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Organizational and business impacts of RFID technology

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Abstract

Purpose – The purpose of this paper is to briefly discuss some aspects of radio frequency identification (RFID) technology, potential applications, and challenges including scientific methods that will help to study the impacts of RFID implementation on businesses.

Design/methodology/approach – As an introductory paper, this paper conducts a brief literature review, provides personal reflection on RFID technology, and consolidates expert opinions.

Findings – This paper identifies a set of research topics that seem relevant for a large-scale implementation of RFID systems. It brings up the importance of business impacts as a result of new RFID systems introduced to organizations.

Originality/value – The paper is original in the sense that it combines literature review, personal reflections, and expert opinions to draw a set of research topics that contribute to both acceptance and large-scale implementation of RFID systems.

Keywords Industrial engineering, Information systems, Innovation, Simulation

Paper type Literature review

Introduction

Information technology (IT) has been the economic gain, costs saving, and quality improvements that serve as the main drivers in pushing for innovative technologies. These are the same relevant drivers for the radio frequency identification (RFID) technology as well. The current research manifests that the use of RFID can significantly transform the current practice of conducting business, improve efficiency of operation and management, and support decision-making process.

In the era when timely information, accurate forecasting of supplies and demands, real-time inventory management, control of warehouses and retail stores are vital for success, the RFID technology yields significant potential for every sector of economy, business and industry such as transportation and cargo, storage and retail, healthcare, manufacturing, and many other sectors and domains. There are many pioneering sectors and domains where the RFID technology has been long used, e.g. transport and traffic control (toll-ways), supply chain management, where tracking, monitoring, security, coordination, and planning play important roles. Similarly, RFID systems have been used to improve healthcare services, construction sites management, and so on. Essentially, in every aspect, when moving objects have to be tracked, RFID has an application potential. But the current state, spread, and application level of RIFD technology is nothing more than a glimpse of the potential that this technology contains. Its real diffusion is far in the future, and for that future to fulfill, a long path of challenges and obstacles should be passed through. Although current literature is reporting on the success of RFID, but the reality surrounding it is rather more challenging.

Business Process Management Journal
Vol. 16 No. 6, 2010
pp. 897-903

1463-7154
DOI 10.1108/14637151011092973

Behind the hypes reported in the recent literature, there are many challenges and impediments to successful implementations of RFID that yet to be identified and discussed (Kapoor *et al.*, 2009). The challenges hindering the large-scale implementation of RFID in industry and business vary from privacy concerns to technical challenges, economics, and operational impacts. Although from economic point of view, RFID is at a price point that could enable its large-scale adoption (Want, 2006), but it is still about the ethical, organizational, and managerial challenges that are more dominant then the cost of the technology alone. For example, a major challenge is the impact that RFID implementation has on businesses and, in its turn, the changes that it requires before the technology can be successfully implemented and integrated into the business existing infrastructure and business processes (Fosso Wamba and Chatfield, 2009).

While application of RFID in some sectors or domains (retailing and warehousing) far moved from obscurity into mainstream applications, there are domains where this technology is seen as a huge potential but privacy concerns and customers perceptions (Pramatari and Theotokis, 2009) are hindering its widespread use. One such a domain is healthcare, where adequately handling patients' privacy concerns is vital to the implementation success of any new technology. As for healthcare, RFID application has enormous potential from patient flow management, to handling laboratory samples, locating devices and instruments, providing instant access to patient information and medical records in emergency rooms, and many more advanced and technologically sophisticated uses. By different accounts, it is estimated that the healthcare segment of RFID is already a multi-billion dollar industry and it will further rapidly grow in the coming years.

Application challenges

Despite the economic promises, adoption of RFID in different industries is far from ubiquitous. In fact, there are only some dispersed examples that can be found in the literature. Before RFID sees any wide diffusion, it requires extensive study of already applied RFID projects, the study of best practices, innovative applications, potential uses, and barriers. As Kapoor *et al.* (2009) argue, the current literature is largely overlooking the challenges and impediments to successful implementations.

We are not undermining the economic potential and business benefits of RFID technology. In contrary, we look at RFID technology as a new wave of innovation, but we urge more scientific and critical approach and study of already implemented projects and scientific and systematic approach towards future implementations. While the potential of RFID technology is obviously high in terms of operational performance optimization, there are various theoretical and managerial issues to be studied (Curtin *et al.*, 2007) such as: what are the factors that influence the managers to adapt RIFD technology in their enterprises? What are the salient factors that should constitute a successful business case for RFID projects? What measures should be implemented to increase customers' acceptance of RFID technology? In the same light, it is worth knowing what considerations are to be taken into account in the extended enterprise network level and throughout the whole industry to maximize the economic impact of using RFID across the whole path of trade partners. Furthermore, introduction of RFID systems will have certain behavioral, managerial, and business impacts ranging from splendid success to disastrous failure. Therefore, it represents a high-research interest to analyze how RFID and real-time decision making will change managerial and

organizational capabilities, how changes are managed, how users behavior are dealt with, etc. Of course, there are many such issues that require a scientific approach for solution. In fact, these issues require a profound classification schema to be grouped as technical, managerial, economical, societal, and ethical issues, which is beyond the scope of this paper. However, we focus only on a few topics and elaborate on them briefly below. But prior to diving into the discussion of these topics that seem to us salient topics, we first briefly introduce what type of technology RFID is and why it is considered as an innovative technology.

