

To Sell or Not to Sell

Determining the Trade-offs Between Service and Sales in Retail Banking Phone Centers

O. Zeynep Akşin

INSEAD, Fontainebleau, France

Patrick T. Harker

The Wharton School, University of Pennsylvania

This article explores the trade-offs between service and sales in phone center operations in retail banking and develops an analytical approach to quantify the costs and benefits of moving toward a sales-focused operation. Empirical evidence from retail banking call centers is provided along with a numerical example demonstrating the use of the analytical approach in the context of one major retail banking call center. It is shown that in addition to its visible costs, such as training and technology to build support systems for sales activities, cross-selling can have detrimental effects on customer service due to the additional load it creates on the system. It is further demonstrated that designing the right process and adopting human resource practices that support this design are critical in determining the success of a cross-sell program.

Call centers, also known as phone or customer service centers, have become one of the most important delivery channels for service firms throughout the world. In these centers, customer service representatives with direct access to their firm's databases and applications provide service to customers over the phone. Whereas for some companies call centers take on a support role next to a major physical

delivery network, for others it is the sole delivery channel that constitutes the firm's entire customer interface. The recent decade has seen a growing focus on phone centers as alternative low-cost service delivery channels across a variety of industries. This growth has in part been enabled by developments in telecommunication and information technology that have allowed phone centers to route incoming calls to the appropriate agents, to perform standard queries or transactions automatically in voice response units (VRUs), and to access and update central customer databases, thereby enabling the online performance of many transactions.

Thus, call centers have emerged as a major part of the service strategy for the financial services industry and all customer service operations. The size of call center operations is phenomenal. In the United States, the number of call centers is estimated to be anywhere from 20,000 to 350,000, and they employ anywhere from 4.0 million to 6.5 million people; in the United States, there are more people working in call centers than in the entire agricultural sector. Annual expenditures on call centers are estimated to be between \$100 billion and \$300 billion, with anywhere from 50% to 75% of this cost being devoted to labor. Similar growth of call center activities is occurring in Europe and Asia.

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Throughout the financial services industry, call centers are being recognized as a critical delivery channel, helping firms to keep existing customers, expand their business, and control costs ("Banks Using Call Centers" 1995). Today, the traditional role of call centers as question-and-answer bases for customers still is a strong motivator for their existence. There is, however, a growing tendency to blend sales-related activities with the traditional transaction-based activities at financial service firms' phone centers. Many institutions view turning a service request into an opportunity to sell additional products as the key to a successful phone center operation. Whereas service-oriented businesses beyond the boundaries of the financial services industry are experiencing a similar proliferation in call centers, the dichotomy of a service center and a sales center is much more apparent in this setting. In particular, we see that phone company operators or Internal Revenue Service centers predominantly engage in customer service-oriented transaction processing, whereas retailing phone centers, such as L. L. Bean, remain as pure sales organizations. The desire to fully blend service and sales in a call center operation seems to be unique to the financial services industry.

The move to sales elsewhere in the financial services industry has been ongoing for some time. Focusing on retail banking, one observes that sales is a relatively new concept. Increased deregulation in the industry has led to growth in competitive pressure, which in turn has forced bankers to incorporate sales into their daily operations. The past decade has seen a growing number of banks implementing cross-sell programs across their branch networks in an effort to become sales-driven organizations. The objective of cross-sell programs is to increase the number of products and services sold to existing customers of a bank. Today, these sales efforts in the branches are being extended to alternative delivery channels, a major one of which is the phone center. Drawing on experiences of 55 marketers in banking, Wright (1991) identifies a list of common roadblocks between resources and sales in banking. Lack of management focus, poor hiring practices, lack of training, ineffective organization for marketing, poor service, and not knowing customers or products are only a few of these barriers mentioned by Wright. The basic motivation of the present article is to identify some of these roadblocks in the context of retail banking phone centers as they move forward with their own sales initiatives. It will be shown that the nature of phone center operations makes them extremely susceptible to the increasing and changing resource needs of sales organizations. In this article, a tool is proposed that will help to identify and manage some of the major trade-offs between resources and sales in phone centers.

To provide a more detailed sense of the backdrop that motivated this research, a snapshot of retail banking phone centers is provided in the next section. The specific questions that are addressed in the research are posed in this section. This is followed by a brief review of some related literature. The analytical approach that is used to characterize the trade-offs between service and sales in phone centers is presented in the subsequent section. Then, the situation at a specific phone center is described, followed by a numerical analysis. Further empirical evidence for the results is then provided. The article ends with a discussion of the results along with future research directions.

A SNAPSHOT OF CALL CENTERS IN RETAIL BANKING

This section presents data obtained from a study of the retail banking industry undertaken by a team of researchers at the Wharton School of the University of Pennsylvania. After a detailed description of the overall study and the data, the discussion focuses on specific data from retail banking phone centers. These data are used to illustrate how the desire to blend service and sales in call centers is being operationalized across this section of the industry. Questions that the current article strives to address are derived from the analysis of these data. (A description of the data collection process can be found in Appendix A.)

Responses from the 49 phone centers in the largest bank holding companies in the United States are considered in the numbers that are reported in what follows. Only one of the banks reported having no phone center, and the number of phone centers within the holding company reported by the remaining portion of the banks ranged between 1 and 25. The bank with no call center at the time the survey was administered commented on an existing pilot to become operational shortly. This clearly supports the claim made by industry experts that call centers have become a major alternative delivery channel to the traditional branch networks. There is a lot of variation in size between the different call centers. In terms of full-time equivalent employees (FTEs), the average size of the call centers in the sample is 127 FTEs, ranging from 6 to 2,000. Average daily call volumes vary between 275 and 650,000.

