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When is RFID right for your service?

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ABSTRACT

Radio Frequency Identification (RFID) is a technology that is being applied increasingly to services. We study several different RFID applications in services to discover how this technology can be used to enhance various aspects of service delivery, and what costs and benefits arise from it. We use a well-known conceptual framework that has been used to explain the evolution of services to show how RFID generally impacts service operations in a variety of scenarios.

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1. Introduction

The evolution and application of new technologies has often played an important role in improving the performance and reducing the cost of services. As a new technology is developed and its potential is proven, firms contemplate using it in processes that can generate value for their customers while improving operational performance in terms of cost, quality, speed, flexibility and so forth. A good example of one such technology is the ATM (automatic teller machine) introduced into the banking industry in the 1980s. ATMs had a significant impact on banking operations by providing continued access to their services and thus offering a competitive edge for banks that adopted the technology.

In this paper we consider the role of RFID (radio frequency identification) technology in services. There are several reasons why it is an opportune moment to study the role of this technology in the provision of services. First, although the use of RFID in services is not a new idea (commercial deployments began more than 20 years ago) many organizations are beginning to experiment with RFID to understand its true potential, thus creating competitive pressure for managers to understand how this technology might apply to their own operations. Second, many experts assert that RFID is likely to have a significant impact on the field of operations management in the years to come (Fleisch and Tellkamp, 2005; Lahiri, 2005; Wyld, 2005). Third, RFID technology is currently evolving at a very fast pace, which creates uncertainty and leaves room for speculation regarding the benefits that RFID investments may or may not provide. Fourth, managers continue to struggle with the decision to adopt this technology, trying to select the configuration that is most appropriate for their operational needs and that enhances the operational performance. As explained by Armanino (2005), because it is a new technology, it is not uncommon to expect payback of less than a year in addition to less quantifiable benefits that the technology provides. For these reasons, we believe that there is a need for a deeper understanding of the reasons for adopting RFID technology in service operations.

Decisions about the selection of new technologies such as RFID require significant investment and can have a strategic impact on the organization. To ensure that the right RFID configuration is selected, the manager must be an informed consumer of the technology. However, industry media suggests that potential RFID adopters are generally in great need of a conceptual framework, as there appears to be a significant confusion about the value of adopting it, and very little understanding among practitioners of the variables that drive the adoption value of RFID in services. The purpose of this paper is to improve managerial decision making about the adoption of RFID in services. It discusses the use of this technology from a managerial viewpoint, provides some conceptual frameworks that are useful for service managers who are contemplating adopting RFID in their organization, and it integrates our analysis into fundamental operations strategy concepts that are well-received in the literature as well as among practitioners. Based on our analysis, we hope that practicing service managers can better understand when RFID might be right for their service, and make better decisions accordingly.

The paper is organized as follows. In the next section we discuss some of the research literature related to RFID adoption in services. Section 2 introduces RFID technology by reviewing some of its salient features. Section 3 presents our conceptual framework of the key performance variables involved in the selection of

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RFID in service operations. Managers might potentially use this framework to determine when RFID is right for their service operation. Section 4 evidences each key variable with one condensed case study. Conclusions follow in Section 5.

2. Literature review

RFID technology was developed over several decades, as reviewed in the works of Landt (2001), Lahiri (2005), Dew (2006). There is a growing body of literature on operations management in service firms that is relevant to RFID adoption in service operations. Ngai et al. (2008a, b) presented a literature review of 85 academic journal papers that were published on RFID between 1995 and 2005, organized into four main categories: technological issues, applications areas, policy and security issues, and miscellaneous. Since then, several other academic studies have been written about the benefits (and costs) of adopting RFID.

Doerr et al. (2006), Niederman et al. (2007), De Kok et al. (2008), Rekik et al. (2008), Szmerekovsky and Zhang (2008), Veeramani et al. (2008) and Kim et al. (2008) studied the use of RFID to improve supply chain and inventory operations. Doerr et al. (2006) combine a multi-criteria tool for the valuation of qualitative benefits with a Monte-Carlo simulation of anticipated financial benefits associated with the implementation of an RFID-based inventory management of military ordnance. Kim et al. (2008) evaluated the benefits derived from using real-time information acquired with RFID technology to track the movement of vehicles during the deployment and shipment in the automotive assembly plant. They find that the technology can significantly improve customer satisfaction by reducing dwell time variability, and by decreasing labor cost, thus leading to profit increase. In addition, they find that RFID-based systems driven by intelligent algorithms can improve the timeliness of supply chain information, raising the quality of the decision making process. Niederman et al. (2007) discussed the technology infrastructure, business process, and managerial issues that need to be adapted with the diffusion of RFID technology in the supply chain. Veeramani et al. (2008) provide a framework for assessing the benefits of RFID implementation by tier-one suppliers in manufacturing and distribution operations. Among the opportunities to increase revenue, they consider reducing stockout opportunities and decreasing counterfeiting incidents in the supply chain. To reduce fixed and overhead costs, they discuss the reduction of non-value-added activities with increased accuracy to identifying and locating defective items, and the elimination of other overhead cost, avoiding capital investment in facilities. Finally, they remind that substantial working capital may be tied up in inventory, thereby making it an area of great opportunity to reduce costs. Szmerekovsky and Zhang (2008) use a game-theoretical model to study the impact on manufacturers and retailers of attaching RFID tags at the item level in a VMI system. Rekik et al. (2008) study a retail scenario with inventory inaccuracies stemming from misplacement errors that occur because products received from the supplier are not available on shelf, either because they are sitting in the backroom, or they are in the wrong shelf, or similar reasons. They analyze the problem using a Newsvendor model to compare three approaches: the retailer is unaware of the errors; the retailer is aware of the errors and incorporates them in the inventory policy; or the retailer deploys a tracking technology to eliminate errors. De Kok et al. (2008) adapt an inventory model by including both the shrinkage fraction and the impact of RFID technology to control for shrinkage due to theft. By comparing the inventory management cost with and without RFID, they derived an analytical expression for the break-even prices of an RFID tag. These prices are related with the value of the items that are lost, the shrinkage fraction and the remaining shrinkage after implementing RFID.

Fry and Lenert (2005), Lee et al. (2008), Ngai et al. (2008a, b), Tzeng et al. (2008) focused on improving the service delivery. Lee et al. (2008) observe three service operations that have adopted RFID for its customer-facing processes, and compare them with typical RFID implementations that are developed to enhance the efficiency of its relationship with suppliers. They conclude that a firm can use the technology to change its basis of competition from an efficiency-oriented strategy to one that provides the foundation for new products or services to enhance customers' value perceptions and improve customer loyalty. Ngai et al. (2008a, b) describe the design and development of an RFID-based sushi management system in a conveyor-belt sushi restaurant to achieve better inventory control, responsive replenishment, food safety control, and better quality of service. Tzeng et al. (2008) propose a framework for evaluating the business value of RFID technology. They illustrate these concepts drawing on the experience of five early adopters from the Taiwan healthcare industry.

