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Abstract
In this paper, a comprehensive review of articles published between 1997 and 2011 in the Journal of Medical Systems (JMS) on RFID technology is presented. A total of 22 papers are analyzed using a classification framework that has three dimensions: RFID-enabled healthcare applications, RFID-enabled healthcare issues, and RFID-enabled healthcare benefits. In addition, an invitation sent to all authors of the papers accepted for the special issue on RFID for the JMS allows them to position their various papers within the classification framework. Finally, a list of future research directions is presented.

Keywords
RFID technology, healthcare, asset management, patient management, issues, benefits

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RFID-enabled Healthcare Applications, Issues and Benefits: An Archival analysis (1997-2011)

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Abstract: In this paper, a comprehensive review of articles published between 1997 and 2011 in the Journal of Medical Systems (JMS) on RFID technology is presented. A total of 22 papers are analyzed using a classification framework that has three dimensions: RFID-enabled healthcare applications, RFID-enabled healthcare issues, and RFID-enabled healthcare benefits. In addition, an invitation sent to all authors of the papers accepted for the special issue on RFID for the JMS allows them to position their various papers within the classification framework. Finally, a list of future research directions is presented.

Introduction

The healthcare sector is currently facing tremendous challenges including: ageing population, management of multiple stakeholders for services delivery, and high operating costs. For example, the U.S. healthcare expenses are expected to grow from 5% of the country gross national product (GNP) (Middleton 2009) to almost 20% of the GNP by 2017 (Wurster et al. 2009). One way of overcoming these challenges is the adoption and effective use of information and communications technology (ICT) to support healthcare activities (Fichman et al. 2011). Indeed, "the need for new ways to providing more efficient health care services, coupled with major advancements in information and communications technology, have resulted in the increased use of the information and communications technology (ICT) applications over the past decade" (p. 1) (World-Health-Organization 2005). For example, ICT has been used to support a range of healthcare-related activities such as: the access to patient record transactions (Lu et al. 2005) for better decision making. Also, ICT can facilitate the tracking and tracing of blood bags and the monitoring of drug allergies (Cresswell et al. 2008), and therefore reduce healthcare costs and improve outcomes (Fichman et al. 2011).

Recently, radio frequency identification (RFID) technology, a 'wireless automatic identification and data capture (AIDC)' technology (p. 615) (Fosso Wamba et al. 2008b) has emerged as a multidimensional innovation (Fosso Wamba 2011) that can accelerate the transformation of healthcare processes (Ngai et al. 2009; Oztekin et al. 2010). However, RFID technology is not that complex. Any basic RFID system has three main subsystems: (a) a tag, which can be embedded in or attached to a physical product to be tracked and traced; (b) a reader and its antennas, which interact with the tag without requiring a line of sight; and (c) a middleware, which is in charge of managing the system, filtering RFID data, aggregating RFID data, and interacting with intra- and inter-organisational information systems to support intra- and inter-organisational business transactions (Fosso Wamba et al. 2008a). Paradoxically, RFID is not a new technology. Its first industrial application was during the World War II by the British army to identify its combat planes. RFID offers more capabilities in comparison with traditional AIDCs (e.g. bar coding); they include communication without the line of sight, unique item-level product identification, multiple tag item product reading, enhanced data storage capability, and data read-and-write capabilities. The effective adoption and use of RFID technology is expected to transform intra- and inter-organisational business processes, thus allowing intra- and inter-firms business process innovation, real-time data collection and sharing at the supply chain level, business analytics and improved decision making.

In the specific context of the healthcare sector, RFID technology –compared to bar coding, another AIDC widely used in the healthcare– offers a better means for patient identification, tracking, and tracing (Fisher et al. 2008; Fosso Wamba et al. 2012). The technology is even considered as a viable solution that will solve major problems in patient care, including order errors, adverse drug effects and allergies issues, patient-medication mismatches, and medication dosage errors (Fosso Wamba et al. 2011; Iris et al. 2009; Menachemi et al. 2007; Oztekin et al. 2010; Thuemmler et al. 2007; Tu et al. 2009). Despite these advantages, the rate of adoption and effective use of RFID technology is still significantly low within the healthcare sector. For example, a recent review of academic articles on RFID technology by (Ngai et al. 2008) noted that the highest frequency of peer-reviewed articles on RFID technology was concerned with the retail sector (17.8%). Indeed, they found that only 3.6% of the papers focused on

applications and issues related to the healthcare sector. This study therefore represents the first attempt to bridge this knowledge gap, by attaining the following objectives:

1. Develop a conceptual framework for the classification of articles dealing with RFID applications and issues in the healthcare.
2. Use the conceptual framework to classify and summarize all relevant articles.
3. Develop future research directions where the deployment and use of RFID technology is likely to transform the healthcare sector.