For accounting purposes, 90% of the banks in the sample consider their phone centers as cost centers, and 10% consider them as profit centers. Only 39% view their phone centers as sources of revenue in formal accounting, implying that the majority of banks view their phone centers as necessary costs. Revenue credits more frequently are given to sales generated than to transactions processed at the centers. The data indicate that, on average, 65% of

the total calls at a center are handled by VRUs (which provide fully automated service through a menu driven interface), and 35% are handled by phone representatives. It is well known that the cost of a call handled by a VRU is much lower than that of a call handled by a service representative, which indicates that most phone centers are choosing the lower cost VRU channel.

To assess the way in which these phone centers evaluate their performance, a list of 12 performance measures was provided, and the respondents were asked to rank the top 5 measures. Averaging these ranks across the banks, one observes that the time to answer a call, abandonment rates, and sales rank as the top three measures of performance in these phone centers. Thus, even though the traditional customer service measures (e.g., time to answer, abandonment rates) rank higher in importance, sales is a close third in determining the performance of a center. Focusing on sales activity in these centers, one notes that, on average, 64% of full-time phone center representatives regularly do sales referrals. In addition, 53% regularly take inbound sales-based calls, and 17% perform telemarketing or outbound sales calls. In other words, on average, more than half of the full-time service representatives engage in some sort of sales-related activity, confirming the belief that sales activities constitute an important part of work at retail banking call centers. There is some effort to support sales activity with technology. On average, 32% of the phone centers provide online cross-sell support with prompts to phone representatives. In 49% of the centers, the service representatives can access product information and pricing displays online. In 77%, the representatives can perform household inquiries (for multiple accounts) online.

Looking at this snapshot from the industry's phone centers, one can see the emergence of the following picture. The majority of the call centers are designed for cost efficiency. This is quite natural given that banking call centers still are mostly viewed as cost centers in formal accounting and are not given revenue credits for transactions processed or sales generated. Simultaneously, the majority of these call centers are striving to increase sales-related activity through their centers. A large portion of service representatives engage in sales activities, but still less than half of the centers provide online cross-sell support. The natural question to ask at this point is whether these two goals are compatible. Can one design a call center operation that is low cost, achieves the high service standards desired by most banks, and generates sales revenue at the same time? It is this basic question that is addressed in this article. The trade-offs that need to be considered among these somewhat conflicting goals are characterized and an analytical approach is developed to enable a formal comparison of the costs and benefits of a sales-oriented operation.

The survey data further indicate that different call centers organize differently. When asked how work is divided up in the call centers, 60% of the centers responded that all customer service representatives can take all requests, and 40% indicated some specialization by task or category of call. In the centers that reported service representative specialization, on average, 45% of the specialized agents could perform some tasks outside their specialties, 30% could perform all tasks outside their specialties, and 25% could perform no tasks outside their specialties. Thus, one can differentiate between call centers where service agents specialize or do not specialize. Among those that do specialize, there is a different degree of cross-training, indicated by the percentage of phone center representatives who can handle calls outside their own specialties.

This discussion implies that there are multiple ways of organizing work in call centers, which in turn indicates different responses by the centers to become sales driven. In the current article, several ways of blending service-sales culture in call centers are analyzed in conjunction with the earlier posed question of whether service and sales are compatible within a call center. The analysis does not attempt to prescribe the right choice of work organization that supports a call center operation blending service and sales. It does show, however, that work organization has an observable impact on the performance of a cross-sell program and can, in some plausible cases, make the difference between a program that is a success and one that is not.

LITERATURE REVIEW

A strong transition to a marketing orientation in banking is seen as early as the 1970s (Rathmell 1974). As noted earlier, this emphasis on marketing has demonstrated itself through sales programs in branches during the 1980s and 1990s. Bank marketers cited in Wright (1991) emphasize the importance of cross-selling in successful bank marketing and report on anecdotes of success in cross-sell programs in their institutions. Richardson (1984) provides guidelines and suggestions for successful implementation of sales initiatives. Johnson and Seymour (1985) study a retail bank before and after a cross-sell program has been initiated across its branches. The program is demonstrated to have improved both sales effectiveness and the number of services sold per sale at the bank. The authors further analyze customer perceptions of this conscious sales effort. It is shown that even though customers are, in general, not dissatisfied with the sales activities of tellers, their responses indicate a need for better implementation in terms of making the sales presentations less mechanical.

Similar to the Johnson and Seymour (1985) study, the analysis in this article focuses on identifying some of the

effects of increased sales activity on customer service in phone centers. Rather than surveying customer perceptions, the focus here is on proposing a methodology that will help to quantify the effects on specific customer service measures identified by call centers. Whereas it is believed that banks can transfer some of their sales knowledge from branches to their call centers, certain characteristics of call center operations indicate some differences that might play a critical role in determining the success of a cross-sell effort. In particular, it is demonstrated in the following section that there is a close tie between capacity and customer service quality in a phone center. Given the current desire to design low-cost call center operations across the retail banking industry, it is clear that resources typically will be allocated with cost minimization in mind, making congestion-related consequences of sales a major determinant in evaluating success. This observation justifies the need to extend the existing work in the literature on sales programs in branches to the call center environment.