Fry and Lenert (2005) introduced MASCAL, an integrated software—hardware system designed to enhance management of information at a hospital during a mass casualty situation. MASCAL uses active 802.11b asset tags to track patients, equipment and staff during the response to a disaster. It is contrasted with the more common method of managing resources and demand at a hospital, using manual processes created explicitly for a disaster situation.

There are well-known characteristics in service operations that make them difficult to manage. These include the *intangibility of outputs*, and the *presence and participation of customers* in the creation of many services. *Intangibility of outputs* results in difficulties in matching demand and supply since such output cannot be inventoried. This is not meant to suggest that lack of inventory is a characteristic of services. In fact, as exemplified by a restaurant, managing inventory of supplies (termed as tangible goods by Sasser et al. (1978)) can be very critical to the success of a service enterprise. Several studies such as Parasuraman et al. (1985) and Apte et al. (1997) conclude that evaluating the quality of a service is a difficult matter, precisely because customer's involvement makes it difficult to standardize the output. The main conclusions of those papers are:

- customers find it difficult to evaluate the quality of service as compared to evaluating the quality of goods,
- customer evaluation of service quality involves comparing a customer's subjective expectations with perceived service performance; in many cases, there aren't clear performance measures for evaluating service quality,
- service quality evaluation is based on the outcome of a service as well as on service delivery.

The *diversity* of services makes it difficult to develop helpful generalizations for service managers. Chase (1981) proposed a theory of the *customer contact* approach to services, which holds that the services with high degree of customer contact have inherently lower potential for efficiency due to the variability and uncertainty that customers introduce in the service creation. Apte and Mason (1995) propose that customer contact be conceptualized in two ways: first, in terms of propinquity, or a physical presence, involving a face-to-face contact between the customer and service provider, and second, in terms of a symbolic contact where the main purpose of customer contact is to exchange the information necessary in service creation and consumption. In general, service delivery requires a combination of both types of

customer contact. With the progress of information technology, a portion of the contact is being increasingly automated, which reduces output variability.

Closely related to the concept of customer contact is the service characteristic of *joint production*. Not only do customers have a presence during the service creation process, but they may have significant tasks to perform as well. Examples range from self-service at gasoline stations and salad bars, to the shared responsibility for communication in diagnostic services and tailored financial services (including tax preparation). In some cases, the customer's participation in joint production is rather passive. But in other cases, such as financial planning or education, the participation may be very active and very significant in determining the quality of service production.

Many service processes must deal with *customer inputs*. Dry cleaning services and diagnostic laboratory services are examples where there can be virtually no customer contact, and where the operations take on a "back-room" character closely resembling manufacturing. It is the customer specific inputs that distinguish such businesses from manufacturers. In many cases, information technology is also being used for redefining, or reengineering, the service delivery, standardizing aspects of *customer contact*, *joint production* and/or *customer inputs*. In what follows, we show that many capabilities provided by RFID technologies may help standardizing service delivery and to improve the performance of service operations in many measurable dimensions.

3. Fundamental capabilities of RFID systems

RFID is a semiconductor-based technology that can be used to identify objects. In its most basic design, an RFID tag can be thought of as a wireless barcode. The system typically includes radio-emitting tags, readers, and a host computer with the appropriate software. A tag is attached to each object that is being tracked, and it emits a unique electromagnetic signature that is captured by the reader. The host computer processes the respective information as needed. Individual systems operate at specific frequencies, which depend on allocations made by regional authorities (Lahiri, 2005). Table 1 provides more details regarding these frequency ranges, indicating in which media they are transparent or opaque, the typical read rate and the read distance afforded by the range.

RFID systems have three fundamental capabilities. First, RFID is a means to wirelessly identify people and objects, answering the question: *Who/what are you?* The ability to identify things without human manipulation is an important service delivery advantage. Consider, for example, a hospital patient. Nurses need to be able to verify the delivery of medicine to the patient, and it is an important advantage of RFID that this can be done 24/7 without disturbing the individual, who might be unable to communicate or simply resting. RFID can help nurses serve patients better by obviating the need to disturb the patient to access a barcoded wristband; instead RFID can be read wirelessly through bedding materials.

The second fundamental capability of (some) RFID systems is to automatically generate data that can be used to track and locate tagged items, answering the question: *Where are you?* RFID systems differ in their location capabilities because RFID systems vary in their range and mode of operation, but fundamentally most RFID systems generate information based on wireless communications between tags and readers that can be used to locate the tag (and the item with it) either directly or indirectly.

A third fundamental capability that (some) RFID systems have is to sense the surroundings answering the question: *How are you?* Some types of tags include a variety of environmental monitoring capabilities, such as the ability to track the ambient temperature, which enables the tag to act as a mobile sensor to wirelessly collect information about its immediate environmental conditions.

RFID systems vary enormously in the delivery of these capabilities: in fact, the RFID industry contains a series of highly specialized niche players that were developed to exploit an amazing variety of practical needs that can be satisfied using wireless technology.

4. Conceptual framework for RFID applications in services

4.1. Methodology used in the study

We used a multi-case approach to study the use of RFID in a wide spectrum of service applications. Because the adoption of RFID technology is quite recent in many service operations, case research is an appropriate methodology to use in this context. This methodology lends itself well to early, exploratory investigations where the variables are still unknown and the phenomenon being studied is not well understood. As argued by Meredith (1998) and Voss et al. (2002), an emergent phenomenon can be studied in its natural setting with case research, and a meaningful, relevant theory can be generated based on the understanding developed through observing actual practice.

Yin (2009) generally classifies case studies in two dimensions. The first dimension is the number of cases in the study: single- or multi-case study. The second dimension is the number of units of analysis drawn from each case. If many units of analysis are present in each case, we have embedded studies within the study. If only one unit of analysis is measured, it is a holistic study. Ours is a multi-case holistic study where the unit of analysis is the service that adopted RFID. We identify the benefit – or the service enhancement – provided by the RFID implementation, and classify the cases according to the similarity between the benefits observed. This classification allows making inferences regarding a conceptual framework for RFID applications in service industries.

The logic behind this multi-case methodology is that, when there is substantial variability in a phenomenon (which is usually

Table 1
Applications and characteristics of each tag frequency.

Band	Frequency	RF transparent materials	RF opaque materials	Antenna size	Read rate	Read distance
LF	125–134 kHz	Plastics, fabrics, oils, liquids, wood and some metals	Dense materials (brick and metals)	Largest	Lowest	Shortest
HF	13.56 MHz			Large	Low	Short
	315–433 MHz					
UHF	868–915 MHz	Most plastics, fabrics, oils, paper, dry wood	Dense materials, wet wood, mud or snow	Small	High	Long
MW	2.45 GHz	Most plastics, fabrics, oils, paper	Dense materials and liquids	Smallest	Very high	Medium
	5.8 GHz					

Source: Lahiri (2005) and authors.

true in services) the researcher samples many cases in order to generate an appreciative theory that encompasses the spectrum of variation. Since the goal of the research at hand is to develop practical and managerial guidelines for the possible use of RFID technology in the service industries, and these services range considerably in their operational requirements, this sampling approach suits our purposes.