The rest of this paper is structured as follows. Section 2 presents the research methodology and the classification framework. Section 3 presents the results and discusses the key findings. Finally, Section 4 provides the conclusion including future research directions.

Methodology

The main objective of this study is to assess the current level of papers written on the deployment and use of RFID technology in the healthcare that have been published in the Journal of Medical Systems (JMS) with the aim of highlighting the contribution of papers included in the "Special issue on radio frequency identification in the healthcare sector: applications, issues and benefits", and thus discussing future research directions. The study follows a methodology similar to the one used by (Ngai et al. 2002), which consists in developing a classification framework, and then conducting a comprehensive review within the journal of papers dealing with RFID technology using the descriptors "RFID technology" or "RFID". This comprehensive review provides a base to understand current RFID-enabled healthcare research (Ngai et al. 2002). A classification framework based on a study by (Van Oranje et al. 2009) was created and has three dimensions (Table 1): RFID-enabled healthcare applications (e.g., asset management, patient management and staff management), RFID-enabled healthcare issues (e.g., technological, data management, security and privacy, and organizational and financing issues), and RFID-enabled healthcare benefits (e.g., efficiency, quality and management gains). Finally, an invitation was sent to all authors of the papers accepted for the special issue on RFID so as to enable them to position their various papers within the classification framework (Table 6).

The preliminary search resulted in 38 articles. After a careful analysis of the content of each paper, a total of 22 papers were finally retained and analyzed using the classification framework.

Table 1: Classification framework, developed from (Van Oranje et al. 2009)

Dimension	Focus
Applications	
Asset management	Centered on applications related to the tracking and tracing of critical healthcare assets (e.g., asset identification, blood bags identification in hospitals to ensure blood type matching, medicine tracking, provision of e-Pedigree, real-time inventory count, and location tracking and tissue bank operations).
Patient management	Centered on the improvement of patients management within the healthcare supply chain (e.g., accurate patient identification, critical information to the patient, dementia outpatients tracking and tracing, tracking and tracing of hospitals for patient flow monitoring, and tracking of drugs supplies and procedures performed on each patient).
Staff management	Centered on applications such as better staff time utilization, improved error prevention, improved labor productivity, reduced processing time, staff identification, staff monitoring, staff tracking, and workflow optimization in hospitals.
Issues	
Technological issues	Covered issues such as the lack of required wireless infrastructure within healthcare facilities to support RFID-enabled healthcare projects, the potential interference of RFID systems with medical equipments, the difficulty to clearly define the scope of RFID-enabled healthcare projects, and the technical realization of such projects.
Data management, security and privacy issues	Covered issues such as RFID data integrity and reliability, management of huge amounts of data generated by RFID systems, RFID-enabled business intelligence.
Organizational and financing issues	Covered issues such as the lack of cost-benefit analysis frameworks for RFID-enabled healthcare projects, the cost of RFID system, change management, training, and skills to support emerging RFID-enabled healthcare processes, integration of RFID with healthcare organizational complexity, culture and norms.
Benefits	
Efficiency gains	Covered benefits such as capital expense reduction, inventory reduction, operating cost reduction, labor cost savings, increased patient management.
Quality gains	Covered benefits resulting from improvements on patient care quality, such as the elimination of wrong patient and wrong medication errors, the elimination of wrong patient and wrong

	procedure errors; as well as gains from an improved coordination between healthcare stakeholders.
Management gains	Covered benefits such as improved compliance with various regulations, the reduction of insurance premiums, the improvement of process and event audit capacity, and improved forecasting capacity.

Results and discussion

I now present and discuss the results of the comprehensive review within the Journal of Medical Systems of papers dealing with RFID technology. First of all, it should be noted that an article may discuss several dimensions of the classification model.