ANALYTICAL APPROACH

In this section, the analytical approach that is used to assess the impact of increased sales activity in a traditional service center is described. This approach attempts to explore the issue of compatibility between service and sales, raised earlier, when viewed from an operations standpoint. Specifically, consider a call center that is primarily designed for low-cost, high-quality customer service. This type of a center will strive to keep customer wait times at a minimum, thereby reducing the number of abandoned calls, or calls in which customers hang up due to long waits, while achieving these goals with the smallest number of well-trained service representatives as possible. What happens when increasing sales revenue generation becomes part of the mission statement at such a customer service center? Initially, there is a stage when some or all service representatives are trained to become proficient in sales-related activities. Then, cross-selling, or selling more products and services to a retail customer once this customer places a call, slowly becomes part of the regular activities at the center. If the phone center personnel are successful in selling additional products and services over the phone, then the bank will begin to experience increases in the revenue generated through its call center. These would not be the only changes, however. A closer look will indicate that simultaneously, one would expect the average talk times, or the time a service representative spends on the phone with a customer, to increase as more sales-related activities are incorporated into a call. Similarly, as sales-related calls are forwarded between departments, the

effective call volumes experienced in certain parts of the call center will increase. This type of call forwarding is hard to avoid in an environment where product and service variety growth has led to specialization among agents, thereby requiring a different agent for a different product or service. The increase in average talk times and effective call volumes, in turn, will translate into an increase in the congestion at the center. Thus, it will result in increased wait times and abandoned calls. Management will need to respond with additional staffing and information processing resources to avoid deterioration of service quality at the center. The latter need will be particularly significant because most existing systems are designed for the capacity needs of a transaction processing center.

This loose description of the transition from service to sales in a call center highlights the presence of multiple trade-offs. Although this type of a transition promises increased revenues, it also indicates additional costs in the form of training expenses, information technology upgrades, and staffing levels that can match the much higher loads experienced in a sales environment. Any choice pertaining to the mix of service and sales activity in the center is contingent on the magnitude of the trade-offs laid out in the preceding discussion. Using the performance model that is described next, one can quantify the magnitude of these trade-offs.

The Performance Model

In Akşin and Harker (1998a), a model for the operations of a phone center is developed, providing a relationship between capacity choice and system performance measures that can then be used to determine the relationship with system revenues. Resources that jointly determine capacity are human resources in the form of service agents, telecommunication resources as phone lines and VRUs, and information technology resources. A specification of these resources at a call center along with characteristics of incoming call volumes lets the model determine performance measures such as the probability of receiving a busy signal when placing a call and the probability of hanging up due to excessive waiting while on hold.

For a detailed analysis of the model, the reader is referred to Akşin and Harker (1998a). In what follows, sufficient detail is provided to illustrate how this performance model can be used in evaluating cross-sell programs in a retail banking phone center. All technical details can be found in Appendix B.

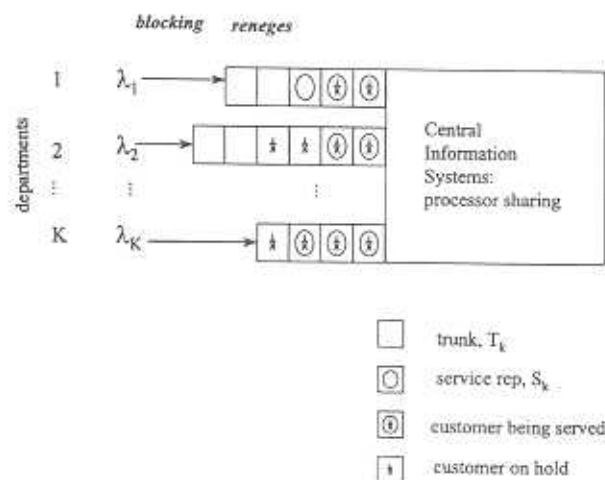
The phone center, as shown in Figure 1, is organized around K departments, each of which specializes in a group of products and services. Customers arrive at the various access channels with an arrival rate of λ_k in channel k ,

where arrivals in each channel are independent of each other and the arrival process is assumed to be Poisson. On arrival, each call needs the presence of an available phone line. There are T_k phone lines in access channel k . If all lines are busy, as in department K of Figure 1, then the customer will receive a busy signal and leave. The calls that receive a busy signal will be labeled as blocked calls in the ensuing analysis. There are S_k customer service representatives in access channel k (VRU channels have only trunks and no service representatives). A call will start being served immediately if both a phone line and a service representative are available on arrival. This situation can be seen in Department 1 of Figure 1. If a phone line is available but all customer service representatives are on the phone with other customers, as depicted in Department 2 of the figure, then the caller is put on hold until a service representative becomes available. However, those customers that are put on hold do not necessarily wait until an agent becomes available. Some customers might exhibit impatience and leave the system while on hold before service initiation; this loss of customers is labeled as *reneges* or *abandonments*. Customers in channel k are assumed to renege according to an exponential distribution with rate α_k . In other words, α_k is the parameter that characterizes the impatience of customer calls of type k .

On service initiation, the service representative will need access to the information system. This joint pool of information technology is capable of processing all transactions from different customers simultaneously. This system can be considered as a single server that processes at a constant rate of 1 service unit per unit time. Notice that during times of high congestion, such central information systems respond with longer processing times. In other words, service times in the system are a function of the total number of customers being served in all channels. This characteristic is modeled as a processor-sharing service discipline in the model.

