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Consumer preference and service quality management with RFID

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Abstract The importance of accurately measuring consumer preference for service quality management to firms in exceedingly competitive environments where customers have an increasing array of access to information cannot be overstated. There has been a resurgence of interest in consumer preference measurement and service quality management, specifically real-time service management, as more data about customer behavior and means to process these data to generate actionable policies become available. Recent years have also witnessed the incorporation of Radio-Frequency Identification (RFID) tags in a wide variety of applications where item-level information can be beneficially leveraged to provide competitive advantage. We propose a knowledge-based framework for real-time service management incorporating RFID-generated item-level identification data. We consider the economic motivations for adopting RFID solutions for customer service management through analysis of service quality, response speed and service dependability. We conclude by providing managerial insights on when and where managers should consider RFID-generated identification information to improve their customer services.

Keywords RFID · Real-time customer service quality management · Knowledge-based system

1 Introduction and background

There has been a massive power shift from vendors to customers in recent years due in part to the seemingly limitless selling channel brought about by the Internet. Customers today have

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more information about where they can look for what they want, including alternate sources of providers. They expect immediate gratification. When a vendor is unable to deliver, the customers are more than willing to move on to competing vendors.

Unlike the traditional corner market scenario, it is becoming rather difficult for vendors to keep track, understand, and appropriately respond to the needs and wants of their customers. In the days long gone, vendors were able to remember almost every one of their regular customers, along with their other relevant information. The means as well as the media used to interact with customers have changed dramatically over the past decade. The luxury of continued business with a loyal customer is no longer a guarantee. Today's customers have more complex demands and much higher expectations than ever before. Added to this is the criticality of the ability of the vendors to pro-actively assess the needs and wants of customers to be able to quickly respond to these with appropriate products and services. In order to be successful under these conditions, a vendor can no longer afford to wait until the signs of customer dissatisfaction appear to take remedial action.

Several factors have contributed to the change in the extent and mode of interaction among vendors and customers. These include (1) compressed marketing cycle times (if the customers' needs/wants are not met by a vendor, there are several competing vendors who are both willing and able to meet those wants/needs—this has led to shrinkage of marketing cycle times), (2) improvement in knowledge of customers' wants and needs, in general, thanks to advances in data collection, analyses, and interpretation techniques as well as the availability of relatively cheap data storage and computing power, (3) increased marketing cost (given the speed of knowing about customers as well as their needs/wants, the extent of competition, and the low margin due to strong competition, the cost to market and value-add to distinguish one's products/services also increases), (4) streams of new product offerings (customers expect their needs/wants to be satisfied exactly and not approximately—thus the increase in product/service variety and the trend toward mass-customization), (5) niche competitors (a vendor's best customer is also on the radar screen of competitors who are niche players), (6) changing customer expectations due to the extensive availability of a wealth of information, and (7) the difference between loyalty and captivity of customers, where the former is favored by customers who choose a vendor based on a superior value proposition in the product and/or service and the latter happens when customers are locked-in for lack of a choice.

Therefore, to be competitive, a vendor needs to make the right offer to the right customer at the right time through the right channel. The right offer and customer here simply refer to making the most appropriate offers while keeping the irrelevant ones to a minimum. The appropriate ones are those that satisfy specific customer's wants/needs. It also refers to (mass) customization since all customers most likely do not have the same wants/needs under all circumstances. The right time is achieved through continual gauging from observations and interactions with customers. Given the availability of several channels, their differing effectiveness, interactive-ability, as well as intrusiveness, the choice of medium for the interaction is important. Consumer preference measurement and service quality management has been touted as a partial answer to the question of being able to offer and deliver the right goods and services at the right price to the right customer at the right time.

Nowadays, consumer preference and customer service management is considered as a way to identify, acquire, and retain customers by providing satisfactory service; a way to automate the front-office functions of sales, marketing, and customer service; a way to leverage the Internet as a channel for customer care and reduce customer churn through the use of Web site personalization; a way to bring the call center to the desktop and provide real-time response to customer inquiries. The research firm Gartner Group defines it as consisting of a selling platform, a communications infrastructure, and a suite of applications. Infrastructure can include email, online chat, among others. And the application can be geared toward self-service, customer service, or data analysis. The diversity of definitions is a result of differences in perspectives.

Radio-Frequency Identification (RFID) tags are increasingly being used throughout the supply chain to generate item-level identification information about tagged objects (Zhou 2009). Researchers and practitioners in this area are beginning to appreciate the potential associated with RFID tag-generated data for consumer preference measurement. The core of consumer preference management in terms of the generated knowledge that is utilized for decision-making purposes is rather dynamic in every sense. As customer profiles continually change, the need to fine-tune customer service initiatives is of paramount importance to maintain or improve customer service. In addition to customer data generated otherwise, RFID-generated data provides complementary levels of visibility into customer characteristics. These need to be appropriately included in the comprehensive suite of data and analysis tools to gain competitive advantage.

As a disruptive technology, RFID tags are endowed with the ability to generate instance-level data that can then be utilized for finer granular decision support. Such item-level identification data were almost unheard of at such large scale before the introduction of RFID tags in supply chains. This ability to identify, locate, and mass-customize items based on item-level identification information opens up a wide range of possibilities for customer service management.