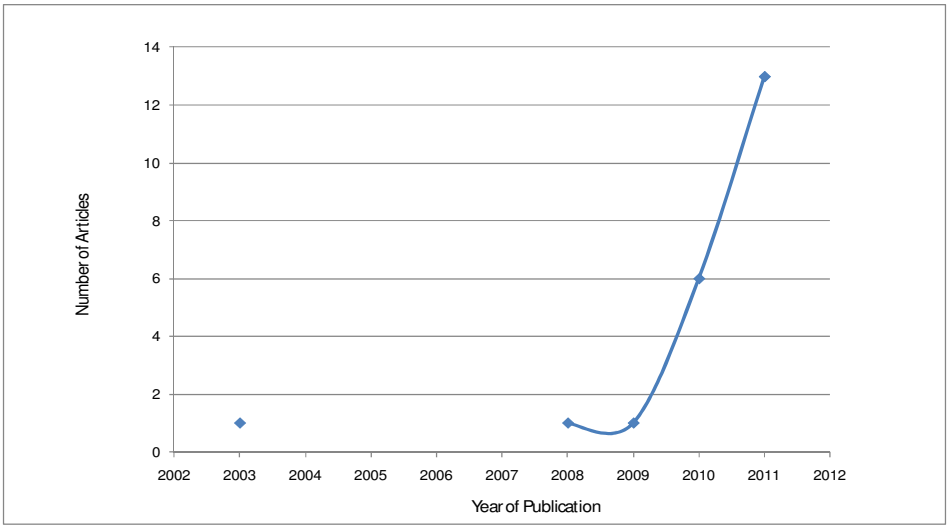

Figure 1: Distribution of articles by year of publication (search done on September 2011: 1997-2011)

Figure 1 presents the distribution of articles by year of publication. There was only one paper published on RFID technology in 2003, 2008 and 2009, with a substantial increase in 2010 (27% of all publications or 6 articles), and a jump to 59% (13 articles) of the overall publications by September 2011.

Table 2: Distributions of articles by applications

Application areas	Number of Articles
Asset management	5
Patient management	13
Staff management	11

Table 2 shows the distribution of articles by applications. So far, the highest number of published articles is concerned with the "patient management" areas (13 articles), followed by "staff management" (11 articles), and "asset management" (5 articles).

The distribution of articles by RFID-enabled healthcare issues is shown in Table 3. Clearly, the most highly published RFID-enabled healthcare issues are related to "data management, security and privacy issues" (15 articles), followed by RFID-enabled healthcare technological issues (8 articles). Only 2 articles deal with RFID-enabled healthcare organizational and financing issues.

Table 3: Distributions of articles by issues

Type of issues	Number of Articles
Technological issues	8
Data management, security and privacy issues	15
Organizational and financing issues	2

Table 4 shows the distribution of articles by RFID-enabled healthcare benefits. The highest number of published articles deal with the "efficiency gains" enabled by RFID adoption and use in the healthcare (10 articles), as well as "quality gains" (5 articles). Only 1 article deals with "management gains".

Table 4: Distributions of articles by benefits

Type of benefits	Number of Articles
Efficiency gains	10
Quality gains	5
Management gains	1

Table 5 presents all the articles that are being reviewed in this study using the classification framework. Table 6 shows the distribution of papers included in the JMS's special issue on RFID. Clearly, the most highly discussed applications areas are "asset management" and "patient management" with 5 articles each, while 4 articles deal with "staff management". With regard to RFID-enabled healthcare issues, the most highly discussed issue is "organizational and financing issues" (4 articles), followed by "technological issues" (3 articles). Only 1 article specifically deals with "data management, security and privacy issues". For RFID-enabled healthcare benefits, the most highly discussed benefit is "efficiency

gains" (6 articles), followed by "quality gains" (5 articles), and 2 articles for "management gains". Clearly, this special issue partially fills the gap identified in the literature. For example, the number of articles from the JMS's special issue on RFID that discussed respectively the application area "asset management" and the RFID-enabled healthcare benefit "quality gains" is equivalent to the number of all articles dealing with "asset management" and "quality gain" that were published in the journal from 1997 to 2011—that is, 5. The number of articles dealing with "organizational and financing issues" and "quality gains" is the double of the articles that are currently published in the journal.

Table 5: Classification of reviewed articles

Type	**Reference**
Applications	
Asset management	(Chen et al. 2011a; Østbye et al. 2003; Shim et al. 2010; Ting et al. 2011; Yu et al. 2010b)
Patient management	(Chen et al. 2011a; Chien et al. 2011; Huang et al. 2009; Ivetic et al. 2011; Li et al. 2010; Shim et al. 2010; Stahl et al. 2011; Sun et al. 2008; Ting et al. 2011; Unluturk et al. 2011; Wu et al. 2011; Yen et al. 2011; Yu et al. 2010b)
Staff management	(Chen et al. 2011a; Ivetic et al. 2011; Li et al. 2010; Østbye et al. 2003; Shim et al. 2010; Stahl et al. 2011; Sun et al. 2008; Ting et al. 2011; Unluturk et al. 2011; Yen et al. 2011; Yu et al. 2010b)
Issues	
Technological issues	(Deng et al. 2011; Min et al. 2011; Østbye et al. 2003; Shim et al. 2010; Stahl et al. 2011; Ting et al. 2011; Unluturk 2011; Unluturk et al. 2011)
Data management, security and privacy issues	(Chen et al. 2011a; Chen et al. 2011b; Chien et al. 2011; Deng et al. 2011; Huang et al. 2009; Lin et al. 2011; Min et al. 2011; Shim et al. 2010; Stahl et al. 2011; Ting et al. 2011; Wickboldt et al. 2010; Wu et al. 2011; Yen et al. 2011; Yu et al. 2010a; Yu et al. 2010b)
Organizational and financing issues	(Stahl et al. 2011; Ting et al. 2011)
Benefits	
Efficiency gains	(Chen et al. 2011a; Ivetic et al. 2011; Østbye et al. 2003; Shim et al. 2010; Stahl et al. 2011; Sun et al. 2008; Ting et al. 2011; Unluturk et al. 2011; Yen et al. 2011; Yu et al. 2010b)
Quality gains	(Chien et al. 2011; Sun et al. 2008; Unluturk et al. 2011; Yen et al. 2011; Yu et al. 2010b)
Management gains	(Yen et al. 2011)