The RFID technology

In this section, we provide a brief introduction to RFID technology. The interested reader will find an extensive introduction in Asif and Mandviwalla (2005) and Want (2006). RFID is a new technology that works similar to barcode, but without a line of sight. In addition to not requiring line of sight, unlike barcode, RFID tags could be active and interact with the readers. These very characteristic differences of not requiring a line of sight and interactivity make RFID a new revolution in retail, replenishment of shelves, warehouse management, inventory control, supply chain management, and practically any domain where management and monitoring of moving objects are involved. Depending on the type of RFID that we will discuss below, the objects that are attached with an RFID tag might be read from a distance in meters to hundreds of meters (Asif and Mandviwalla, 2005; Jedermann *et al.*, 2009).

RFID infrastructure

Any basic RFID system is a combination of three major components, namely: a tag (active, passive or semi-passive) which serves as an electronic database and can be attached to or embedded in a physical object to be identified; a reader and its antennas which communicate with the tag without requiring a line of sight; and a host server equipped with a middleware responsible to manage the RFID system and interacts with intra- and inter-organizational information systems.

RFID tags can be classified by their size and functionalities such as power source, operating frequency, data storage capacity and capability, operational life, and cost. For example, active tags have an embedded tiny battery as power source, whereas passive tags do not contain any power source, and semi-passive tags work as a passive tag. But semi-passive tags have a power source that allow them to use an aboard sensor to monitor their environment (e.g. temperature, vibrations, and shocks), and therefore are more suitable for cold supply chain monitoring, e.g. monitoring of the quality of food products (Jedermann *et al.*, 2009). With regard to operating frequency, the low-frequency tags use frequencies ranging from 125 to 134 kHz; the high-frequency (HF) tags use the 13.56 MHz frequency, and the ultra-high-frequency (UHF) tags use from 866 to 960 MHz frequency. Whereas the microwave tags work with frequencies ranging from 2.4 to 5.8 GHz. When dealing with data-storage capacity and capability, RFID tags may either be read-only or read/write. In addition, the data transmission rates of the active tags are higher than that of the passive tags, and likewise, the data-storage capacity of the passive tags is smaller than that of the active tags. With regard to operational life, the active tags' operational life is usually shorter than that of the passive tags. Finally, as it should be obvious, because passive tags do not require a power source, they are less expensive than active or semi-active tags. This fact positions passive tags as the best

solution for RFID enabled supply chain applications (Véronneau and Roy, 2009) with decreasing costs. For example, the price of a passive UHF tag decreased from about 57 cents in 2003 to 16 cents in 2008, and at the same time those of a passive HF tag when from about 91 cents to about 30 cents (Ilie-Zudor *et al.*, 2006). While analysts estimated that the price of an active tag is between five and ten times the price of semi-passive tag (Jedermann *et al.*, 2009) with an average price of an active UHF tag estimated between \$10 and \$30 (in some specific applications, this price can reach several hundred dollars), and therefore are more suitable for identifying and tracking high-value products (Asif and Mandviwalla, 2005).

In addition, RFID tags have a variety of sizes and can be applied to or embedded into products at various levels (e.g. item, box or pallet). In general, RFID active tags are much bigger than RFID passive tags. For example, the passive read only Hitachi mu-chip with less than 0.4 mm on a side is among the smallest RFID tags, and it is designed to be embedded into paper to enable the tracking and tracing of important documents. The passive Verichip tag has a size of a grain of rice and it is designed to be implanted into living beings (e.g. human and pets) and it is well suited for authorization of people in sensitive and secure environments or identification of Alzheimer's patients (Garfinkel and Holtzman, 2005). The Memory Spot is another tiny passive RFID tag with extraordinary functionalities: a capacity of 4 MB of data and a 10 MB/s data transfer rate. This type of tags is designed to be attached to items (e.g. pharmaceutical products to fight counterfeiting) or embedded into items (e.g. passports), and allows to carry and to encrypt a large amounts of sensitive data that can be read from a short distance (O'Connor, 2006).

With regard to the tagging level, a vast majority of the current RFID applications are at the box and pallet levels. However, the constantly falling price of RFID tags now makes it possible to track and trace almost any product in any industry at the item level (Zhou *et al.*, 2009, p. 576). This new capability also raises operational issues such as RFID tags collision and RFID tags information overloads and strategic issues such as how best to share RFID tags costs and information generated from these tags.