Assume that each customer in class k (with $k = 1, \dots, K$) has a service requirement that is exponentially distributed with an average of $1/\mu_k$. That is, on arrival to the system, each type of call will require a certain amount of processing that is distributed exponentially. If the call were the only call in the system, it would be processed with average duration $1/\mu_k$. Since the speed of the processor is normalized at 1, a faster processor will manifest itself as a smaller value for $1/\mu_k$ for the same type of call. Because the information processing resource is shared by all calls, and since it processes at a normalized rate of 1 service unit per unit time, each call will get only a fraction of the processing resources when there are multiple calls in progress. Thus, the service rate for a class of calls at any point in time will be a function of the number of calls of each type that are being served at that time. This rate is labeled as the *state depend-*

FIGURE 1
Phone Center Dynamics



ent service rate. The state dependent service rate for class k customers takes the form

$$\mu_k(\mathbf{n}) = \frac{\min(n_k, S_k) \mu_k}{\sum_{k=1}^K \min(n_k, S_k)}, \quad (1)$$

where $\mathbf{n} = (n_1, \dots, n_K)$ denotes the state vector with n_k being the number of class k customers in the system. The term $\min(n_k, S_k)$ represents the number of class k customers in service. Recall that a call can be in service only if there is an available service representative. Because there are S_k service representatives in class k , there can be at most S_k calls in service at any time. Note that the model assumes simultaneous use of the service representative and the information processing resource throughout the duration of the call. Whereas in its basic form, as considered in this article, it is assumed that the labor content and the computer content of a call are equal to each other, a modification of the state-dependent service rate allows for the case of call centers where the computer content of a call is less than its labor content. This case is discussed in more detail in Akşin and Harker (1998a).

Every call that is handled in the center is a potential source of revenue for the bank. Calls that are lost either because the customers receive a busy signal or because they are held on hold for a duration that exceeds their patience will not be handled at the center, resulting in a loss of potential revenues. Thus, to determine revenue losses due to congestion in the system, one would be interested in determining the probability of a customer being blocked on arrival as well as the loss that occurs due to renegeing. Blocking probability in channel k is denoted by $B_k(S, T)$. Reneges are the second source of customer loss. Denote

the long-run probability of renege for a customer of type k by $R_k(S, T)$.

A Framework to Evaluate Cross-Sell Alternatives

In the current context, calls that are not lost due to congestion-related effects determine revenues for the center. More specifically, this implies that knowledge of the characteristics of system throughput can be translated into a knowledge of the properties of average system revenues, assuming a given rate of revenue generation per customer call. The specific relationship among call center revenues, resource allocation (S and T), and call statistics can be expressed in terms of the performance measures derived earlier.

Using notation from the preceding subsection, the throughput in channel k can be written as

$$TH_k = \lambda_k(1 - B_k(S, T))(1 - R_k(S, T)).$$

Now, assuming a fixed average revenue rate v_k for calls of type k , total revenues in the system can be expressed as a weighted sum of throughputs,

$$\sum_{k=1}^K v_k \lambda_k (1 - B_k(S, T))(1 - R_k(S, T)). \quad (2)$$

It is this relationship that will be used in capturing the costs and benefits of different cross-sell scenarios in the phone center.

Two Delivery Channel Designs

As banks have moved to a call center paradigm that marries service and sales activities over the phone, different delivery channel designs have emerged, implementing this shift in thinking. A close look at these designs indicates the presence of two extreme models, with call centers in between having a mix of these two designs. To control for the impact of channel design on service and sales performance, the trade-offs of increased sales are analyzed in the context of these extreme cases.

The first case is an extension of the current service paradigm. A special sales department is established within the center, which deals with inbound sales calls only. Sales leads are generated in other parts of the phone center, either by all service representatives or by those in some departments. In other words, these service representatives will have the additional duty of trying to determine the customers who have a potential to buy new products and services and then to forward their calls to the sales department where the actual sales transactions will take place. This de-

livery channel design will alternately be called the *specialization* or *sales lead generation* scenario in the following discussion.

The additional time spent with customers on the phone trying to generate sales leads will translate into an increase in average talk times. This is equivalent to a decrease in the service rates for the performance model. Sales calls that are forwarded to the sales department will, in turn, affect call traffic experienced by this department. This part of the call center will see an increase in effective call volumes. Both of these changes will have an impact on system throughput, which will then translate into a change in call center revenues. In particular, an increase in average talk times will have a diminishing effect on the throughput of the department generating the leads by increasing congestion. Call forwarding will increase congestion in the sales department. A look at the throughput expression in Equation 2, however, indicates that it will simultaneously increase throughput in this department because the potential number of calls handled by this department will increase. The ultimate impact on the sales department will depend on the magnitude of these changes. The impact of any change in a particular department also will be felt by the other departments because all departments share the same information processing unit, which is expected to slow down under increased congestion. What becomes obvious from this discussion is that disentangling the costs and benefits of the sales and cross-sell activity is not an easy task.

Some call centers might prefer a delivery channel design in which all departments within the center are capable of handling both service and sales-related calls. This design is referred to here as the *nonspecialization* scenario. A specialized sales department still might exist but will handle only occasional calls that cannot be dealt with elsewhere. This design creates much lower call forwarding to the sales department; hence, in most cases, a much smaller specialized sales department will suffice. One would expect all departments involved in the sales effort to experience some increase in their effective call volumes, the magnitude of which depends on the degree of cross-training in the center. A center with more cross-training would imply customer service representatives who are capable of handling calls pertaining to different departments, which means that they would need to forward calls less. If they are trained to handle only a certain family of products or services, however, then selling a product outside this family would require forwarding the call to someone who is proficient in dealing with that type of call. The time that service representatives spend on the phone with customers in those parts of the call center other than the specialized sales department will increase significantly because one would expect the mixing of service and sales activities to increase average talk times. The impact of these changes

on system throughput and revenues can be established following a logic similar to the one for the specialization scenario.

Reflecting on the two scenarios, one notes that in addition to the differences in process, one would expect to see a different group of representatives within each call center. The specialist call center would have a group of people who specialize in service (with some additional training in sales) and a group of pure sales personnel. In the nonspecialist center, service representatives would have to be extensively trained in sales and be able to excel in both dimensions. These types of training costs need to be incorporated into a comparison of the two scenarios discussed. Differences in organizational culture and personal capabilities at these two types of call centers are not captured in the analysis of this article but constitute a major factor in sales program choice and implementation.