In total, we reviewed more than 40 cases, and analyzed 21 of them, described in abbreviated form in the next section. They were based on our interviews with managers involved in their implementations, or observations that our students or we made *in loco*. Only 5 examples come exclusively from published sources. We started with a database of public sources of information on RFID, which encompasses documents collected in the 2002–2006 period and data gathered from approximately 50 interviews with managers, technologists and other individuals involved in the RFID industry. From this database we screened an initial sample of RFID applications in service industries. Based on our initial assessment of the key variables at play in this sample, we searched public data sources for additional case examples and material that verified data in the initial case sample. Table 2 details the 21 cases that we selected. In order to limit the length of the paper, we have kept the descriptions of these cases brief, but further details are available from the authors upon request.

We took several steps to analyze the 21 cases in depth. First, we coded the case data on a number of dimensions, identifying descriptive variables in each application. Next, we reviewed the qualitative case descriptions to gain insights into the key variables underpinning the choice of RFID in each service application. Here the goal was to surface the key operational benefits that affect service operators, and that have driven the adoption of RFID. Lastly, we analyzed how the variables we identified fit within a classic operations strategy framework: cost, quality, speed and flexibility. We iterated between case data and this framework, rereading the cases and experimenting with different conceptualizations of the benefits variables and with the cases that best exemplified them, until we developed a coherent framework that captured the key variables of concern. In the rest of this section we describe our framework, describing the key variables and illustrating them with the case material. Finally, we consolidate everything in Table 3, which summarizes our findings.

4.2. An operations strategy framework of RFID benefits

A successful operation, be it manufacturing or service delivery, requires understanding the operations capabilities of the firm: quality, speed, flexibility or cost leadership. To maintain leadership in any of these capabilities, a firm must be in a permanent effort to improve. Most world-class operations strive to deliver high performance in all four of these capabilities.

A well-known characteristics of service operations is that performance is hard to quantify and hard to standardize. Radio frequency technology is one alternative to enhance the operations capabilities of the service delivery, as shown in Fig. 1. Service *quality* is improved whenever reliability, conformance to specifications, process features, and customer perception about the delivery are standardized. RFID delivers that through reduced inventory spoilage, clear matching and identification of service subjects, greater security and safety, reduced inventory loss and greater service personalization. Properly designed RFID systems can deliver these benefits. Greater service *speed* is achieved with better tracking capabilities in the supply chain. These benefits are the focus of most developments in the field. Service *flexibility* is another beneficiary of the tracking capability. Faster identification of customers in the system allows serving a wider variety of customers without compromising process quality. Finally, RFID technology enables the standardization of the service output, with significant advantages to the service delivery: it may improve cost by increasing *capacity*, reducing *cycle time*, enabling *self-service* or *automating* value-adding processes.

5. Descriptive cases

Before turning to the key variables and the case descriptions, we present a brief overview of the descriptive data on the 21 cases

Table 2
RFID cases—descriptive data.

#	Case	Tagged item	Customer	Service provider	Tag type	Frequency
1.1	Container yard management	Containers	Shippers	Shipping company	RTLS	433 MHz
1.2	Automobile distribution yard	Automobiles	Dealers	Automobile distributor	RTLS	433 MHz
2.1	Highway and city toll collection	Registered automobiles	Drivers	Transit authority	Passive	2.45 GHz
2.2	McDonald's cashless payment	Customers	Consumer	Fast food outlet	Passive	13.56 MHz
3.1	Public library customer service	Books	Readers	Library	Passive	13.56 MHz
4.1	Industrial laundry management	Bedding and uniforms	Hospitals and hotels	Industrial laundry	Passive	13.56 MHz
4.2	ATM cash transfer	Cash securing boxes	Banks	Security transportation company	Active	125 kHz
5.1	Beer keg distribution control	Beer kegs	Breweries	Keg supplier	Passive	13.56 MHz
5.2	Lab supply vendor-managed inventory	Lab supplies	Research labs	Laboratory supplier	Passive	2.45 GHz
6.1	Railcar tracking	Railcars	Shippers	Railroads	Passive	915 MHz
6.2	Prison inmate tracking	Prison inmates	Government	Prison management company	RTLS	915 MHz
6.3	Ocean going container tracking	Ocean going containers	Shipper	port authority	Active	433 MHz
6.4	Airline luggage tracking	Luggage	Air traveler	airline	passive	915 MHz
7.1	Hospital patient identification	Patients	Patients	hospital	passive	13.56 MHz
7.2	Specialty container identification	Intermediate and bulk containers	Container lessors	Chemical and pharmaceutical company	RTLS	433 MHz
8.1	Fashion boutique management	Clothes and accessories	Consumer	Fashion boutique	Passive	13.56 MHz
9.1	Refrigerated cargo control	Containers	Frozen goods manufacturer	Shipping company	SEMI passive	2.45 GHz
9.2	MREs (Meals Readyto-Eat) control	Pallets	Military personnel	US Department of Defense	Semi passive	2.45 GHz
10.1	Theme park visitor location	Children and family members	Park visitors	Theme park	RTLS	433 MHz
10.2	Student location	Students	Students	College or school	Passive	13.56 MHz
10.3	Mine worker identification	Mine workers	Mine workers	Mine company	RTLS	433 MHz

Source: Authors.

Table 3
RFID benefits in services.

	Case	Quality					Speed	Cost			
		Spoilage control	Matching	Security and safety	Loss prevention	Personalization	Tracking movements	Capacity expansion	Cycle time reduction	Self service	Automation
1.1	Container yard management		p					P	C		
1.2	Automobile distribution yard						p	P			p
2.1	Highway and city toll collection							P	C	C	p
2.2	McDonald's cashless payment							P	C		
3.1	Public library customer service				p				C	P	p
4.1	Industrial laundry management		p		c						P
4.2	ATM cash transfer			c					p	p	C
5.1	Beer keg distribution control				C				p		
5.2	Lab supply vendor-managed inventory				P					c	
6.1	Railcar tracking						P		p		p
6.2	Prison inmate tracking			p	p		P				
6.3	Ocean going container tracking			P			C		p		
6.4	Airline luggage tracking			C			P				p
7.1	Hospital patient identification		C	c							
7.2	Specialty container identification		C				p		P		
8.1	Fashion boutique management					C				p	p
9.1	Refrigerated cargo control	C					P				
9.2	MREs (Meals ready-to-eat) control	C					P				p
10.1	Theme park visitor location			C			c				
10.2	Student location			c			c				P
10.3	Mine worker identification			C			P				

Source: Authors.

that we studied in depth. This data is summarized in Table 2. As the table shows, the cases we sampled varied on several key dimensions:

- We covered a wide variety of services where RFID has some critical role, everything from the inventory control of reusable beer kegs to the identification of mine workers.
- Cases covered a wide variety of service industries, ranging from leisure, to health care to transport.
- Tagged items varied greatly, from individuals to objects; from prison inmates to automobiles to key rings to containers.
- Customers and service providers reflected the wide range of industries that use RFID tagging as well as the range of service types that benefit from it.
- Tag types included passive, active, semi-passive and RTLS. RFID frequency types varied with the application needs. Together, our sample covered all the common tag types and frequencies.