This paper is primarily motivated by the need and existing gap in service & operations, technology management, and managerial strategy literature on how IT and refined fine-granular identification information could benefit marketing operations. The paper is also motivated by the need to understand the business impact of emerging identification technology such as RFID. We consider these issues from a technological as well as service economy perspectives. We assume the use of passive RFID tags throughout this paper. The incorporation of active or semi-passive tags would not change the proposed adaptive knowledge-based framework nor the essence of the presented discussion.

The remainder of this paper is organized as follows. We provide a brief overview of existing literature in this area in Sect. 2. In Sect. 3, we discuss the adaptive knowledge-based framework presented in Piramuthu and Shaw (2009) and propose a modified knowledge-based framework incorporating RFID-generated data. In Sect. 4, we discuss the suitability of RFID-generated item-level identification data for consumer preference detection and service optimization for use from functional to corporate strategic levels. We conclude with a brief discussion in Sect. 5.

2 Related literature

During the past few years, several research publications have considered the beneficial aspects of RFID-generated data in service & operations applications (e.g., Ferrer et al. 2010; Shin et al. 2011; Tan and Chang 2010). We now consider a few of these publications.

Schloter and Aghajan (2005) propose a system for real-time customer service management. This system comprises RFID-embedded store cards that are distributed to the customers who carry these cards when visiting the store, wireless sensors and aggregator motes that are distributed throughout the store to collect RFID information, aggregation server, database, means to mine data in database, and a Web server for input and output of information. The sensors are manually moved to various locations within the store to gather relevant information from shelves in different aisles. A Web interface is used to let the customers sign into the system before the process begins, and the authors mention that this could be automated through use of RFID readers at the store front. Information from the card is linked with the customer's demographic information including ZIP code, gender, age group, level of education, purchase history, product booth visited, among others. These data are then visualized using "heat maps" to identify problem areas and address them as they occur. They propose addressing customer privacy issues by assuring the customers that the data thus collected will be used solely for statistical analysis. Being among the earliest publications in this area, this paper does an excellent job of identifying opportunities for RFID-enabled systems for customer relationship management.

Lin et al. (2009) provide a generic overview of customer service issues associated with supply chain management in the presence of RFID. Unlike Schloter and Aghajan (2005), they do not identify specific issues that could be addressed nor propose a system that incorporates customer service issues. The objective of Bayraktar and Yilmaz (2007) is similar to Lin et al. (2009) in that they provide a generic overview of customer loyalty issues but do not provide any specifics to develop a system that incorporates these issues.

Inaba (2009) addresses issues related to reducing costs through appropriate supply chain management and improving profit through better customer service. Inaba proposes algorithms that address issues related to customer loyalty status and inventory turnover through RFID-generated data to provide customized one-to-one promotions. Inaba also develops a prototype and present results using this prototype. The proposed system includes loyalty cards with RFID tag, RFID reader with display, a dynamic pricing engine that computes instantaneous price information based on the customer's loyalty status and the item's inventory level, a customer database, an inventory management system, and a recommendation engine that provides recommendations on other comparable products. He proposes providing customers with RFID tag-embedded loyalty cards and placing RFID tag readers with display in the store for customers to scan their cards to receive the item price on their items of interest. His main idea is to present different prices to different customers based on their loyalty levels. RFID-embedded loyalty cards already exist, and these cards have been shown to be effective in generating data about a customer's purchasing habits, among others. However, stationary RFID tag readers with display do not seem like a feasible idea since customers are expected to pick up an item that they are even remotely interested in purchasing, walk to the nearest tag reader, and scan. On the other hand, as was experimented by Metro in Germany, these readers could be placed on all shopping carts. This may be an expensive option depending on the number of carts at the store and the security of these carts themselves since the customer's privacy and security could be violated when any of these RFID readers are compromised. Inaba also provides a mechanism to control inventory levels, but given the extensive literature in inventory control the proposed mechanism ignores the complexities associated with this process and is therefore neither novel nor effective in practice. To address issues related to customer privacy and security, he mentions that measures that prevent other customers from viewing the display screen need to be in place. As for the legality of simultaneously charging different customers different prices for the same item, he does not offer a solution.

We considered a few related publications that address some of the issues related to gathering information using RFID tags and utilizing this information to evaluate consumer preference and eventually to optimize the service rendered to customers. Given the recency of this phenomenon (using RFID tags to aid in service management), there are no standards nor time-tested frameworks that address several issues that are specific to this domain. In Sect. 3,

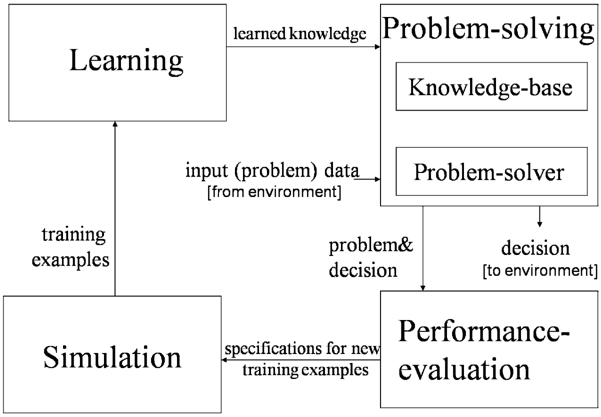

Fig. 1 The knowledge-based adaptive learning framework

we present our attempt to address some of these issues through an adaptive knowledge-based framework.