It is possible that for both scenarios, a change occurs in the average revenue generated per call as a result of cross-selling. The magnitude of this change would depend on the revenues generated per successful sales call divided by the total call volume, where call volume includes the internally transferred calls as well. Both anecdotal evidence from the field and data from the retail banking study described earlier indicate that revenue data are difficult to obtain and that only a few banks can actually estimate average revenue generated per call. This type of data probably will become more available as phone centers push forward with their increased sales agendas. For the current analysis, it is assumed that revenues per call remain the same before and after the sales effort. In other words, the differences in revenue among the various scenarios is due only to the differences in the volume of calls handled in each case. All results should be interpreted in the presence of this assumption.

In the analysis that compares the two scenarios, a distinction is made between a case that assumes no restaffing action taken by management as a response to the load increases created by sales-related activities and a second case that looks at the impact of sales given a restaffed center. Ideally, this type of a comparison for the latter case would be made for a center that has been optimally restaffed. For the current analysis, a heuristic restaffing action is considered. This analysis is meant only to illustrate that taking the right staffing action can make a difference in the end result of a sales initiative. To formally quantify the impact of sales on center revenues, one would have to compare optimally staffed centers. This is the objective of ongoing research.

The analysis in this article looks at the capacity implications of sales only. The methodology is proposed as a preliminary "what if"-type tool that will enable management to foresee some of the more tangible and quantifiable

aspects of increased sales activity in a call center. Other issues that constitute the sales versus service dilemma for banks, especially those pertaining to human resources, should be incorporated into any real evaluation endeavor.

SITUATION AT A MAJOR PHONE CENTER

In this section, the situation at one phone center of a major U.S. retail bank is reported based on data provided by this center. The phone center is the largest of four centers at the bank. Expressed in different variables, its size is approximately 200 FTEs and it has call volumes of approximately 6 million calls a year, approximately 200 "800 trunks" (i.e., phone lines) that are shared among six specialized departments where service is provided by service representatives, and approximately 150 "VRU trunks" in three separate VRU channels. In terms of the performance model described earlier, this means that there are nine access channels, six of which share their phone lines and three of which are fully automated VRU channels. Sharing 800 trunks translates into a change in the state space and is easily incorporated into the earlier analysis. In the VRU channels, reneging or call abandonment can happen during service because service occurs on the phone line. This difference, again, can be easily incorporated into the analysis of the performance model. No service representatives are needed for the VRU channels because service provision is fully automated.

One of the non-VRU specialized access channels in the call center is a sales department (Department 2). This department specializes in sales and handles all inbound sales calls for products and services that are sold over the phone by the bank. The remaining five departments (non-VRU channels) focus on service calls. As of October 1995, the center did not have an aggressive cross-sell initiative under way. Although management reports some cross-training of service representatives and optional training programs in cross-selling, a formal cross-sell program was not instituted at the time. Service representatives are encouraged to cross-sell whenever they can; however, they are not given incentives based on the number of sales leads they generate. Online technological support for cross-selling currently is unavailable. This picture indicates that the center has not embarked on an aggressive cross-sell effort as described earlier in this article; however, there are some activities that indicate a desire to move in this direction. Informal conversations with management support this observation. The next section describes how a cross-sell program may impact the current operations of the center.

Data availability to estimate parameters for the performance model are described next. Recall that model pa-

TABLE 1
September 1994 Average Abandonment Rates Experienced in the Call Center

	Department								
	1	2	3	4	5	6	7	8	9
Percentage abandoned	2.35	0.34	1.57	0.53	0.00	1.16	0.11	0.45	0.69

TABLE 2
Model Parameters for the Base Case

Department	Minutes/Day	λ (calls/minute)	μ (calls/minute)	α	Positions Staffed
1	43,200	4.350	0.48	5.46	23
2	29,700	1.500	2.80	0.75	6
3	28,800	0.495	18.00	5.00	2
4	19,800	0.900	8.00	3.33	3
5	11,400	0.300	28.00	2.86	3
6	17,100	0.375	6.00	2.50	5
7 (VRU)	43,200	9.000	0.75	6.00	132 (trunks)
8 (VRU)	43,200	0.300	30.00	6.00	12 (trunks)
9 (VRU)	43,200	0.750	30.00	6.00	7 (trunks)

NOTE: VRU = voice response unit.

parameters of interest are the call arrival rates λ_k , required service time rates μ_k , and abandonment rates α_k , with $k = 1, 2, \dots, K$. Given these parameters and data on the phone center configuration in terms of service representatives staffed in each channel and the number of phone lines, the model generates performance measures such as blocking probabilities and reneging probabilities in each channel.

Reneging rates, as experienced in the center in September 1994, are tabulated in Table 1. The center reports no blocked calls, which implies that blocking probabilities experienced at the center are zero in terms of the earlier terminology. Looking at these numbers (and similar average numbers for different months of the same year), one notes that, overall, the center experiences very low call loss. Average reneging probabilities, or abandonment rates as they are called in the center, are between 0% and 2% throughout the center. Although these numbers vary among channels, they mostly cluster around 1% abandoned calls.

For the most part, the data available to the authors consist of monthly and yearly averages for call volumes, talk times, and abandonment rates. This level of detail does not allow for a precise estimation of model parameters. To this end, detailed data for 1 day were obtained. These data included the number of calls, the total number of calls abandoned, the average abandonment time, the average talk time, and the number of positions staffed per 30-minute interval throughout that day. These data were available for all departments except the VRU channels. It is clear that estimates obtained by considering only 1 day of operation will yield a very crude idea of model parameters. Any

missing data at the 30-minute interval level are replaced by equivalent monthly or yearly average figures that further distort the quality of the estimates. These estimates are presented simply to give the reader a feel for the example.

A 1-day sample of data from September 1994 is used to estimate reneging (abandonment) rate parameters based on the average abandonment times in each department. Because these 30-minute data are not available for VRU calls, the abandonment rate parameters for these channels are assumed to resemble those in other parts of the center. The arrival rates, λ_k , are estimated using the average total number of calls for a peak 30-minute interval on this day. Because this particular day in September does not necessarily reflect the yearly peak for this center, the arrival rates are further multiplied by a constant of 1.5. The latter constant was determined arbitrarily. Given average talk times and the average number of calls in each channel (as an estimate of $n_k s$), one can obtain an estimate for the $\mu_k s$ from these 1-day data. Each department's working hours are converted to total minutes per day. All of these parameters are shown in Table 2.

Looking at average positions staffed in each 30-minute interval (as provided in the data), staffing levels matching the parameters estimated were obtained. The number of trunks was taken directly from the data.

The snapshot of the center obtained in this way was analyzed using the performance model. All results reported are computed using the Monte Carlo summation method as described in Akşin and Harker (in press). They are based on 750,000 iterations of this method. Importance

TABLE 3
The Two Cross-Sell Scenarios

	<i>Average Talk Times</i>	<i>Effective Call Volumes</i>
Scenario 1: Sales lead generation	10% increase in Departments 1, 3, and 4	20% increase in Department 2
Scenario 2: Nonspecialization	20% increase in Departments 1, 3, and 4	5% increase in Department 1, 2, 3, and 4

sampling is used to reduce the variance of the estimators. Blocking probabilities generated by the model are zero in all departments, indicating a match with the experience at the center of having no blocked calls. Similarly, abandonment rates generated by the model (as tabulated in Table 4 under the column labeled Base) are within the 0% to 2% range observed at the center and resemble the abandonment rates tabulated in Table 1. This analysis is not presented as a model validation or an exact representation of the center. However, it is argued that, in many ways, it is close enough to the actual situation at the center to be viewed as a realistic example from one phone center operation.

ESTABLISHING THE SERVICE VERSUS SALES TRADE-OFFS IN THE PHONE CENTER

What would happen if management decided to initiate a cross-sell effort in the center? An example is presented that illustrates use of the proposed analytical approach in assessing some of the impacts of such a move. The purpose of this analysis is not to derive a prescription for the center under study. This type of a prescriptive study would require a formal model validation stage, followed by a phase of close collaboration with management in evaluating all relevant "what if"-type questions extensively. The example in this section would constitute only one such speculative question. In addition to demonstrating how the model may be used to aid decision making at the managerial level, the objective of the analysis is to draw some generalizable conclusions for phone centers in retail banking embarking on new sales initiatives. In particular, it is used to illustrate that cross-selling could deteriorate both service and profit performance of a call center if it is not implemented in the right way and at the right level.

The data discussed in the previous section provide a base case for the situation at a phone center before embarking on a sales effort. The situation that emerges after a conscious sales effort is analyzed in the context of the two delivery channel designs described earlier. For the example under study, these two scenarios take the following form. The sales lead generation scenario, or Scenario 1, has Departments 1, 3, and 4 generating sales for the sales department, which is Department 2. The nonspecialization

scenario, or Scenario 2, has Departments 1, 3, and 4 adding sales to their regular servicing activities.

Given the current functionality of Departments 1, 2, 3, and 4 at the call center, their involvement in a sales program appears to be a realistic scenario. In the analysis, Departments 5 and 6 and the VRU channels will not be involved in the sales activity; however, they will experience the impact of this activity through the use of the shared processor. As described earlier, the impact of increased sales activity on the call center's operations will be captured through changes in effective call volumes and average talk times. The qualitative nature of these changes for each scenario matches the effects described earlier. The magnitude of the increases used in the examples are shown in Table 3. These magnitudes are arbitrary, and different magnitudes could easily be tested using the proposed methodology. Determining appropriate magnitudes would constitute a significant part of implementing this methodology.

Percentage abandonment or renege probabilities for the base case and Scenarios 1 and 2 are shown in Table 4 along with 95% confidence intervals. The first number in each cell denotes the point estimate for abandonment probabilities (the midpoint of the confidence interval) and has been added for easier readability. All intervals where the lower and upper limits are less than 10^{-3} have been denoted as (0, 0)* for compactness. Blocking probabilities remain zero throughout and, therefore, are not tabulated.

It is not surprising to observe that the sales activity can deteriorate the customer service measure that captures the percentage of abandoned calls, as illustrated by the case of Department 1 in the example. In general, the load on the center has increased, both through additional call volume and through longer average talk times, implying a general increase in congestion. However, this increase is distributed differently across the various departments, implying that in the sales scenarios (tabulated in the second and third columns), the shared processor is now shared differently among departments. This effect, along with the impact of random variation on the estimates, explains the qualitative nature of the changes in abandonment rates that can be observed in Table 4. As a result of these effects, the impact of sales activity on service quality in the center varies by department; some experience deteriorating rates, whereas others exhibit improvements.