In the following sub-sections we discuss the implementation in the selected cases, and identify benefits to the service provider or to the client. The benefits directly relate to the key variables in Fig. 1. They are the drivers of the competitive capabilities that the firm acquires or enhances with the adoption of the RFID technology.

5.1. Capacity expansion

Some RFID applications create benefits by increasing the throughput of service facilities. These systems work by generating real time information about the location of items within a facility; this information then reduces search time within the facility thus eliminating wasted labor effort (Ngai et al., 2007). Within the operations strategy framework (Diagram 1), increases in throughput translate into increases in volumes and lower costs. The effect of RFID on the capacity can be particularly important where it eliminates congestion of a whole site.

Case 1.1: Container yard management: In 2003, NYK Logistics implemented a real-time location system (RTLS) at its 70-acre Long Beach distribution center, which handles 50,000 oceangoing containers annually. The site has 1100 parking spaces and 250 dock doors. Its old yard tracking system involved tracking the location of containers manually (people with clipboards). With the RTLS system, every truck arriving at the site is given an RFID tag, which can be automatically located within 10 feet in real time and monitored on a computer screen. The key benefit of the system is the reduction of the average time that a trailer stays in its yard from 10 to 6–8 h, which increases throughput, especially during periods of peak demand. Check-in time at the gate is also cut in half. Hostlers reduce the time it takes to find and move loaded trailers and empty containers, because each hostler tractor is equipped with a touch-screen computer showing the location of

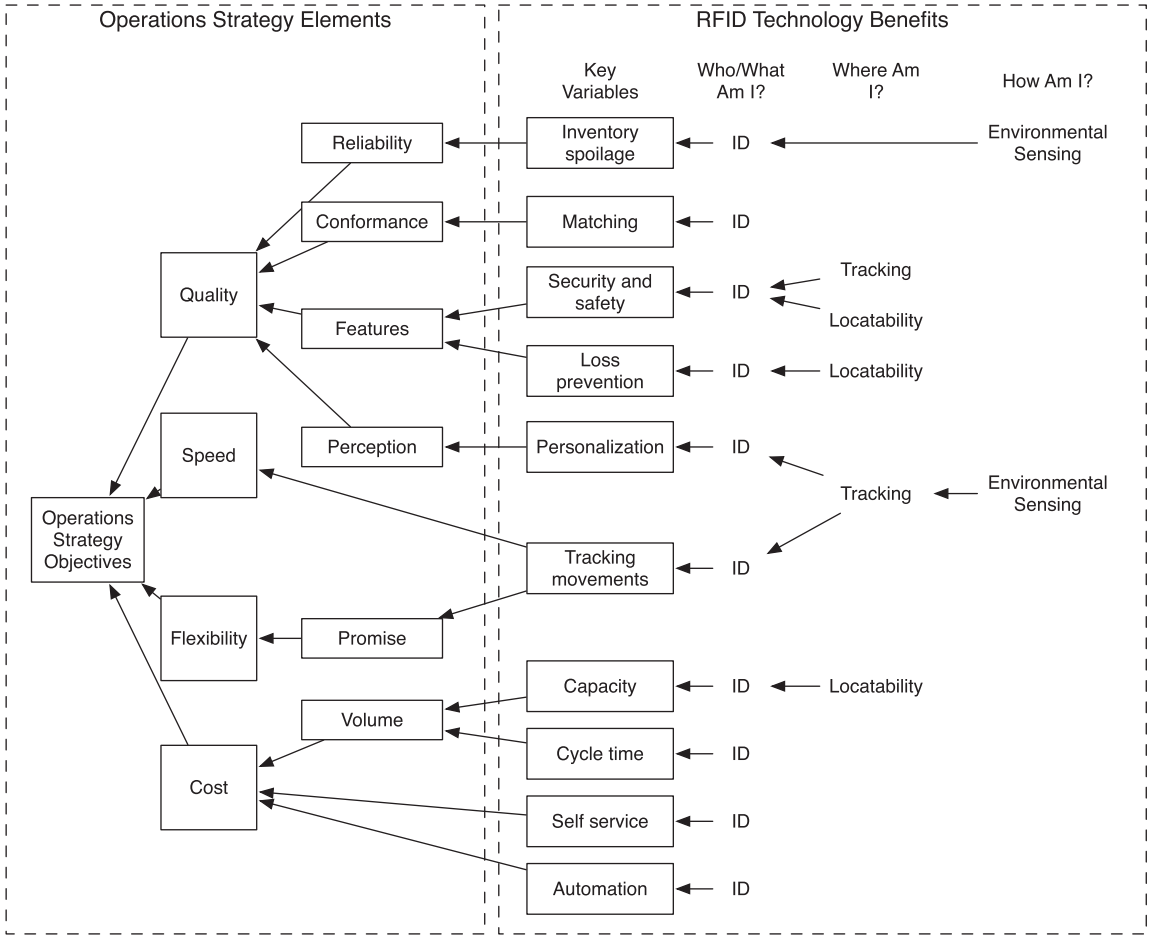

Fig. 1. Operations strategy framework and RFID benefits.

every container. Delivery promise is improved because the system alerts hostler drivers in real time of priority items that have to be moved first. Finally, the system allows more efficient allocation of dock doors, allowing containers to move more quickly through the facility (Armanino, 2005; Wasserman, 2005).

Case 1.2: Automobile distribution center: In another capacity expansion application, Gulf States, a Toyota distributor for five states, uses an RTLS system to locate 200,000 vehicles processed each year in its yard. Before the new system was implemented, workers had to walk the lot to find and match individual cars with the dealer that ordered it. The current RTLS system assigns a tag with each car's vehicle identification number (VIN), so the system always knows the precise location of each vehicle at any moment in time (Armanino, 2005). The tag stays on the vehicle until it is ready to ship to the respective dealer.

5.2. Cycle time reduction

A second variable through which RFID affects service operations is transaction speed, with impact on overall cycle time. Many service operations have significant transaction elements, such as payment for services, which affect the provider's cost of operations as well as the customer's consumption experience. In these situations the velocity at which the transaction can be performed is an important variable in the service. Because it is a wireless technology, RFID tags can be embedded in key chains and tickets, or attached to moving objects in order to provide completely automated, contactless transactions that eliminate manual labor and significantly reduce transaction times.

Case 2.1: *Highway and city toll collection*: The use of RFID tagging for automated toll collection has a long history, dating back to the 1970s (Landt, 2001, 2002). A good example is the system launched by the Singapore government in 1998. The system applies tags to vehicles and readers are installed onto gantries above the highway, to identify the date and time when each vehicle passed through the checkpoints for appropriate charges. The key benefit of this RFID system is increased transaction speed. As traffic volumes increase, toll road operators need more space for tollbooths, space that is not often physically available. RFID tagging increases transaction speed, which raises the throughput of tollbooths, reduces the number of booths required and therefore relaxing space constraints. This makes RFID-equipped toll roads very appropriate in big cities, where space is limited and very expensive.