3 The adaptive knowledge-based DSS framework

The adaptive DSS framework presented in Piramuthu and Shaw (2009) is an example of an approach that integrates Design Science with Behavioral Science wherein the behavior dynamics of the system can be evaluated through interactions with users and organization in general. This generic adaptive DSS framework (Fig. 1) contains four main components that work in concert to effectively render its adaptive capability: Learning, Problem-solving, Simulation, and Performance-evaluation. These synergistically work together to deliver a framework that benefits from the combined strength of each of its individual components. The considered framework incorporates learning, simulation, and performance evaluation mechanisms.

While the considered framework can be used for decision support in most environments, it is most beneficial in dynamic environments and problem-solving situations where generating optimal solutions in real-time is impractical due to the complexity of the problem and solution spaces of interest. These include for the most part cases where the problems are known to be hard (e.g., NP-complete) and heuristics are the primary, if not the only, means to generate good (i.e., satisfying) solutions that are usable in such resource-constrained and complex environments.

The adaptive knowledge-based system operates by learning to automatically respond to any given snapshot of ambient conditions and operating environment. This is accomplished by the various components that act in consort to synergistically and seamlessly operate in a dynamic environment. The Problem-solving component uses the knowledge-base and the problem-solver to determine the most appropriate course of action at any given point in time. The Learning component is instantiated whenever deficits in knowledge is found, as evident from the overall performance of the system. When such deficits are identified, the Simulation component is instantiated to generate appropriate examples for the Learning component to learn and update missing knowledge. The primary purpose of the Learning component is to learn the patterns of interest in the system. Almost all real-world knowledge-based systems operate in dynamic environments where knowledge in the knowledge-base can not remain static. I.e., unless the system operates in a completely static environment, the knowledge-base needs to evolve as the operating environment and the system evolves over time. This adaptive knowledge-based system is, therefore, able to adapt and operate in highly dynamic environments.

3.1 Consumer preference mining framework with RFID

An important objective of consumer preference data mining involves the use of technology to attract new and profitable customers as well as forming tighter bonds with existing ones. The capability to observe and understand customer preferences is of paramount importance for a firm to develop an effective strategy. The existence of consumer preference has been widely acknowledged in academic literature from different disciplines. For instance, Carpenter and Nakamoto (1989) show that consumers form preference not only in a mature market but also on new products that have "pioneering advantages." Dynan (2000) evaluates household data on food expenditures and finds evidence for habit formation.

Consumers not only form preference on items sold but also on shopping behavior. Bell and Lattin (1998) show that brick and mortar shoppers with "large basket" are more likely to benefit overall from everyday low price than other marketing strategies. On the other hand, shoppers with a relatively short shopping list may prefer occasional deep promotions. Assessing consumer preference is critically important for practitioners to fully understand and utilize this consumer preference information in the market. Consumer preferences on price and other easily quantifiable product attributes have been studied extensively. Other preferences, such as environmental attributes, related to a product's production are often difficult to assess, but nevertheless may have important welfare implications for certain consumers. Wessells et al. (1999) evaluate consumers' possible acceptance of an eco-labeling program that integrates environmental attributes for seafood products based on a contingent choice survey in which respondents chose among a variety of certified and uncertified seafood products.

Overall, despite extensive importance assigned to it in related business disciplines, customer service quality management with fine-granular information enabled by modern identification technology such as RFID has not been studied until recently. We consider RFID technology, consumer preference assessment, and computerized adaptive learning mechanism to develop an effective customer targeted service management framework. In what follows, we present an adaptive knowledge-based framework utilizing RFID-generated fine-granular information for service quality management.

3.1.1 Knowledge-based operational dynamics of consumer preference and service provision

Figure 2 illustrates the knowledge-based operational dynamics of consumer preference and service provision with RFID data acquisition and consumer preference learning. Consumers in the market form preferences on items, and these preferences have a direct influence on their shopping behavior. At the same time, marketers carefully estimate the value of the market and adjust as well as target their products to appropriate groups of consumers. Transactions are made during some of these interactions between customers and marketers. Information from transactions as well as non-transaction information are collected and learned to form a knowledge base on consumer preference that is further utilized to design an effective customer service strategy.

While the objective here is to retain maximum customer patronage, fine granular information acquired through RFID-generated data provides more accurate and useful decision

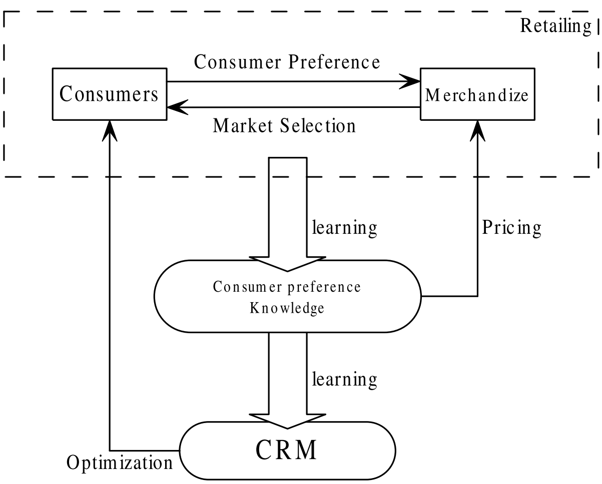

Fig. 2 Consumer preference analysis & knowledge management with RFID

support for the marketers than those obtained through traditional (relatively coarse) information collection methods.