Regarding RFID readers, they can be either "fixed" or "mobile" and may have a read or read/write capability (Ngai *et al.*, 2007). In addition, an RFID reader can be configured to control the timing communication with the RFID tags (the reader talks first) or to react to messages from the tags (the tag talks first) (Asif and Mandviwalla, 2005). Finally, the RFID middleware is considered as the backbone of any RFID system. In fact, it is the place where all business rules that are used to manage the entire RFID system are configured (Fosso Wamba *et al.*, 2008). More precisely, the middleware consists of the data repository, the operating system, and the processing algorithms that convert multiple tag inputs into visible tracking or identification data (Floerkemeier and Lampe, 2005).

Future research topics

The study of RFID technology, application domains, business impacts, and economic gains presents a promising potential for research to address a host of issues. As mentioned earlier, a comprehensive classification of these issues for research is beyond the scope of this paper, however, in this section, we identify only issues deemed most relevant to achieve large-scale implementation of RFID applications, e.g. across the entire supply chain, distributed retails stores, partner businesses, etc.

Business impacts of RFID application
RFID technology is widely expected as a new wave of supporting technologies and business process enablers. In this capacity, the current literature presents only a glimpse of the impacts this new technology might have on businesses, both from quantity and quality perspectives. In particular, the relation of business process reengineering (BPR) and RFID application needs more scientific and profound research. An improved life cycle might be needed to study the impacts RFID applications have on business and how this technology and the BPR efforts should be aligned and interrelated.

Data management of RFID application
Large-scale application of RFID technology undoubtedly results in a more complex data management system. First of all, it might result in enormous data volumes. Whether the concerns of these data volumes are profound or it is rather exaggerated is a subject of research. Furthermore, it is also of research interest to study the relationship between different data hierarchy at items, box, and pallet level. The data management issue is also of interest for real-time decision-making applications. Both analytical and simulation methods may help with the study of data volumes and data management in large-scale RFID applications.

Implementation of RFID application
It is obvious that RFID is an add-on application to the enterprise existing IT infrastructure and information systems. As such, rigorous approaches are needed to study the entire cycle of RFID acquisition from search and choice phases to implementation and integration. What makes RFID unique from other information systems is its purpose of tracking moving objects. Tracking of these moving objects requires a complex implementation of both hardware and software components on one hand and integration of these new components into the enterprise existing IT infrastructure. A rigorous life cycle model (guidelines) needs to be developed to take this uniqueness into account.

Implementation scale of RFID application
Unlike many information systems, the success of RFID application depends on many factors such as the size of enterprise as data should travel along the movement path of the tracked objects, hardware components (tag readers) should be installed, signal collision among the tags at different levels (item, box, and pallet) need to be dealt with. An RFID application can be least expensive and most effective if it is implemented cross organizational than one single organization since the costs of data collection and management can be shared and the gathered data can be reused along the supply chain of the moving objects from one to another party. In general, the relation of the enterprise size (or the implementation scale of RFID application), its implementation complexity, costs, and business values constitute an interesting research topic.

Methods for the study of RFID application
New technologies and application domains put forward new demands for research methods and techniques that are needed to adequately address the underlying issues, i.e. either develop new methods or adopt and enhance existing methods and techniques. There are evidences merging that simulation could serve as a potential method and technique to study certain aspects of RFID application. Simulation as a research method

and technique plays a significant role in implementation of new technologies and the study of impacts that a new technology might have. More prominently, simulation helps to study dynamic behavior and change management as a result of new technology. However, designing an accurate simulation models require certain research breakthrough. For example, the signal collision problem in RFID applications, due to the signal simultaneously emitted from the tags, necessitates for the simulation model to develop or adopt an anti-collision algorithm to take the signal collision factor into account.

Domains of RFID application

Undoubtedly, the practice and success of RFID application can be generalized across different application domains and economic sectors, but it is also evident that each domain may present different sort of challenges ranging from technical to ethical ones. For example, healthcare domain is one of the important domains where application of RFID technology can bring significant improvement. In particular, RFID technology can be applied in healthcare management in respect to patient flow management, patient basic medical information implant, etc. However, security and safety are dominant concerns of healthcare domain. Generally speaking, ethical concerns pose a host of research topics for the application of RFID in healthcare domain, while technical challenges could be less dominant.

These are only some issues that require scientific intervention in order to lay out a foundation for large-scale implementation of RFID technologies. We tried to articulate them here. Addressing these issues will better equip adopters and practitioners of this technology to overcome the challenges they face, answer the questions that cause doubts about the efficiency and outcomes of implementing RFID systems.

Conclusion

With a brief discussion in this paper, we attempted to highlight that RFID is a promising, affordable, and profitable technology for supporting business processes and operations management. However, implementation of the RIFD technology is challenged by certain impacts on the established routine of the adopting enterprises. It means that RFID applications force changes of the way that the daily operations are conducted. Since not always changes may have desired outcomes, therefore scientific methods and intervention allowing studying the impacts and extents of changes and the dynamic behavior of the whole system, impacted by the new technology, are very important. One such a method, as mentioned above, is simulation. In particular, we attempted to highlight the importance of simulation as a technique and method to study and analyze the impacts of RFID applications and dynamicity of some of the parameters. The topics that we briefly discussed in this paper require a more in-depth discussion and research to increase and expedite RFID diffusion and large-scale implementation.

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Further reading

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