Case 2.2: McDonald's cashless payment system: Fast food restaurants are constantly searching for technology and methods to reduce transaction times in order to relax capacity constraints at peak times. With this goal, McDonald's has adopted contactless credit cards issued by MasterCard and American Express across its US restaurant chain. Payment service vendors are eagerly promoting the technology under the brand names *MasterCard PayPass*, *American Express ExpressPay* and *VISA Contactless*. Research shows that these RFID cards are 65% faster than paying by cash, and both faster and simpler to use than a conventional debit or credit card.

5.3. Enabling self-service

As we mentioned earlier, ATMs created value in banking services by allowing customers to serve themselves. This switch to self service often requires technology enablers. Likewise, we have observed that RFID can also be a self-service enabler, creating value in service operations. For service producers, self service is an advantage because it transfers certain tasks (often labor intensive) from the service provider to the customer while making the transaction more convenient and speedy for the customer (thus increasing the customer's willingness to adopt self service activities). Self service therefore lowers service providers' costs, thus connecting these RFID benefits directly to a key operations strategy factor.

Case 3.1: Public library customer service: It has been estimated that approximately 70 million library books were RFID tagged worldwide by 2004, with hundreds of libraries all around the globe using RFID systems (Rafiq, 2004). The biggest RFID installation in the world is the National Library Board Singapore. All 9 million books, videos and DVDs in Singapore's library system are embedded with RFID chips that allow self-checkout. Library patrons simply walk past the check-out reader station without stopping and their items are automatically recorded. An RFID reader in the library's return chute automatically records the return of items. The key advantages of RFID in libraries is the automation of the check out and check in process, allowing the elimination of manual labor in these processes, thus improving staff productivity and eliminating a source of repetitive stress injuries. Self-check out is also convenient for library patrons, who no longer have to wait in line. Finally, the time taken to check inventory is significantly reduced (RFID Journal, 2002a; Ipsen, 2004; Kern, 2004; Coyle, 2005).

5.4. Automation

The substitution of capital for labor is a generic theme in the process of industrialization. Whether described as automation or mechanization, many service industries have significantly reduced the costs of providing services by replacing tasks that were previously performed manually (often repetitive tasks) with machine technology. RFID affects the provision of some services by allowing the automatic identification of items, which in turn allows the automation of certain tasks. Implementing RFID therefore lowers the cost of providing some services, enabling firms that adopt RFID to achieve a competitive cost advantage over those that do not.

Case 4.1: Industrial laundry management: Industrial laundries have used RFID tags for several years, as an alternative to using barcodes to identify individual items of laundry. RFID appeals to industrial laundries because garments can be read automatically with no line of sight and because tags may be encased in plastic, which allows them to survive multiple washings. The key benefit of this application is the automation of processes such as sorting, recording and folding garments. This reduces labor costs and decreases error rates. RFID tagging provides additional benefits such as theft prevention of high value garments, high volume scanning (which removes bottlenecks and increases capacity). In addition, it can be used to support automatic garment dispensing machines (Reyes et al., 2009).

Case 4.2: Receipt-free ATM cash transfer: When delivering cash to ATMs, security procedures require that cash-in-transit security companies cannot inform banks the exact time when the cash delivery will arrive. However, at least one authorized staff member of the bank branch must be present to issue a receipt for the cash delivered to the branch's ATM. This creates inefficiencies because the branch has to keep one employee available during all possible cash delivery times. Brink's Security has developed a solution that uses an RFID tag to identify individual cash bags, while RFID readers are installed in each drop box (Violino, 2003). The reader records the time cash bags are dropped or removed and issues a receipt for every transaction. The primary benefit of the system is reducing the cost of cash receipt for the security company's customer—the bank. Song et al. (2006) report a similar process for paperless delivery of pipe spools in industrial projects.

5.5. Inventory loss prevention

Porter (1998) points out that selling products and services that systematically lower costs for their customers is one method firms use to gain a competitive advantage. Often the source of these lower costs is superior technology that enables certain features of products and services that customers use to lower their own costs. We identified the creation of lower costs for customers – in the form of reduced shrinkage – as one variable through which RFID creates economic benefits in several service cases that we examined, and suspect that this one common reason RFID is applied in service operations. The simpler application could be the use of tags to reduce theft in retail operations. However, other elaborate uses of RFID have helped the reduction of inventory loss, as follows.

Case 5.1: Beer keg distribution control: Beer kegs are used to transport beer from the brewery to the points of sale. After each use, they are returned to the brewery where they are washed, repaired (if necessary) and refilled for next delivery. For many years, barcodes have been used to track kegs. Using this system, a typical brewery experiences 4% shrinkage of kegs annually. RFID tagging provides a solution to this problem (De Kok et al., 2008). Encapsulated in plastic, a tag is more robust than a barcode, can be used for multiple trips, "reads" almost 100% of the time and can have encrypted information written to it. This results in several benefits. Brewers have fewer kegs stolen, and increase their sales by better controlling "unofficial" beer seeping into the distribution chain. Moreover, the tags can store the precise weight of each keg upon delivery and return on the tag, measuring the exact amount of beer that they recover from the bottom of each keg on its return, which reduces the taxes paid on the amount of beer sold (this tax is typically levied on the volume of beer distributed).

Case 5.2: VMI of Laboratory supplies: Szmerekovsky and Zhang (2008) discuss the advantages of using RFID to coordinate VMI deliveries. In another application to prevent inventory shrinkage, Promega, a life science research supplier, has adopted RFID to improve accountability in the consumption of expensive supplies. Typically, materials used by research institutions in the life sciences are stored on campus in cabinets installed by the respective suppliers for the researchers' convenience. In this version of VMI (vendor-managed inventory), the sale does not conclude until a staffer in the lab removes the item from the cabinet. However, tracking who used each item and whom to assign the expense can be time-consuming and prone to errors and confusion. The solution was to install locks in the cabinet requiring individual RFID passkey. If the items stored inside the cabinets are fitted with individual RFID tags, a reader can count the inventory whenever the cabinet is opened and closed, fully identifying the material that was used and who used it (Collins, 2005a).

5.6. Tracking movements in a wide network

Automatic tracking information is valuable in many service operations. Several RFID applications demonstrated the benefits

that firms derive from tracking data. Tracking data normally takes the form of "tag 123 last seen by reader 789", with reader location acting as a surrogate for tag location. For many applications of RFID, it is sufficient to know that a tag has passed by a reader in a given location. The automatic wireless reading of RFID tags creates a flow of data that is beneficial to the operational management of many services, enabling improvements in the accuracy of delivery promise, and in the speed of delivery. Some RFID systems also incorporate sensor tags that generate additional benefits by providing information on the condition of tracked items.

Case 6.1: *Railcar tracking*: For many decades, US railroads have had difficulty dealing with the competition from long haul trucking, which was deregulated in 1980 and thereafter showed significant service improvements. By comparison, railroad service was poor: "They'd lose railroad cars or whole trains." (Landt, 2002). To effectively compete with the trucking industry, it was essential for the railroads to identify and locate a railcar to know how it was moving through the system. The railroad companies implemented RFID technology across North America using 3000 readers to track 1.5 million railcars and locomotives. Benefits of the system included service improvement in terms of speed of delivery and reliability of promised delivery times.

Case 6.2: *Prison inmate tracking*: RFID has emerged as a popular technology for tracking the movements of inmates in many prisons. RFID inmate monitoring works by issuing every inmate with a bracelet that has an active RFID tag embedded in it, carrying the inmate's identity number. The tag is referenced to personal information contained in the prison's database, as well as some specific restrictions such as restricting the inmate movement within the prison or preventing violence by setting an alarm when two opposing inmates come too close to each other. The transmitter is housed in a tamperproof casing and strapped with screws with tamper-resistant covers. If the band is cut or a prisoner manages to slide the band off, an alarm is automatically triggered at a central monitoring station (RFID Journal, 2002b).

Readers with antennas are set up around the prison yard and throughout the interior of the building to pick up signals from every transmitter in the facility. The system is built with redundancy, so usually more than three readers pick up the signal from each transmitter at any time. The signals are sent to a collector node, which calculates the person's location to within a few feet and puts a time of arrival stamp on the information. Readers throughout the complex continuously log signals received from inmates' bracelets and relay this data to a control center. The key benefits of this system are to protect the personal safety of the correctional guards, to deter escape efforts and to prevent theft and property damage.

Case 6.3: Oceangoing container tracking: Container monitoring is considered a major security issue in many countries. The US Homeland Security Agency introduced the Smart and Secure Tradelanes initiative (SST) with the objective of identifying each container, including its contents, and securing cargo containers at their point of origin using special RFID tags that, once sealed, could not be opened in transit without being detected. This reduces security risks by ensuring the integrity of ocean-going containers between their outbound ports and their destination ports in the US (RFID Journal, 2003b).

One approach is the use of an active RFID device that clamps to a standard intermodal shipping container. Its sensor can detect if the container has been opened, while monitoring other sensors inside the container that report on the conditions and integrity of goods. It also provides two-way wireless communications within a supply chain network to enable real-time auditing. Once clamped to the edge of a container's door, the transponder communicates with the RFID tags wired to other sensors that measure changes in environmental variables (light, temperature and pressure), vibration and radioactivity. Users may choose to enable the tags to work with GPS technology and RFID readers located at shipping terminals to furnish shippers, carriers and logistics service providers with real-time visibility about the location, status, security and integrity of their shipments.

Case 6.4: Airline luggage tracking: A number of airlines – British Airways, Asiana, Southwest, Delta Air Lines, among others – have experimented with RFID-tracking systems. Delta has seen the performance of its current bar code-based system stop improving, with bar-coded labels being successfully read by scanners only 85% of the time. One of the main problems with barcodes is that if the tag is wet, readers cannot read it well. However, an experiment using RFID to track 40,000 pieces of luggage in its Jacksonville–Atlanta route reported more than 96% reader accuracy. Another benefit of the system is that it can prevent that a luggage boards a plane without the respective owner, a significant security enhancement (Collins, 2004a, 2004b, 2005b; O'Connor, 2005a; Price, 2005; Wyld et al., 2005).

A recent pilot study at the McCarran International Airport in Las Vegas, with the participation of three medium sized airlines observed reader accuracy of 99.5%. The success of this initiative led to the integration of RFID in baggage tags issued by all carriers operating from that airport.

5.7. Matching item (or person) with service

Service facilities that handle a large variety of jobs have to ensure that individual customer receives the service desired. This type of conformance is a critical aspect of many services where it is mandatory to ensure that the right person gets the right service and the right time. It requires matching a positively identified customer with a positively identified service. In this environment, RFID systems may create value by increasing the accuracy of matching, usually by tagging customers and items that are part of the service. This enables automatic matching, checking and flagging if a mismatch is bound to occur.

Case 7.1: Hospital patient identification: A number of hospitals have started to tag patients to ensure that the service delivered (a medication, a surgery, a blood transfusion or a specific diet) is the one assigned to that particular individual. Jacobi Medical Center in New York has deployed a pilot system that puts RFID-enabled wristbands on patients admitted into the two wards at the hospital's acute-care department. The nursing staff uses RFID readers installed in portable PCs to automatically identify each patient and open the patient's medical file on the PC screen, enabling the patient's records to be reviewed and updated at bedside. The old barcode system the hospital used proved an invasive way to check a patient's identity and match it to drugs administered because patients often have their arms under bed sheets and get medications at nighttime as well as in daylight hours. By contrast, the re-usable watch-sized tags are inserted in the existing disposable wristbands used in hospitals. Tags are read automatically at long ranges, through bedcovers, without disturbing patients, and enabling a fully automated solution for accurate patient identification while reducing labor and the threat of manual errors. For wandering patents and infants, the tags provide tracking and protection by alarming as they exit through controlled doorways. The system also reduces the administrative burden on nurses and reduces costs (Roberti, 2006; Abraham et al., 2008; Lee et al., 2008; Tzeng et al., 2008).

Similar systems have been used in some hospitals to identify newborns, enhancing their safety. At Lucile Packard Children's Hospital at Stanford University, RFID was deployed within its

postpartum and nursery units – a 36,000-square-foot, two-floor operation – in a bid to prevent newborn abductions, a not so rare occurrence in hospitals worldwide (Collins, 2005c). RFID readers installed on the ceiling generate signals that are triangulated to track the exact location of all newborns. Readers installed at the exits ensure that a baby is not removed from the unit without permission.

Case 7.2: Specialty containers for pharmaceutical and chemical products: Companies specialized in leasing storage containers have difficulty tracking their location and ensuring fast turn-around. pH Europe leases out intermediate bulk containers (IBCs), which include large stainless steel or plastic drums and folding plastic pallets, to pharmaceutical and chemical companies. The company adopted a real-time locating system (RTLS) that simplifies its operations by giving it visibility into the availability of its containers and ensuring that once they are returned, they are prepared for service and redeployed as quickly as possible. Key benefits include fast turnaround and ensuring that containers dedicated to specific lines of products are never put to mixed use (O'Connor, 2005b).

5.8. Personalizing the service

Customer perception of the quality of a service offering is an important variable in the strategic management of many service operations. Across a wide range of service industries, firms frequently base their service strategies around using technology to dazzle the customer, thus affecting the consumer's perception of service quality and justifying higher prices for the services offered. RFID appears to offer great potential for adding value to services by increasing customer perceptions of quality and making products "intelligent" while the source of this intelligence remains invisible to consumers. Here are key examples:

Case 8.1: *High-fashion boutique management*: A permanent concern for high-fashion boutiques is to dazzle the consumer with an exclusive purchasing experience, and to find opportunities to upsell (i.e. introduce customers to high margin items, such as accessories). When Prada opened its retail store in Manhattan, it immediately got attention for its extensive use of technology, including the use of RFID to enhance the purchasing experience of customers and create new sales (RFID Journal, 2002c).

Alternatively, customers can take an item to Prada's smart dressing room and use the touch screen monitors to browse images of accessories that match their outfit. Inside the dressing room, there are two boxes showing thick, flat bronze ribbons embedded in them—the RFID antennas. One is small and square and is used for small items, and the other is long and narrow, for hanging clothes. The closet reads the RFID tag and displays information about the suit on a liquid crystal screen with a touch-screen overlay. You can flick through accessories or see the same item in different colors. The content displayed is all related to the item in the closet, and part of the same line.