3.1.2 Adaptive knowledge-based system on consumer preference & service management

Figure 3 presents the proposed knowledge-based framework for consumer preference and service management using RFID-generated data. Traditionally, stores have obtained information about customers through several means including non-transaction data (surveys, telephone/fax/mail/email inquiries, complaint logs, cookie logs when the customer visits the store's Web site) and transaction data (order information tracked when a customer uses a loyalty card). We assume all these to be present. In addition, we introduce RFID-generated item-level information data to aid in decision-making with the ultimate goal to improve customer service.

This framework evolved from the one presented in Piramuthu and Shaw (2009), with the specific needs of consumer preference measurement and RFID-generated information taken into account, and can readily be mapped to the earlier (Piramuthu and Shaw) framework. For example, the *Data Mining & Learning* module maps to the *Learning* module in the Piramuthu and Shaw framework. The operationalization inside these modules are quite similar in that they both extract usable patterns from input data. The *Measurement & Evaluation* module is a submodule within the *Data Mining & Knowledge Discovery* module and, again, it serves the same purpose in the proposed framework as in the earlier framework. Similarly, the *Simulation* module performs the indispensable service of generating example input data that are otherwise not readily obtained in day-to-day customer service scenarios. The *Recommendation System* in the proposed framework maps to the *Problem-solving* module in the earlier framework, and their overall general purpose is similar. The *Knowledge-base* module is modeled separately in the proposed framework since it encompasses additional features and can be used to generate ideas for service and/or product development and customization purposes.

Similar to related systems in extant literature, we assume the existence of RFID-embedded store-issued loyalty cards that the customers carry with them when visiting the store. A reader at the store entrance reads these cards as customers enter and leave the store. This provides data on the time that any given customer spends inside the store during any

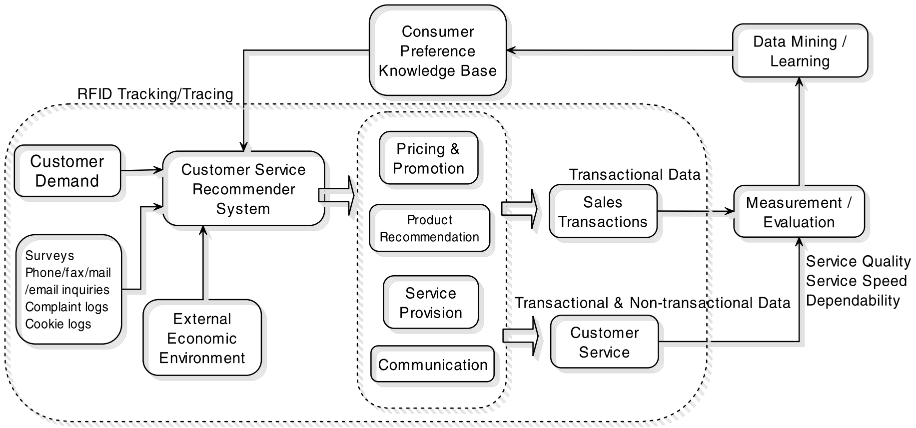

Fig. 3 Adaptive knowledge-based system on consumer preference & service management

given visit. The store is also assumed to contain RFID readers in all its carts and shelves so that a customer is always in the field of a reader at all times when inside the store. Issues related to collision due to multiple readers simultaneously attempting to read a card are not considered, and are assumed to be taken care of through other means (e.g., Piramuthu 2008). We also do not consider security/privacy issues here since this is an extensively studied area (e.g., Kapoor et al. 2008). These readers are assumed to be able to accomplish at least the following when the customer is inside the store: (1) identify the (approximate, to a reasonable degree of accuracy) location of the customer at all times, (2) identify the items that are present in the cart at all times including those that were placed and later removed from the cart, (3) identify the items (on shelves) that are in the proximity of the customer at all times, and (4) be able to compute the time duration that the customer spends at each location of the store using the above three.

In general, data about customers are generated whenever customers interact with the store through the store's Web site, a call center, a retail outlet, a response to a promotion, etc. These data are usually stored in operational databases that are designed for speed rather than for data analysis purposes. In most cases, the focus of these databases is on fast response to queries and keeping the delays to a minimum while interacting with customers. Therefore, historical data are usually archived elsewhere or destroyed. Padmanabhan et al. (2001) identify differences in results using data from user's side vs. log data obtained from customer's visit to the store Web site.

The most critical feature of any customer service management solution is the ability to transform customer data, collected from a wide variety of sources, into the type of detailed customer information around which a company can organize its enterprise and build its customer relationships. In the proposed framework, (transaction, non-transaction, and RFID-generated) data collected in the system are first cleaned and pre-processed to remove noisy data as well as to format the data in a form (e.g., feature selection, feature construction) that is conducive to extracting useable patterns in the data. The cleaned and pre-processed data are then used as input for data mining and knowledge discovery, including the process of association rule mining. The useable knowledge extracted from this process is then stored in the system knowledge-base. The knowledge-base also contains domain knowledge on the products in the store as well as the store layout. The knowledge-base can then be used to generate ideas for service and product development and customization. The requirements matching engine matches recent transaction data with related knowledge in the knowledge-base to generate customized promotional offers including coupons, discounts, additional store hours for premier customers, among others.