Table 6: Classification of papers accepted in the special issue on RFID of the JMS

Type	Number of Articles	Reference
Applications		
Asset management	5	(Bendavid et al. 2011; Catarinucci et al. 2011a; Jesun et al. 2011; Pacciarelli et al. 2011; Wen et al. 2011)
Patient management	5	(Bendavid et al. 2011; Catarinucci et al. 2011b; Chen-Yang et al. 2011; Jesun et al. 2011; Wen et al. 2011)
Staff management	4	(Bendavid et al. 2011; Ching-Hsiang et al. 2011; Jesun et al. 2011; Wen et al. 2011)
Issues		
Technological issues	3	(Chen-Yang et al. 2011; Ching-Hsiang et al. 2011; Wen et al. 2011)
Data management, security and privacy issues	1	(Hawrylak et al. 2011)
Organizational and financing issues	4	(Bendavid et al. 2011; Catarinucci et al. 2011b; Jesun et al. 2011; Pacciarelli et al. 2011)
Benefits		
Efficiency gains	6	(Bendavid et al. 2011; Catarinucci et al. 2011a; Chen-Yang et al. 2011; Jesun et al. 2011; Pacciarelli et al. 2011; Wen et al. 2011)
Quality gains	5	(Bendavid et al. 2011; Catarinucci et al. 2011b; Ching-Hsiang et al. 2011; Jesun et al. 2011; Wen et al. 2011)
Management gains	2	(Bendavid et al. 2011; Jesun et al. 2011)

Conclusion and future research directions

In this paper, the results of comprehensive review of papers dealing with RFID technology within the Journal of Medical Systems were presented and discussed. The review was guided by a classification framework with three dimensions: RFID-enabled healthcare applications, RFID-enabled healthcare issues, and RFID-enabled healthcare benefits. The review showed that in 2003, 2008 and 2009, there was only one paper published on RFID technology. However, in 2010, there was a substantial increase in articles on RFID technology (6 articles or 27% of all publications), with a jump to 59% (13 articles) of the overall publications by September 2011. The analysis of articles on RFID-enabled healthcare applications shows that the highest number of published articles is concerned with the “patient management” areas (13 articles), followed by “staff

management" (11 articles), and "asset management" (5 articles). As for the articles on RFID-enabled healthcare issues, the most highly published RFID-enabled healthcare issues are related to "data management, security and privacy issues" (15 articles), followed by RFID-enabled healthcare technological issues (8 articles). Only 2 articles deal with RFID-enabled healthcare organizational and financing issues. The analysis of articles on RFID-enabled healthcare benefits shows that the highest number of published articles deal with the "efficiency gains" enabled by RFID adoption and use in the healthcare (10 articles), as well as "quality gains" (5 articles). However, only 1 article deals with "management gains". Finally, the analysis of articles included in the special issue on RFID of the JMS shows that the most highly discussed applications areas are "asset management" and "patient management" with 5 articles each, while 4 articles deal with "staff management". With regard to RFID-enabled healthcare issues, the most highly discussed issue is "organizational and financing issues" (4 articles), followed by "Technological issues" (3 articles). Only 1 article specifically deals with "data management, security and privacy issues". For RFID-enabled healthcare benefits, the most highly discussed benefit is "efficiency gains" (6 articles), followed by "quality gains" (5 articles); there are 2 articles for "management gains". While this special issue partially fills the gap identified in the literature, a better assessment of the impact of RFID technology within the healthcare sector requires more research. For example, future research topics may include an exploration of the network effect of RFID technology within all healthcare value chain activities, an analysis of the key technical and business challenges of integrating RFID technology within the whole healthcare value chain, and an exploration of key technological enablers and inhibitors of RFID-enabled healthcare applications. Other expectations from further research are: an investigation on how RFID technology can facilitate the optimization of healthcare processes for better patient service and healthcare cost reduction; and a better analysis of RFID-enabled healthcare issues. For example, digging into the best strategy to protect RFID-enabled patient data is a promising research area. So goes with an exploration of RFID-enabled healthcare business analytics.

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