All items in the store have an RFID tag, with the antenna and chip clearly visible. On shelves around the store there are small handheld readers to identify the tags on any item. Staff can scan the tags and use a monitor to show a video of the item on the runway, provide images of alternative colors, and see accessories that match the item. If a customer wants to try on an item, she enters the high-tech dressing room and hangs it in the smart closet to see all the different ways that she can match it to her taste. The chief benefit of the Prada RFID retailing concept is to provide a unique level of service that is not found in competitor stores. It dazzles the customer with an innovative retailing experience that significantly affects customer perceptions of the quality of service received at Prada. This technology is further explained in Hum (2001).

5.9. Spoilage control

Sensing the environmental condition that surround perishable items can be an important advantage in service operations. Sensor tags can be used to collect various kinds of information about these conditions. This information is valuable because it allows the development of contracts based on the quality of the items, which is determined by the tags ability to track environmental conditions.

Case 9.1: Refrigerated cargo control: Sysco, the distributor of temperature-controlled food, is testing a system to identify, locate and track individual trailers as they move through the supply chain, and to monitor and record at regular intervals the temperature conditions inside refrigerated trailers. The trailers are transported by independent truck drivers, who may be tempted to save fuel by turning off the refrigeration unit during transport, compromising the quality of the contents. Upon delivery, the tags are handed to the customer, who can use the manual reader to inspect the temperature log before accepting shipment. Two tags are attached to the inside wall of the trailer, one at the forward end and the other halfway along the trailer's length. Another tag is similarly mounted inside, close to the trailer's doors. Each tag records the temperature at 15 min intervals. According to SYSCO, monitoring the temperature at more than one point in a trailer can distinguish if there is a problem in just one area. Tags are read with a PDA from inside, so that any problems can be identified before the shipment is unloaded (Collins, 2005d; Gilbert, 2005).

The system uses semi-passive RFID tags that increase battery life, have low initial purchase costs, and are reusable. Temperature monitoring supports quality by assuring the customer that the goods were kept at the correct temperature through the supply chain. Ultimately this also saves costs by providing the ability to detect which party was responsible for losses and by reducing insurance premiums. Additionally, these tags enhance security by creating a custody chain that decreases the opportunity for theft or tampering. Tight management controls of shipped food is also discussed by Kärkkäinen (2003) and Jones et al. (2005).

Case 9.2: Control of MREs (*meals ready-to-eat*): Before Sysco started trials of semi-passive temperature-sensing RFID tags, the US Dept. of Defense identified a need for such devices to monitor its combat feeding program. They observed that the three-year shelf life of rations stored at 80°F is cut to six months if stored at 100°F and down to just one month at 102°F. This created an operational need to identify individual MRE pallets and to record their storage temperature at regular intervals. They tested a large-scale test program using open standard EPC-compliant semi-passive tags with temperature sensors on each pallet of MREs and used a mathematical model to estimate the remaining shelf life of each MRE pallet. With this capability, they intend to ensure that MREs sent to troops in operating areas are used before their shelf life expires (Gilbert, 2005; Hernandez and Thomas, 2005).

5.10. Security and safety

Security and safety needs are prominent in a wide variety of services and form the basic content for some services. RFID creates safety and security benefits in several ways: by providing location information or by controlling access in one of two ways – keeping people and things *out* of certain facilities (for instance, keeping soccer hooligans out of sport venues) and by keeping

people and things *inside* certain facilities (for instance, preventing the theft of weapons from an armory). Junglas and Watson (2008) discussed user perceptions of location tracking services provided by RFID. In all, we found security and safety to be a variable that frequently justifies the adoption of RFID across a wide range of service industries.

Case 10.1: *Theme park visitor location*: Several theme parks, water parks and ski resorts have adopted RFID to track visitors in their sites, including Legoland (Denmark), Steamboat Ski Resort (CO), Wild Rivers (CA) and Dolly's (TN) (RFID Journal (2003a). When families visit a park, parents and kids often have different interests, and are tempted to take on different activities; however, once they stray in different directions, it becomes quite difficult to find each other in the park. In fact, Legoland reports that 1600 children may become separated from their parents each year.

Armanino (2005) describes the process as follow: Park guests that want the service pay a small fee per user. The group registers together and tamper-proof wristbands are strapped onto their wrists. Guests from the same party can go to location kiosks, swipe the low-frequency tag, and find out where other individuals in their group are located. A reader in the kiosk identifies the person and displays the location of the other members of the party on a cartoon map of the park. The map divides the park into logical zones, and a reader is placed in each zone, which can vary from 20 to 300 feet in diameter. The size is chosen based on the concentration of people, number of visual obstructions and other factors. A large zone would typically be used to cover an open plaza. A smaller zone might cover the entrance to a popular attraction. The kiosk displays an icon of each member of a party with a time stamp that shows when their tag was last read. If someone just passed a reader near a water slide, the icon might say "Dad, 34 s ago". The key benefit of this system is security and safety. It improves the service offering by adding greatly valued peace of mind for parents taking their children to large resorts.

Case 10.2: Student location tracking: Several examples exist of RFID being used in schools and universities to monitor students' attendance. The basic system automates attendance-taking using RFID readers located on classroom doorways and passive RFID tags embedded in student identity cards, decreasing the amount of time that teachers spend taking attendance manually. The system can be enhanced to prevent kidnapping by expanding the installation of readers on the school's entry and exit points as well as in school buses.

Case 10.3: *Mine worker location*: In tunneling and construction industries personnel safety and security benefits can justify using real time location systems (RTLS) to enable workers' locations to be tracked. For instance, at a 15 mile railroad tunnel project in León, Spain, the operator deployed an RTLS system that allows workers to be located in the event of emergency by displaying their locations on a web-based map of the site. The system also tracks vehicles and equipment, enabling improved asset utilization.

In a South African mining complex owned by Anglo American, people and items are tracked using proprietary software used in conjunction with bar code technology to record the movement of miners. The software connects the RFID reader network with the mine's enterprise resource planning (ERP) system, consolidating it with the small asset usage database, which is updated in real time with the help of RFID readers. The information is invaluable alerting managers when an employee has not returned to the surface before blasting the area. For example, the system recognizes if a tagged lamp has not returned past a predetermined point, indicating that the worker holding it is still in the danger area. That would show in the exception report generated by the system. Another benefit from the use of RFID and the integration with the ERP system is the ability to track the movement of miners through the turnstiles, from the surface to their underground stations and back. This guarantees their safety while the system manages small assets (Violino, 2005).

6. Comparative analysis

To conduct a comparative analysis of the 21 cases, we coded the perceived primary and secondary benefits provided by the RFID technology in each case. These variables identify when the direct beneficiary is the service owner or provider (P or p) and when the beneficiary is the user or client (C or c). We use capital letters to denote primary effect, and lower case to denote secondary effect. Table 3 summarizes the benefits, indicating the operating capability affected by the respective benefit (see Fig. 1).

