedical engineers, and maintenance specialists) and the administrators. It is therefore critical to better understand these organizational issues and, for managers and IT specialists, not to underestimate them.

Second, empirical evidence shows that the process of RFID implementation is indeed highly iterative. Participants revisited and modified previously agreed steps. For instance, the benefits assessment and the analysis of KPIs (phase 5) led to reconsider the stated objectives (phase 1) and the retained technological scenario (phase3). Such iterations, although inevitable, are also time-consuming. By carefully assessing all implications of each phase on subsequent phases, some iterations may be prevented.

Third, the results also prove that benefits are derived from RFID implementation. The new RFID-enabled processes provide information on assets availability rate, utilization rate, and real-time localization. Information on asset status could however be improved, either by increasing the nurses awareness to the new technology or by integrating RFID tags in the design of infusion pumps. Both options may require some time. KPIs represent an effective tool to formally evaluate and assess the benefits derived from RFID implementation.

RFID represents a new paradigm for asset management in healthcare. It increases in productivity through elimination of search delays from the staff and impacts the care dimension.
Indeed, accessibility to critical resources allows care professionals to respond more efficiently and faster to clinical events, and therefore improves patient care and the patient experience. Other strategic objectives targeting cost effectiveness can be as well be derived from such implementation thanks to a potential reduction of overbuying and or replacement, unnecessary rentals, and under-utilization of hospital assets.

References:


