# Process Redesign for Improving the Traceability of Medical instruments at a Hospital: A proposal for RFID Technologies

Afrooz Moatari-Kazerouni[1] and Ygal Bendavid[2]

[1,2] Department of Management and Technology, Université du Québec à Montréal (UQAM), Canada
Moatari_Kazerouni.Afrooz@courrier.uqam.ca; Bendavid.Ygal@uqam.ca

**Abstract.** Since mid-2000s hospitals have begun implementing Radio Frequency Identification (RFID) technology in order to improve their operations management. This paper aims to explore the potential of RFID technology in improving the traceability of medical instruments in a hospital environment. A case study is conducted at a hospital in Montreal, Canada and the business process reengineering (BPR) approach is used to assess realistic potential of the technology. Specific key performance indicators (KPIs) are identified and eventual issues related to implementation of the redesigned processes is discussed.

**Key words:** business process redesign, traceability, hospitals, RFID technologies

## 1 Introduction

Traceability is defined as *"the ability to track forward the movement of products through specified stages of the supply chain and trace backward the history, application or location of products under consideration"* [11]. The adoption of novel automated identification technologies such as radio-frequency identification (RFID) technologies have attracted the attention of professional and scientific community in various domains including food traceability such as dairy product [1], cattle/beef [8], or aquaculture [15], as well as in manufacturing environments for job-shop scheduling [7] or in healthcare environment were the technology is used for tracking and tracing of medical supplies, high value products [2], mobile assets, patients, and hospital staff [3]. In the hospital setting, RFID enables automatic identification and tracking of products, people, and assets which result in real-time visibility and improved efficiency in the delivery of services [9] [19-20].

On one hand, ensuring "products" tracking and tracing at hospitals allows for increasing the efficiency of operations such as logistics and quality management processes, complying with regulatory requirements, guidance on product recall, as well as supporting safety of patients, etc. On the other hand, ensuring traceability can be a

challenging task. The organization should have a system to uniquely identify “products”, and collect, store, manage, and share information about them with the key stakeholders of the processes.

This paper aims to explore the potential of RFID technology in improving traceability of medical instruments at a hospital environment. The rest of this paper is organized as following. In Section 2, the specific problem and research objectives are presented. RFID technologies are then presented in more details in section 3. In section 4, the methodological approach of the research is presented to clarify data collection and analysis within a case study context. In section 5, a high level analysis of the case is presented to better estimate the impact of RFID technology on the traceability process. The paper concludes in section 6 with the future research avenues.

## 2 Problems and Objectives of the Research

Deploying real-time location systems (RTLS) to manage high-value mobile assets in hospitals drove the initial momentum in the adoption of RFID technologies. In recent years, hospitals have implemented a broad range of RFID applications related to supply chain and condition monitoring, security and access control, patient safety management etc. [4] [9] [19]. Numerous business cases are documented on the most renowned RFID web site: RFID Journal [http://www.rfidjournal.com/healthcare]. Among the cited benefits, increased patient satisfaction, improved business processes and workflow, decreased equipment costs, improved inventory management, and decreased overall operating costs are often reported [18].

Although numerous implementations of RFID enabled RTLS have been conducted at hospital settings [3] [12], the reality of RFID adoption in healthcare is far behind earlier expectations [19]. Beside cost which still is a significant issue [10] [20], barriers to RFID adoption can be classified as (i) technological; (ii) data management, security and privacy; and (iii) organizational and financing issues. It is interesting to see that “designing and implementing RFID-enabled healthcare processes” is ranked as one of these key issues [10]. Generally, implementing the RFID-enabled system is done in conjunction with the redesign of processes as well as the design of a facility layout; since the early design of a facility layout is critical as it directly and indirectly results in higher efficiency of the material flow and control [14].

Since RFID is an enabler of efficient traceability, the main objective of this research is to explore the realistic potential of this technology for improving the traceability of surgical instruments. More specifically, this research focuses on the flow of medical equipment between the Central Sterilization Department (CSD) and operating rooms (OR) at a hospital in Montreal, Canada.

## 3 RFID Technologies in Hospitals

An RFID system is a multi-layer system composed of hardware and software that integrates into back-end information systems (*see* Fig.1). This first layer allows the automatic identification of tagged objects (e.g., patients, instrument sets) by automatically capturing RFID tags ID. Usually, passive Ultra High Frequency RFID tags (powered by the reader RF) are used in logistics applications due to their relative low cost and great performance (e.g., read range up to few meters, multi-tag read). Semi-passive tags, equipped with embedded sensors (powered by a battery), can be used in applications such as cold chain logistic management. Active tags, on the other hand, are often used for RTLS applications since they have a read range up to few hundred meters [4].

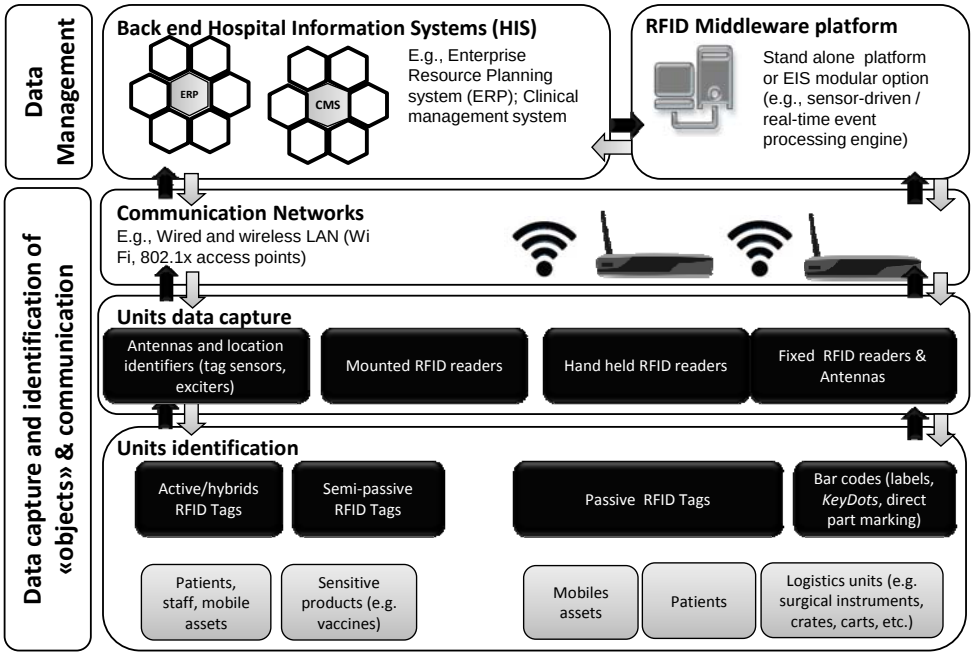


**Fig. 1.** RFID system - adapted from [2]

Various types of RFID readers can be used to capture data from RFID tags signal. As such are: fixed readers (e.g., RFID portals for choke point reads or zone monitoring), portable readers (i.e., handheld "guns" used for inventory management), and mounted readers (e.g., on carts as a mobile tracking solution). The data registered by the RFID readers is then transferred to data management layer using a communication network.

The second layer is the data management layer, composed of (i) a RFID middleware, which is used to process and distribute RFID based data into (ii) specific back-end

hospital systems (i.e., Enterprise Resource Planning systems-ERP, Clinical Management System-CMS), where this information is managed to improve the decision making process.

## 4 Research Methodology: Using a Case Study Approach

RFID-enabled projects in the healthcare context is an emerging phenomenon in complex environments [17], which involve numerous stakeholders, with references to change management as well as ethical and legal considerations [13]. Therefore, the case study approach was selected as the preferred research strategy to facilitate the identification of the main concepts involved and to investigate the problem *"within its real-life context"* [21]. The case study was conducted at a hospital, where the underway construction of a new building will be the new home for the CSD and OR departments. This relocation brought up the opportunity of improving the flow of items (e.g., surgical instruments) from CSD to OR. Using case carts for transferring items as well as implementing a traceability system were considered. The business process re-engineering (BPR) approach was adopted to identify the impact of RFID technology on selected surgical equipment tracking and tracing processes (*see* Fig. 2). BPR is an approach that focuses on value-added business processes [6] and how an organization should operate to better meet the needs of its customers.

This approach involves discovering how business processes currently operate, how to redesign these processes to improve the efficiency, and how to implement the process changes to gain competitiveness [5]. As presented in Fig. 2, this research followed four steps which are elaborated in the following sections. Within this paper we focus on steps 1 and 2, namely understanding specifications of the current process and modeling them, whereas the main objective is to redesign the process to include the traceability system as well as the case cart practice.

***Steps 1 and 2: Understanding current business process and modeling As-Is process:*** In order to map and analyze the current process, the flow between CSD and OR was studied in detail. Information in regards to the stakeholders of the process, as well as the activities, inputs, outputs, control points, and the information flow within the IT system of the hospital was gathered. The main sources of data collecting were (i) on-site observations, (ii) open ended interviews with project managers, head manager of the CSD and OR, employees from CSD, and managers responsible for material management and purchasing, and (iii) complementary documents such as internal business analyses. The "As-Is" process flow between CSD and OR in the actual building was then mapped, analyzed, and served as a basis for the "To-Be" analysis. This exercise supported proposing scenarios (in step 3) by recognizing the changes that come with relocating these departments to the new building, as well as the requirements for including the traceability system (e.g., IT system and interfaces). Since the emphasis of this research was on

processes related to the traceability of medical items and the case cart incorporation, new steps in the process were considered.

***Step 3: Performing a To-Be analysis:*** A first scenario of a process flow was proposed and mapped between CSD and OR in the new building. In this case, the existing barcoding system is used for tracking and tracing of crates and instrument sets throughout the process. This initial mapping is discussed in section 5 as it constitutes the basis of comparison with alternative options including RFID enabled traceability. In order to evaluate the performance of designed processes, different control points were identified and process owners were asked to identify relative key performance indicators (KPIs). As further research to this paper, each scenario will be modeled, measured and analyzed by using *Arena* as a discrete event simulation software.

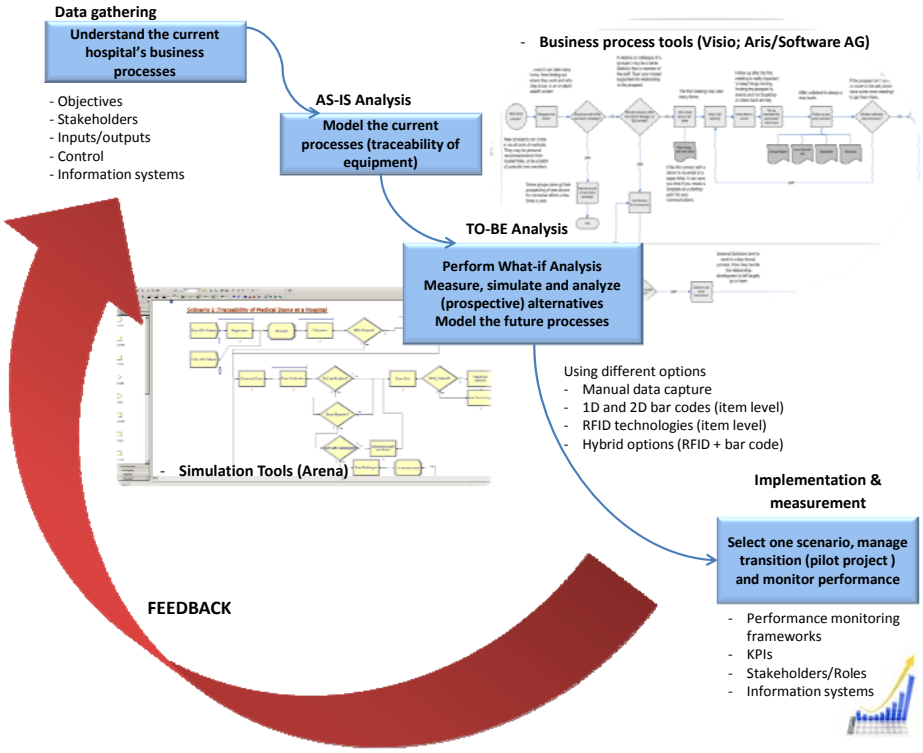


**Fig. 2.** BPR approach for this research

***Step 4: Implementing and measuring:*** The "what if" analysis results of the simulations will lead to decisions regarding the selection of processes with the highest performance. Additionally, a trade off analysis will need to be performed to weight decisions by taking into account factors such as (a) the marginal contribution on the process performance of

each technological scenario, (b) the total cost of ownership (investment costs, identification/tagging costs, operations cots), and (c) the probability of technical success. Therefore, the technical feasibility of the proposed solutions will need to be validated and the business process robustness be tested. For this purpose, a prototype of an RFID enabled traceability system will be (i) built and tested in a RFID lab, and then (ii) implemented onsite as a pilot project. The selected scenarios/process flows will constitute the guideline for tagging and tracking of designated assets (crates, instruments). Finally, its performance will be compared with the alternative processes (e.g., using barcodes).

# 5 Analysis: Redesigning Traceability Process at the Hospital

## 5.1 A Scenario of Traceability Process

Since hospital managers are mainly interested in leveraging on actual barcoding systems, a scenario was proposed and designed, based on the original "As-Is" tracking and tracing process of instrument sets and crates between CSD and OR. In this scenario, existing uni-dimensional 1D barcodes are used for the traceability at the case cart level (used for transporting instruments) throughout the process and two-dimensional (2D) data matrix barcodes are used for the preparation of instruments sets (*see* barcoding system in Fig. 3 and redesigned process in Fig. 4). A further "What-If RFID technology was used" analysis will be performed for a better understanding of the marginal contribution of using this technology over the existing one.

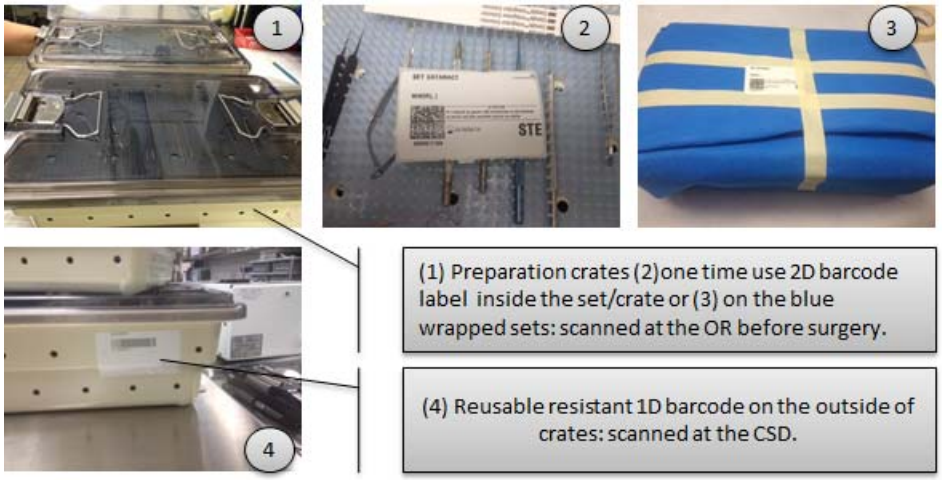


**Fig. 3** Barcode system used for tracking crates and instrument sets

Fig. 4 presents the macro processes related to case cart preparation by CSD, the picking process at sterile core and how the instruments are treated inside the operating theatres, the reprocessing of soiled instruments, as well as replenishment activities for CSD and sterile core storage. For an increased granularity, each main process was also decomposed into specific sub processes and activities (not presented in this paper).

In order to identify all the locations and stakeholders involved in the process, the layout of new CSD department was separated in different zones: soiled case cart zone, soiled zone (decontamination zone), clean zone (assembly zone), sterile zone, and storage zone (carousel and shelving). Similarly, the OR was divided into three sections: OR general management, operating theatres, and sterile core. Additionally, all the scanning points (and related update of information in the hospitals ERP system) have been specified. The tracking and tracing of instrument sets/trays is done (i) during picking in the CSD storage zone, (ii) inside the operating theatre and before using the instruments in the surgery, and (iii) during the reprocessing of soiled instruments and re-assembling the instrument sets.

The process starts once a CSD employee receives a preparation list based on the surgeries planned for the next day. He picks the items from storage and send the case carts to sterile core where an OR attendant will complete the case cart -and so on.

Using 1D barcodes to identify and track crates and 2D data matrix barcodes to identify the list of instrument sets throughout this process was identified by key respondents as a way of (i) reducing errors in assembling the instrument sets, (ii) linking patients with instrument sets used in specific surgeries, (iii) locating instrument sets at each point of time, and (vi) keeping records of cleaning and disinfection cycles. Although this visibility at the crate level is interesting, it does not provides a full accountability for every surgical instrument and every step of the process.

This is why other scenarios were envisioned, firstly by considering a different level of tagging (barcodes at the crate and instrument level) and then by considering different technologies (RFID, hybrid RFID/barcode solutions). For instance, in one scenario, the engraved numbers of 2D barcodes (permanent marking using micro-percussion or KeyDots- labels applied directly to an instrument’s surface), could be used similar to a license plate for tracking individual surgical instruments beyond the crate/tray level. While these solutions are highly reliable, reading each individual instrument (which requires to correctly align the laser) takes few seconds per item, leading to limited productivity gains. Since each tray contains an important amount of instruments, each time that the instruments need to be scanned this leads to a time consuming non value added activity. Therefore, respondents suggested to identify and match individual surgical instruments with the crate during the preparation of the set at the CSD and use barcodes at the crate level for the following processes.

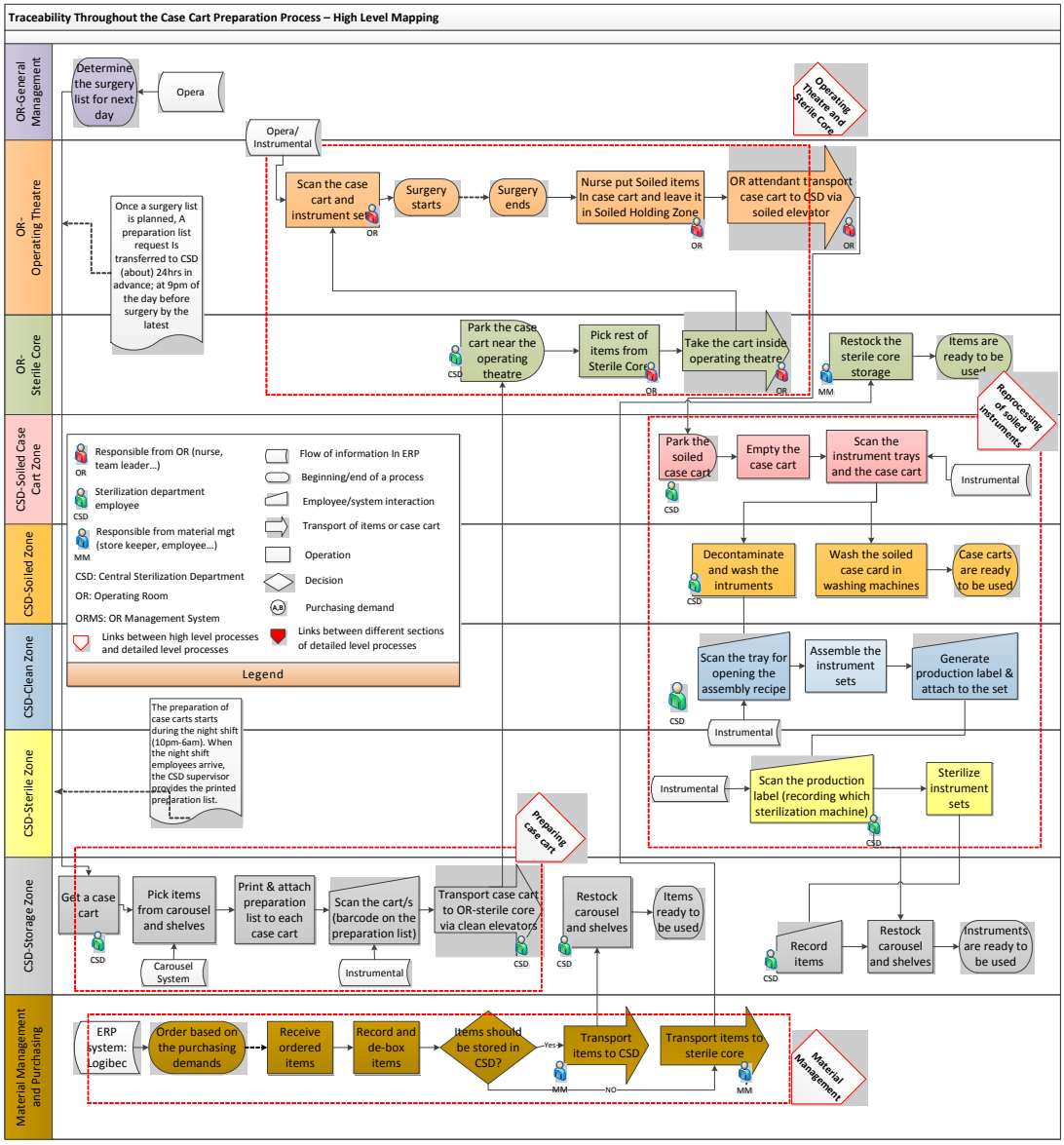


**Fig. 4** Process mapping of redesigned process – scenario 1

### 5.2 "What- If" RFID Technology Was Used?

A "What- If" analysis has started to explore the marginal contribution of using RFID technology over the existing system.

One envisioned impact of using RFID is to increase the automation of internal logistic processes for the tracking of equipment while progressing through all stages of the processes.

With RFID enabled bulk-reading of tagged instruments, a whole tray/crate can be automatically loaded into the CMS, eliminating non value added activities at (a) preoperative stage (e.g., preparation of the crates and related time spent at CSD storage zone for scanning items), (b) intraoperative stage (e.g., verification of crates before surgical interventions and related time spent at the OR sterile core and inside the operating theatre) (c) postoperative stage after usage by the OR (i.e., tracking instruments through the sterilization process and ensure the compliance with sanitary regulations). Additionally, enabling identification at the instrument level prevent the loss of instruments who might be left aside during one operation. In the past years, some RFID suppliers started to propose surgical instruments traceability solutions that leverage on RFID technology (e.g., *Xerafy and Caretag*, *Haldor Advanced Technologies*). For instance, Xerafy developed a series of highly resistant (IP68), autoclavable, FDA compliant, small UHF RFID ceramic tags that can be mounted on individual metal surgical instruments (i.e., Dash-On XS; Dot-On XS tags; Dash-iN XS; Dot-iN XS for instruments or MicroX II-Autoclavable Version and Roswell tags for surgical Trays). Thanks to the standards regulating passive RFID UHF technologies, these tags can be read with any RFID equipment from different vendors in the industry such as *Zebra/Motorola*, *Alien technology* or *impinj*. For the Middleware solution, vendors like *Caretag* have developed specialized modular traceability solutions for the management of surgical equipment. Additionally, actual players in hospitals are leveraging on their own solutions to enable RFID integration. While the business logic is the same, the data capture is radically different with RFID.

Conversely, while using RFID for the tracking of instruments is interesting in terms of process efficiency, embedding or attaching RFID tags on instruments requires specific competencies and equipment (e.g., covering the tag with FDA-approved USP Class VI epoxy resin to secure the tag in place and ensuring the right tag placement to maximize performance). While this step can be outsourced to specialists, it was identified as an issue in the project, considering (a) the important amount of individual equipment to be tagged, (b) the time required to identify and match each item in the data base, and (c) the upfront investment costs for RFID hardware infrastructure, middleware platform configuration and integration, project management, etc. There is no doubts that potential benefits need to be properly evaluated for accurately measuring operations savings and building a business case.

## 6 Conclusion and Further Research

This paper raised the importance of using simulation software such as *Arena* as a "process analyzer" to efficiently compare the "What-If" envisioned scenarios. As further steps to this research, modeling of different scenarios for the designed process will need to be done. Additionally, in order to measure the performance of the traceability process, control points and relative KPIs need to be identified by process owners as well as by looking at existing logistic performance frameworks [16]. In this research some KPIs are already specified and will constitute the basis for further analysis. The first KPI is obviously related to the productivity of the process and its "*responsiveness"*, by analyzing the activities related to the *"fulfillment cycle time"*, in particular by measuring the *"average time for case cart preparation"*, i.e., the time spent to prepare the case cart at CSD and sterile core. In fact, the time factor will be measured elsewhere in the process wherever there is a time consuming activity that can be reduced or eliminated with RFID technology – such as *"average time for"* counting/ verifying/ validating/ etc.

The second KPI is related to the *"reliability"* of the process by analyzing the *order fulfillment* performance, in particular with measuring the *"accuracy of case cart preparation"*, i.e., the % crates that are delivered according to demands from OR (item accuracy and quantity accuracy). This is of a particular importance since any discrepancy between the preparation list and the instruments delivered will have an impact on the productivity of the process and will involve re-processing the orders. Of course, the situation might be worst if the discrepancy is not detected before surgery where instruments are need immediately.

Other KPIs may also be of interest for other departments such as material management and purchasing in charge of renewing instruments, as well as the CSD storage (on carousel and shelving). For instance, the status of each instrument (in its life cycle) and the *"inventory availability"* may be measured for ensuring high quality in service delivery without creating excess inventory of instruments.

Since the main objective of this research was to explore the realistic potential of RFID for improving the traceability of medical equipment, the next steps will be (i) proposing a redesigned flows that facilitates the traceability processes of case carts and/or individual instruments between CSD and ORs, (ii) identifying the "best case" scenarios, and (iii) realistically assessing the potential of RFID technologies for improving this process.

## References


1. Barge P., Gay P., Merlino V., Tortia C.: Item-level Radio-Frequency id. for the traceability of food products: Application on a dairy product. *J. of Food Eng.* 125, 119-130 (2014).
2. Bendavid Y., Boeck H., Philippe R.: RFID-Enabled Traceability System for Consignment and High Value Products: A Case Study in the Healthcare. *J. Med. Sys.* 36(6), 3473-3489 (2012).

3. Bendavid Y.: RFID-enabled Applications to Improve the Delivery of Healthcare Services: A Typology and Supporting Technologies. *J. Med Biological Eng.* 33(5), 433-442 (2013).
4. Bendavid Y.: RFID-enabled Real-Time Location System (RTLS) to improve hospital's operations: An up-to-date typology. *Int. J. RF Tech. Research App*. 5(3), 137-158 (2013).
5. Chen Y.C.: *Empirical Modelling for Participative Business Process Reengineering*. PhD Thesis, University of Warwick, Coventry, UK (2001).
6. Choi C.F., Chan S.L.: Business process re-engineering: evocation, elucidation and exploration. *Business Process Mgmt. J.* 3(1), 39-63 (1997).
7. Chongwatpol J., Sharda R.: RFID-enabled track and traceability in job-shop scheduling environment. *Euro. J. of Operational Res.* 227(3), 453-463 (2013).
8. Feng J., Fu Z., Wang Z., Xu M., Zhang X.: Development and evaluation on a RFID-based traceability system for cattle/beef quality safety in China. *Food Control*.31(2), 314-325 (2013).
9. Fosso Wamba S., Anand A., Carter L.: A literature review of RFID-enabled healthcare applications and issues. *Int. J. Inf. Mgt*. 33(5), 875-891 (2013).
10. Fosso Wamba S., Ngai E.W.T.: Importance of issues related to RFID-enabled healthcare transformation projects: results from a Delphi. *Prod. Plan. & Control.* 26 (1), 19-33.
11. GS1: Business process and system requirements for supply chain traceability: GS1 Global traceability standard for healthcare (2009). http://www.gs1hk.org.
12. Harrop P., Das R.: RFID for Healthcare and Pharma. 2009–2019. *IDTechEx*. (2009).
13. Kumar S., Livermont G., Mckewan G.: Stage implementation of RFID in hospitals. *Tech. and Health Care.* 18(1), 31-46 (2010).
14. Moatari Kazerouni, A., Chinniah, Y. Agard, B. Integrating Occupational Health and Safety in Facility Layout Planning, Part I: Methodology; *Int. J. Prod. Res.* Online first (2014).
15. Parreño-Marchante A., Alvarez-Melcon A., Trebar M., Filippin P.: Advanced traceability system in aquaculture supply chain, *J. of Food Eng.* 122, 99-109 (2014).
16. SCC-supply chain council: SCOR Framework /Supply chain operation reference model (2010). https://supply-chain.org/f/SCOR-Overview-Web.pdf.
17. Ting S.L, Kwok S.K, Tsang A.H, Lee W.B.: Critical elements and lessons learnt from the implementation of an RFID-enabled healthcare management system in a medical organization. *J. Med. Syst.* 35(4), 657-69 (2011).
18. Tzeng, S.F., Chen W.H., Pai F.Y.: Evaluating the business value of RFID: evidence from five case studies. *Int. J. Prod. Econ.* 112(2) 601-613 (2008).
19. Yao W., Chu C.H., Li Z.: The adoption and implementation of RFID technologies in healthcare: a literature review. *J. Med. Sys.* 36(6), 3507-3525 (2012).
20. Yazici, H.J.: An exploratory analysis of hospital perspectives on real time information requirements and perceived benefits of RFID technology for future adoption. *Int. J. Inf. Mgt.* 34(5), 603-621 (2014).
21. Yin R.K.: *Case study research: Design and methods*, 3rd ed. Sage, Thousand Oaks, California, USA (2003).