TABLE 4
Percentage Abandonment Rates and Associated Confidence Intervals in the Call Center

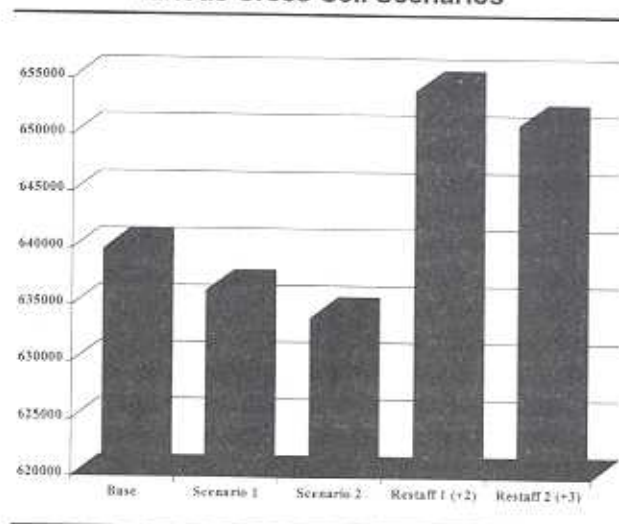
Department	Base	Scenario 1 (sales lead)	Scenario 2 (nonspecialization)	Restaff 1 (+2 to Class 1)	Restaff 2 (+3 to Class 1)
1	2.523 (2.517, 2.529)	8.608 (8.592, 8.625)	11.770 (11.751, 11.789)	0.539 (0.537, 0.541)	3.359 (3.350, 3.368)
2	0.25×10^{-6} (0, 0)*	0.999×10^{-5} (0, 0)*	0.08×10^{-6} (0.0, 0.0)*	0.20×10^{-6} (0.0, 0.0)*	0.0 (0, 0)
3	1.601 (1.596, 1.606)	0.031 (0.031, 0.031)	0.029 (0.029, 0.029)	0.0 (0.0, 0.0)	0.387 (0.386, 0.388)
4	0.6×10^{-6} (0, 0)*	0.124×10^{-5} (0, 0)*	0.178 (0.178, 0.179)	0.0 (0, 0)	0.0 (0, 0)
5	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)
6	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)
7	1.054 (1.052, 1.057)	1.378 (1.376, 1.381)	1.289 (1.286, 1.291)	0.035 (0.035, 0.035)	0.081 (0.081, 0.082)
8	0.529×10^{-4} (0, 0)*	0.567×10^{-4} (0, 0)*	0.854×10^{-4} (0, 0)*	0.18×10^{-6} (0, 0)*	0.118×10^{-5} (0, 0)*
9	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)	0.002 (0.002, 0.002)	0.955×10^{-3} (0, 0)*	0.239×10^{-3} (0, 0)*

NOTE: All intervals in which the lower and upper limits are less than 10^{-1} are denoted as (0, 0)* for compactness.

Recall that both scenarios assume that management does nothing to react to this additional capacity utilization once the sales program is initiated. In the fourth and fifth columns of Table 4, percentage abandonment rates are re-evaluated for the two scenarios, where the center has been restaffed. Looking at the high abandonment rates in Department 1 after the sales effort, two customer service representatives were added to this department in Scenario 1, labeled as "Restaff 1" in Table 4. Three customer service representatives were added to Department 1 for Scenario 2, the results of which are tabulated in the column labeled "Restaff 2." As noted earlier, no claims are made about the optimality of either restaffing choice. The restaffing was done with the objective of bringing the abandonment rates in Department 1 back to an acceptable level.

In an earlier discussion, it was stated that the increase in the effective call volumes of certain departments increases their revenue generation potential because the number of calls offered to these departments increases. To capture this benefit of cross-selling and to see how it trades off with the service quality deterioration, the five scenarios in Table 4 are compared based on total system profits, where the word *profit* is used loosely to denote revenues net of staffing costs. Some clarification on the assumptions made for this analysis is in order. First, it is assumed that, on average, every call in the center generates revenue of \$1. This number was picked arbitrarily due to the lack of revenue data at the call center. All costs for the base case and for Scenarios 1 and 2 are taken to be identical. More information on differences in cross-training would indicate a difference in personnel costs between the two scenarios. For simplicity in the current analysis, it is assumed that these costs are the same. The profits are evaluated by incorporating the monthly wages of the service representatives in each scenario based on a \$17,000 average annual salary. This represents the salary of Level 1 customer service representatives (lowest of four levels) in the center under study.

FIGURE 2
Call Center Profits Under Various Cross-Sell Scenarios



One month's profits for the center under these assumptions for the various scenarios are shown in Figure 2. With no restaffing action, Scenario 1 (the sales lead generation scenario) performs slightly better than Scenario 2 (the generalist scenario) from a profit standpoint; however, for both cases, profits deteriorate compared to the base case with no selling. The center's profits benefit from additional staff in the restaffed scenarios, leading to higher profits than in the base case. Scenario 1 still outperforms Scenario 2, even though fewer staff members (two vs. three) were added in this case.

It is difficult to draw any generalizable conclusions about the choice between the sales lead generation and nonspecialization delivery channel designs. An extensive analysis, like the one in the previous example for different levels of change in the model parameters, needs to be performed. To illustrate this point, a second example with different arrival and service rate parameters and appropri-

TABLE 5
Model Parameters for the Second Base Case

Department	Minutes/Day	λ (calls/minute)	μ (calls/minute)	α	Positions Staffed
1	43,200	3.560	0.109	5.46	30
2	29,700	0.270	0.001	0.75	15
3	28,800	0.080	0.300	5.00	2
4	19,800	0.200	0.080	3.33	4
5	11,400	0.070	0.052	2.86	3
6	17,100	0.050	0.017	2.50	5
7 (VRU)	43,200	0.306	0.750	6.00	132 (trunks)
8 (VRU)	43,200	0.037	30.000	6.00	12 (trunks)
9 (VRU)	43,200	0.068	30.000	6.00	7 (trunks)

NOTE: VRU = voice response unit.