While we cannot exclude sampling bias given the multi-case methodology used in the study, we did deliberately incorporate variety into the sample of cases that we selected. In spite of this disclaimer, the results of Table 3 are quite interesting. Four benefit variables appear consistently across the final sample of 21 service cases: *tracking movements, automation for labor replacement, cycle time reduction, and personal security and safety*. These results emerged when we coded for secondary benefits as well as the primary benefit variable in each case. Table 3 also suggests that whatever the primary benefit of applying RFID in a given service operation, decision makers would be wise to also consider whether *tracking movements*, *automation*, *cycle time reduction*, and *personal security and safety* benefits are also available. Understanding the benefits of RFID that justify adopting the technology is the first step—this helps managers gain the buy-in they need in order to obtain the support necessary for major technology investments, before they can move on the technology implementation, and its coordination with existing practices (Cohen and Apte, 1997).

Schmenner (1986) proposed a service × process matrix that qualifies services as *service factories*, *service shops*, *professional services* or *mass services*, characterized according to their level of customization and of labor intensity, shown in Fig. 2. We post the location of each case *prior* to the introduction of RFID in the respective quadrant of the service × process matrix. As argued by Schmenner, "mass service controls often relate to labor costs and efficiency, for these services are trying constantly to get a grip on labor scheduling and productivity. Here, plant and equipment are rarely constraints." Moreover, "service shop frets about control of the service itself. With this kind of service, plant and equipment are constant constraints. Therefore, there are concerns for how frequently unpredictable jobs… can be scheduled through expensive capital equipment." Hence, Schmenner proposes that *successful* service organizations are most likely to operate as a service factory or as a professional service.

All cases identified as mass services or service shops in our study adopted RFID to help move the process closer to the service factory quadrant, described as follow: "…the service factory shares many of the benefits that manufacturing operations enjoy. The labor needed is well known for given levels of demand, and scheduling of labor, plant and equipment is fairly straightforward." Our intuition is that service factory is efficient because it delivers standardized services using lower proportion of labor (which is typically hard to standardize).

We would not expect a priori that RFID would be helpful in a business characterized as professional service, where high labor intensity and high interaction and customization are expected. Among our cases, we only identified one case that would be characterized as professional service, the Prada boutique, case 8.1. In this instance, the technology is being used to enhance the

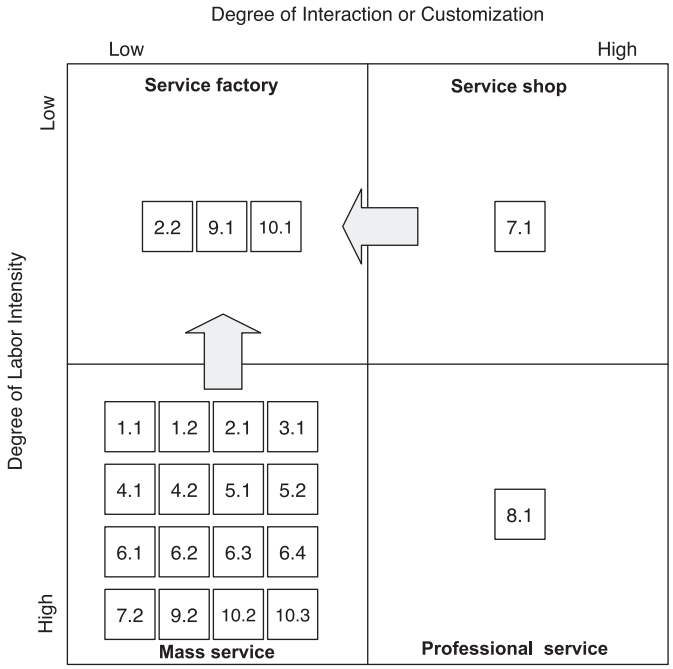

Fig. 2. RFID applications and the Service × Process Matrix.

organization's position in the matrix: RFID helps the organization to improve its customization process and to deliver better service.

Finally, we noticed three applications of RFID in service factories: cases 2.2, 9.1 and 10.1. In these cases, the RFID technology performed an accessory role not associated with the process itself, but adding new features that are valued by the customer. Again, the technology reinforces the business position in the matrix.

The ability to identify the service target is one of the most basic prerequisites for correct delivery of goods and services. Being an automatic identification (or auto-ID) technology, RFID can help machines identify physical objects, animals or customers, and dramatically simplify the operational processes. In addition, RFID technology has the ability to store and exchange large amounts of information about objects in the system. RFID can be used as a sophisticated data-gathering platform to support and enhance the decision and control capabilities in computer integrated service operations. In many of these examples we recognize the use of the technology to introduce mass customization as a new capability (Pine (1993). RFID can serve as an infrastructural technology to customize services, which may be the main attraction of this innovation.

RFID technology is in its early phases of adoption and organizations are just scratching the surface of the benefits that this technology can provide. It is a sophisticated information technology that can be readily used to support and enhance service operations. Our observations lead us to believe that RFID technology should be adopted in service operations only if one or more of the following conditions are satisfied:

- It helps reduce the labor intensity in businesses characterized as mass services.
- It helps reduce the number of errors caused by the large number of custom work in service shops with the current levels of labor.
- It helps increase the perceived customization of professional services, by providing additional tools to existing labor.
- It adds new features (usually associated to theft prevention or personal security) to service factories.

7. Conclusions

RFID is a promising technology and many organizations are presently contemplating its adoption to improve the performance of their services. As is the case of any new technology adoption, managers must consider how the technology adds value to their operations. In this paper, we have focused on improving managerial decision making by building a conceptual framework that explains key variables through which RFID benefits service operations. Helping managers understand these variables is the main objective of the current research. Based on the appropriate performance objectives, managers should be able to select the right RFID application and provide the correct justification to senior management and stakeholders to secure their buy-in.

Since the use of RFID technology in business application is quite recent, we selected several examples among those that we came across in our interviews with professionals in the field, and enriched them with reports mostly found in the practitioners' literature. Our conclusions are ripe for further validation through rigorous study of individual cases to identify implementation barriers or industry-specific side effects. Quantitative analysis of larger data sets gathered through survey may help identify relationship between specific benefits and the type of applications.

Specifically, we studied 21 RFID applications across a wide variety of industries to demonstrate how the technology affects service operations. We identified the variables through which RFID generates benefits, and found that most applications in service industries have four common benefits: replacement of labor through automation, cycle time reduction, enabling self-service, and loss prevention. We also found that the use of RFID technology facilitates the movement of service businesses towards the diagonal in the *Service* × *Process matrix* defined by Schmenner (1986). Since this movement can result in better control and lower costs, service businesses can gain competitive advantage by suitably adopting RFID technology to enhance their operations.

Finally, as discussed by Eckfeldt (2005), Sackmann et al. (2006), and Günther and Spiekermann (2005), RFID customization will only be successful if consumers can trust the network. The benefits derived from the use of RFID have to outweigh the privacy concessions. As the examples in this paper have shown, we expect that the more successful applications will require minimal concessions, compared to the benefit derived.

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