Several advantages can be realized using RFID-generated data in customer service applications. For example, the following exemplifies potential improvements in information content of knowledge used for service decision-making in a retail store setting.

– *Departure/arrival time information*: It is widely accepted that the longer a customer stays in a store, the higher the likelihood for the customer to purchase (more) items. The store personnel could, therefore, study the purchase, behavior, and demographic characteristics of customers who spend more time at the store and try to accentuate store characteristics that would entice the customers to stay longer in the store. The actual time of day (e.g., 8 A.M.–8:10 A.M. on a Wednesday) and duration could also be used to appropriately target customers for promotional offerings.
– *Instantaneous location of customer information*: For example, if the customer stood next to some item for a long time but left the store without buying that item, this customer may be provided with necessary coupon(s) for the item of interest. Knowing this information, the customers could be targeted with appropriate instantaneous dynamic pricing as well as coupons for their next visit to this store.
– *Instantaneous shopping cart information*: same as above.
– *Information on items considered but not purchased*: When a customer picks an item from a shelf but puts it back without purchasing it, it is highly likely that the customer was unsure of his/her decision to purchase this item. The store could offer some promotion (e.g., discount, coupon) to facilitate the customer's decision to purchase this item either right away or during the next visit to this store. The store can also, maybe, target a few carefully chosen items that are in the cart for additional discount.
– *Information on customer response to promotions*: These promotions can be instantaneous based on RFID-generated data. The response from the customer to such a promotion can be monitored and learned to fine-tune the promotional offerings custom-tailored to each customer.

4 Customer service optimization with consumer preference measurement

The goal of high quality customer service is to create an overall view of all interactions with customers in order to maximize the lifetime value of customers for the business practice through pre-sales, sales transaction, to post-sales services. These customer interaction functions may include marketing, sales, order processing, service and support. It is critically important that the firm is able to provide a high rate of successful service in a relatively short time period. An RFID-supported IT system is able to improve both successful service rate and service time by providing instantaneous item-level identification information. Moreover, after decades of evolution, modern customer relationship management implementation focuses on the integration of the customer front-end systems with entreprise back-end systems to gain extensive knowledge of every individual customer. The business intelligence associated with RFID system naturally fits this domain by facilitating data collection, data mining and managerial control through generated recommendations.

We view customer service management with matching consumer preference from three different perspectives: the corporate level, the customer level, and the functional (process) level. The corporate level represents the service practice for the entire organization from a big picture perspective including those of supply chain management through extensive low-level information about customers and their preferences. The customer level represents the interaction with customers through all contact channels. At the functional level, it considers the set of processes to fulfill customer services such as sales automation or post-service support. We consider the implications of using RFID-generated item-level identification data in customer service from a functional level (as is discussed in the next section) to the strategic corporate level.

4.1 Functional analysis with item-level identification

In general, not limited to retailing industry, with RFID refined item-level information visibility and its potential for analyzing consumers' preferences, managers in charge of customer relationship are able to enhance customer satisfaction by improving the time taken for customer service as well as the quality of such service. Such service improvement could be easily accomplished through easier information communication thanks to RFID's real-time operational information. With RFID-generated fine-granular information, business practitioners could also achieve better consumer preference discovery, more accurate anticipation and consequently more efficient return acceptance, better market selection and more efficient service provision. Theoretically, superior endogenous service quality could be achieved without limitation on time, which could be used to enhance customer service, to study customers' preferences.

With technology and resource limitations in practice, customer service provision has to find the balance among critical factors such as service speed, intrinsic quality, and dependability. Modern information systems/technology provides the capability including RFID-enabled item-level real-time information to be able to improve overall customer service quality through improved service rate, service quality and enhanced customer/business intimacy. RFID can help improve the efficiency of business information communication, thanks to its touchless real-time identification and automated data acquisition capabilities. Service time can be greatly reduced with RFID as well. For example, compared to bar code based matching/searching mechanism, RFID reduces the product search time for customers. RFID also helps business practitioners enhance relationship with their customers by reducing response time through better understanding of their customers' shopping behavior and preference (Zhou et al. 2009).

Customer service speed is primarily constrained by service quality requirement. In general, the higher the service quality standard, the longer it takes to fulfill the requested service. A high quality customer service process starts from a good understanding of the customer of interest, followed by carefully choosing the solutions, then the service implementation and follow-up. From a lower-level perspective, a complete customer service process can be seen as a series of small tasks. The probability of successfully completing each segmented task ranges from zero to one and is subject to the service quality requirement constraints. In general, the higher the required quality the lower the probability.

Tolerance on time that is needed to fulfill customer services not only directly impacts the intrinsic service quality provision but also the service dependability that measures the rate of successful completion of the service up to the pre-set standards. With more accurate and refined information on a real-time basis, RFID is able to enhance the service dependability, which is another important factor. Dependability in general signifies the degree to which the service provider is able to meet the promise it has made to its customers. Real-time item-level information allows for enhancing service dependability in a way that uncertainty due to incomplete information during service provision can be reduced to a minimum. Zhou

(2009) developed a model to quantify the benefit of RFID-generated refined information compared to the base case of complete randomness. Refined item-level information reduces or even eliminates uncertainty in traditional business operations so that decisions can be made to achieve the maximum output. Dependability arises from the foundation of a set of events that are in general treated randomly. Information at finer levels of granularity generated using RFID tags can facilitate achieving superior dependability by strategically dealing with known events. If we denote the level of dependability as D, it can be formalized as:

$$D = \Omega[n, X, \psi(X), g(X)] \tag{1}$$

where X indicates the traceable factors that directly influence the output, $\psi(\cdot)$ represents the actions on X associated with a business strategy and $g(X)$ is the transforming function that maps the input to dependability. Dependability is more of the issue with uncertainty in business operations than with other factors such as service quality and rate, and RFID can reduce such uncertainty by rendering transparency in business processes.

Overall, service rate, technology level, intrinsic service quality requirement and the service dependability requirement are mutually dependant during service provision. Specifically, service time t can be considered as a function $t = f(\gamma, \theta, \phi)$, where γ represents the technology factor, ϕ indicates the service quality level and θ defines the service dependability requirement. A simple numerical example of service time improvement could help illustrate the comparison of RFID and bar code from the perspective of successful item search. It is known that RFID, due to its superior capability to provide real-time item-level information visibility, generally reduces the time it takes for a customer to find the product needed or for the vendor to locate the right product for the customer (Zhou et al. 2009). For this example, assume the probability for an individual consumer to find the right product to be approximately 30% during each attempt with bar code, which could be increased to 60% by implementing RFID tracking and tracing technology. If each try takes one time unit with normalization, it would take approximately 2.519 time units to ensure a match with 90% probability, which indicates improvement in service dependability. It would take 6.455 time units to reach 90% service dependability with bar code.

It should be noted that dependability relies on a high level of read rate accuracy. While RFID read rate accuracy has been recorded as low as 30% in some applications, it is safe to assume that this accuracy is fairly high in typical retailing environments. Competing techniques/technologies such as paper-based manual approach and bar code do not fare well when compared to RFID systems since they are rather challenging when it comes to automation. RFID read rate accuracy can also be improved with various technological improvements such as by increasing the transmission power, increasing the number of tags on an item, switching to efficient communication protocols, etc. Moreover, several studies have attempted to improve RFID read rate accuracy with minimal effort resulting in fairly successful outcomes (e.g., Tu et al. 2009; Tu and Piramuthu 2011 and the references therein). Given recent successful attempts at drastically improving RFID read rate accuracy through disparate means and the overall different focus of this paper, we do not concern ourselves with this facet of RFID systems. It is really a non-issue since the purpose here is to propose an adaptive knowledge-based framework and study related dynamics present in such a system.

Next, we generalize the above discussion in order to analyze the optimal service level in practice.

Model:

θ: [0%, 100%]—service dependability level
ϕ: $[\underline{\phi}, \overline{\phi}]$—service quality level
τ: $[\underline{\tau}, \overline{\tau}]$—service time
γ: $\{t_1, t_2, \ldots, t_n\}$—technology index
p: [0%, 100%]—successful service provision rate

We consider p as the successful service provision rate for each service attempt. Clearly, the higher the service quality requirement, ϕ, the lower the success rate to complete such a service. τ represents the service time. In general, with everything else remaining the same, the longer the service time the higher the probability of successfully completing the customer service. Service rate is the inverse of service time, such that $s = 1/\tau$. θ indicates the service dependability requirement that characterizes the overall successful service rate. The longer the time allowed, the higher the dependability, which can be modeled as the probability of successfully completing the service after a series of n trials (2).

$$\theta = \sum_{i=1}^{n} p \cdot (1-p)^{i-1} \tag{2}$$

As a result of (2), we are able to derive the total service time as a function of dependability and service provision rate (3).

$$\tau \simeq n = \frac{\ln(1-\theta)}{\ln(1-p)} \tag{3}$$

A simple form of the successful service provision rate that ranges from 0 to 1 can be defined to be positively related with technology level and negatively related with quality requirements.

$$p = f(\gamma, \phi) = \frac{\gamma}{\phi}$$

where $\gamma \in (0, \phi)$ represents the technological characteristics that indicate the level of convenience different technologies can bring into the service. The service quality in its normalized form is subject to $\phi \in [1, \Phi]$. Therefore,

$$\tau \simeq n = \frac{\ln(1-\theta)}{\ln(\phi-\gamma) - \ln(\phi)} \tag{4}$$

Figure 4 shows the topology of the relationships among service time, service quality, dependability and technological level. We use a weighted measurement to evaluate the overall service quality, which includes the intrinsic service quality, service speed and dependability. The overall service quality (Q) can be represented as:

$$Q = \alpha + \beta_1\phi + \beta_2\theta + \beta_3 f(\gamma, \theta, \phi)^{-1} + \epsilon \tag{5}$$

subject to:

$$\underline{\phi} \le \phi \le \overline{\phi} \tag{6}$$

$$\underline{\theta} \le \theta \le \overline{\theta} \tag{7}$$

$$\beta_1 \ge 0 \tag{8}$$

$$\beta_2 \ge 0 \tag{9}$$

$$\beta_3 \ge 0 \tag{10}$$

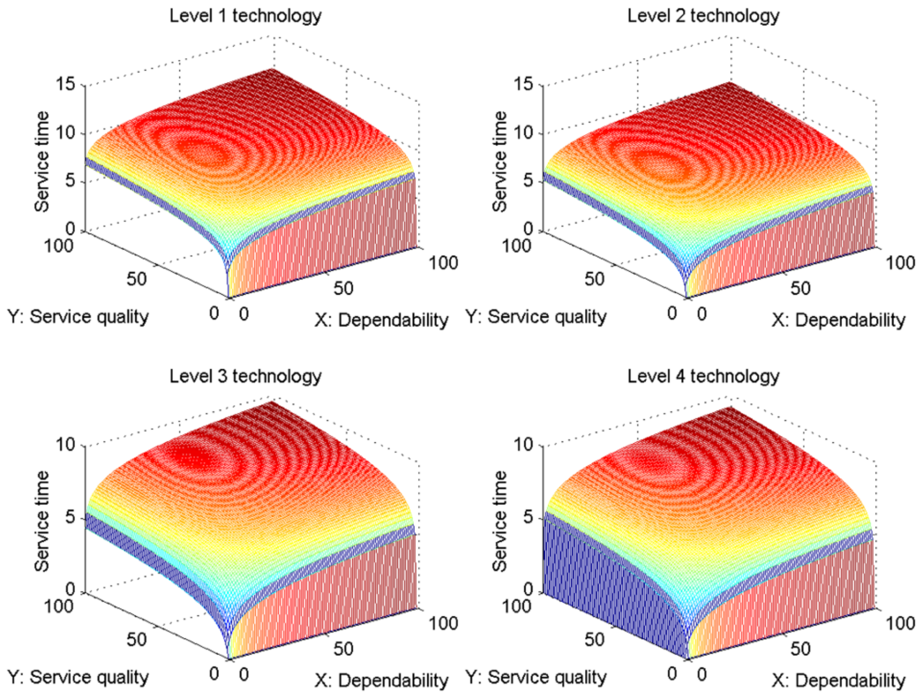

Fig. 4 Relationship of technology factor, service rate and service quality in customer service provision

We assume the overall customer service quality, Q, to take the form of a linear combination of service rate, service quality and dependability. In practice, depending on the characteristics of the scenario of interest, Q could be represented in different forms. Above all the overall customer service quality is a positive combination of all the three factors involved.

4.2 Managerial insights

Figure 5 shows the relationship between service time and service quality requirement to achieve certain quality level under different technology choices represented by curves A, B and C. C represents the most appropriate and efficient technology for the service of interest while it requires the least time constraints with the same quality demand. Pre-defined level of service quality requirement is enabled by the technologies selected. For example, customer service #1 can be successful only if it is implemented with C-type technology, while #3 service succeeds with any type of technology. Better understanding of the intrinsic characteristics of the service as well the properties of available technologies, which are well measurable in both practice and in a lab environment, enables business practitioners to make better decisions for IT infrastructure investment.

Furthermore, within the range of acceptable service rate, quality and dependability, the business practitioner can strike a good balance among the service parameters. Figure 6 shows the indifference curves between service rate and service quality based on different technological levels. For example, $\{\theta^*, \phi^*, \tau^*\}_A$ and $\{\theta^*, \phi^*, \tau^*\}_B$ would provide the same customer service satisfaction. Business practitioners can thereby customize their customer services based on the existing technological platform.

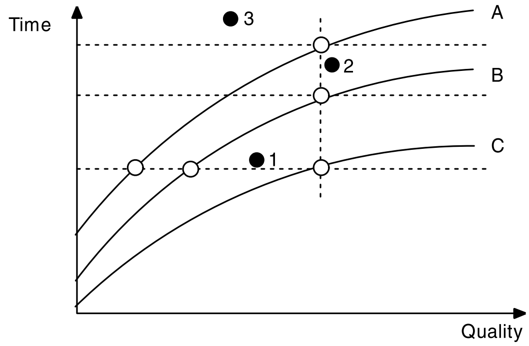

Fig. 5 Relationship between service time and service quality

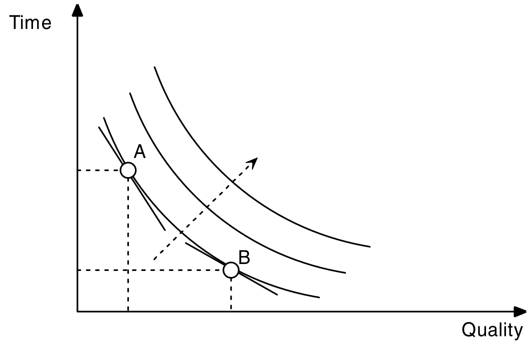

Fig. 6 Indifference level of service rate and service quality with different technology levels

Given that RFID solutions provide refined information on both customer and physical assets in a wireless and instantaneous way, its appropriateness increases when business demands high service speed, dependability and quality. With a simple linear relationship among different factors related to customer services, Fig. 7 illustrates the general trends in such an environment. The shaded area indicates the feasible region to adopt RFID solutions. It shows that RFID solution is more demanded in those industries with higher service quality, dependability or service speed demand.

At the strategic level and under the generic framework of traditional customer-based marketing metrics, when customers' life value is considered through several factors such as the acquisition rate, average inter-purchase time (AIT), retention and defection rate, life time duration and win-back rate among others, we find that refined item-level identification information on both customers and physical goods has the potential to boost the life-time value from prior calculations. The source of these arises from two primary dynamics: one of these is that item-level identification information provides more accurate and timely information about the customers and their preferences so that the acquisition rate can be improved; the other is that these improvements can be accomplished while simultaneously not compromising on service quality (or can even be improved, Fig. 4) and improving retention rate, win-back rate and life-time duration. Although intuitively it's clear that accurate knowledge of customers and their preferences would result in higher value using traditional marketing metrics such as Recency-Frequency-Monetary Value (RFM) or Share-of-Wallet(SOW), there is a need to study the dynamics of such low-granular information.

Following earlier discussion on possible benefits RFID and how refined identification information could result in better management of customer relationship, if we consider cus-

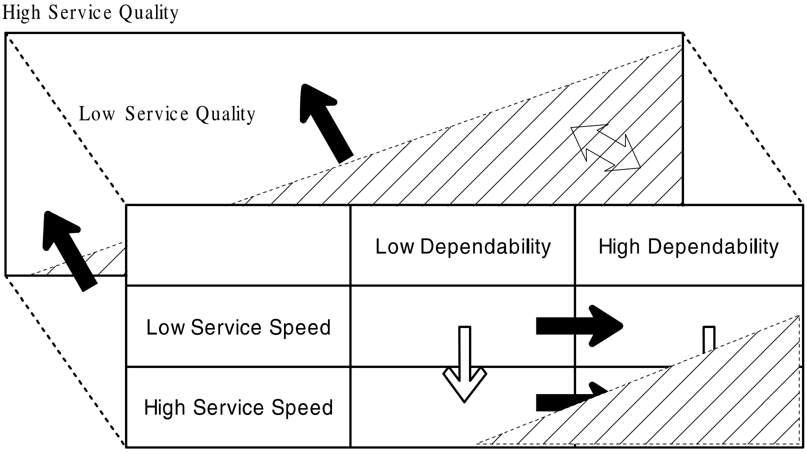

Fig. 7 Suitability of RFID solutions for customer service optimization

tomer lifetime value as the guideline for formulating and implementing customer-specific strategies for maximizing customers' lifetime profits and extending their lifetime relationship duration, we have (11) for the ith individual customer

$$CLV_i = \sum_{t=1}^{T} \frac{\Pi_{it} - C_{it}}{(1+d)^t} \tag{11}$$

where i and t indicates the customer index and the time index respectively. Π represents the future contribution margin from the customer and C represents the future costs, which comprises both the marketing cost and the marginal cost of using RFID. As the unit cost of RFID decreases with technological advances as well as its increasing popularity and therefore volume of demand, we find that the potential benefit in customer's future contribution, Π, increases asymmetrically.

5 Discussion

RFID has garnered much attention from both industry practitioners and academic researchers recently thanks to its advantages in being able to render fine-grained item-level information. Its additional value and potential applications in consumer targeted service management are still being studied. We used a generic dynamic knowledge-based DSS framework to develop a framework for consumer targeted service optimization incorporating RFID-generated data. We considered some possible potentials in utilizing RFID tracking/tracing identification technology to gain refined and better information about consumer preference, which in turn can be beneficially utilized as input for effective strategy design. With refined information on (1) time and duration of consumers' shopping activities (2) shopping cart details and (3) customized promotions, we show that marketers can develop effective strategies using the proposed adaptive learning mechanism. The artifact renders it easier to consider the crucial components in the proposed system.

We considered the proposed framework with item-level RFID-generated identification and related information by analyzing its potential benefits and its implementation conditions. Three major service parameters (service rate, quality and dependability) are taken into consideration and the results show that technologies such as RFID enable business practitioners to achieve superior customer services that can't be reached with traditional approaches. Our analysis also support the decision maker in choosing an appropriate balance among service rate, service quality and dependability with RFID-generated item-level identification information.

While traditional practice in this field has been operationalized with class-level information since instance-level identification data were not available, the introduction of RFID tags on items facilitates the generation and use of instance-level identification information. Retailing service benefits through mass customization enabled by recent developments in the ability to capture and use instance-level information. Recent advances in auto-ID technologies such as RFID and related back-end systems provide necessary support for operationalizing customer service based on item-level identification information. Given the ease with which enabling technologies are adapted by competing firms, there is an urgent need for these firms to differentiate themselves from their competitors through means that are not easily transferred. The use of item-level identification is one such where products are uniquely identified along with the customers and these information can be beneficially utilized by retailers to gain competitive advantage, among others. The adaptive knowledge-based system for consumer targeted customer service provision presented in this paper is a step in the direction of utilizing such fine-level identification information. More studies are needed to identify other opportunities for utilizing RFID-generated item-level identification data covering various facets in retailing and retail customer service.

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