TABLE 6
Percentage Abandonment Rates and Associated Confidence Intervals: The Second Base Case

Department	Base	Scenario 1 (sales lead)	Scenario 2 (nonspecialization)	Restaff 1 (+3 to Class 2)	Restaff 2 (+3 to Class 2)
1	0.292 (0.291, 0.292)	3.599 (3.590, 3.609)	2.804 (2.795, 2.812)	3.622 (3.612, 3.631)	2.541 (2.533, 2.548)
2	6.149 (6.133, 6.164)	8.985 (8.963, 9.007)	9.383 (9.355, 9.411)	4.653 (4.639, 4.666)	8.087 (8.063, 8.112)
3	0.0 (0, 0)	0.03×10^{-6} (0, 0)*	0.605×10^{-3} (0, 0)*	0.02×10^{-6} (0, 0)*	0.038 (0.038, 0.038)
4	0.117×10^{-3} (0, 0)*	0.019 (0.019, 0.019)	0.021 (0.021, 0.021)	0.018 (0.018, 0.018)	0.501 (0.499, 0.502)
5	0.11×10^{-4} (0, 0)*	0.61×10^{-6} (0, 0)*	0.238×10^{-4} (0, 0)*	0.46×10^{-6} (0, 0)*	0.331×10^{-4} (0, 0)*
6	0.47×10^{-6} (0, 0)*	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)
7	0.182×10^{-4} (0, 0)*	0.18×10^{-6} (0, 0)*	0.306×10^{-5} (0, 0)*	0.06×10^{-6} (0, 0)*	0.289×10^{-6} (0, 0)*
8	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)
9	0.754×10^{-5} (0, 0)*	0.01×10^{-6} (0, 0)*	0.0 (0, 0)	0.0 (0, 0)	0.0 (0, 0)

NOTE: All intervals in which the lower and upper limits are less than 10^{-3} are denoted as (0, 0)* for compactness.

ately modified staffing levels is provided. The parameters for this example were determined arbitrarily. The idea is to illustrate how the same analysis for a similar center with different initial capacity utilization can lead to a different result. The parameters for this second example are tabulated in Table 5.

In this second example, call characteristics are distinctly different, with lower call volumes and longer talk time requirements (or equivalently smaller μ s). The center experiences higher initial congestion levels than in the first example, as demonstrated by the higher abandonment rates for the new base case tabulated in Table 6. Using the same changes in average talk times and effective call volumes as a result of cross-selling, tabulated in Table 3, the new abandonment rates for Scenarios 1 and 2 are obtained. In the fourth and fifth columns of Table 6, percentage abandonment rates are reevaluated for Scenarios 1 and 2, where for each scenario the center has been restaffed. Confidence intervals are tabulated next to the point estimates, as in the previous example.

Observing the higher abandonment rates in Department 2 after the sales effort, three customer service representa-

tives were added to this department in both Scenarios 1 and 2. The additional service representatives in Department 2 decrease renege probabilities in this channel (as tabulated in the Restaff 1 and Restaff 2 columns) in both scenarios; however, more improvement can be observed for the case of Scenario 1.

A profit analysis of the new base case yields the situation in Figure 3. Whereas the first base case resulted in the sales lead generating design (Scenario 1) outperforming the generalist design, the new base case leads to the opposite result. In particular, it can be observed that the generalist design (Scenario 2) leads to higher profits, even though the restaffing results in a bigger decrease in abandonment in Department 2 for the sales lead generating design. In fact, if one were to look at abandonment rates only, one would conclude that Scenario 1 outperforms Scenario 2 in the restaffed cases. This is not true, however, when one looks at profits. This can be explained by taking a closer look at the model parameters. For this center, most of the call volume is handled by Department 1. As a result, a small difference in abandonment rates for this department implies a bigger improvement in throughput (and hence

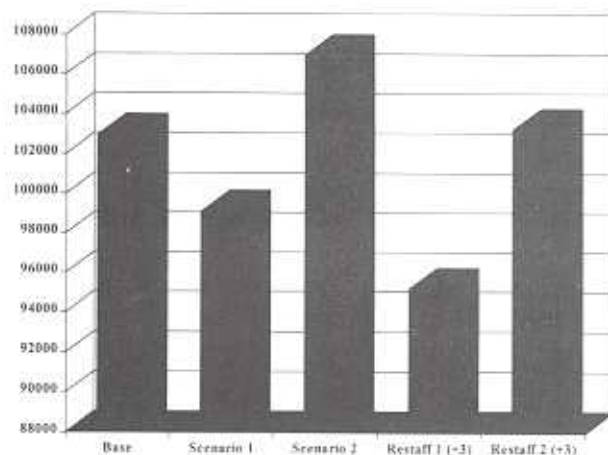
revenues) than does a similar (or even bigger) reduction in abandonment rates in another department. The comparison of the scenarios before and after restaffing leads to another interesting observation. Even though restaffing reduces abandonment rates, this reduction is not big enough to compensate for the additional cost of three service representatives. The analytical approach proposed in this article enables the quantification of these different effects on call center profits.

Both examples demonstrate that if no action is taken, then increased sales activity can simultaneously deteriorate customer service measures and decrease profits at a call center. Delivery channel design and the magnitude of the changes on average talk times and effective call volumes both play a role in determining this *congestion cost*, indicating the need to design and implement sales programs appropriately. A comparison of the two examples leads to the conclusion that the negative impact of cross-selling can be partially overcome by moving to a new work organization in some instances. *Different call centers can succeed in cross-selling by adopting different work organizations.* In other words, the congestion cost associated with cross-selling not only is a function of the work organization but also is a function of call characteristics. The same sales program implemented in another center with different call characteristics (in this instance, different call volumes and service time requirements) leads to a different choice in terms of work organization. In the preceding analysis, delivery channel designs are compared from a capacity perspective. As noted earlier, other issues need to be considered in determining the ideal design.

EMPIRICAL VERIFICATION OF SALES/SERVICE TRADE-OFF

In a forum held at the Wharton School in February 1996, results from this study were presented to a group of phone center managers from all segments of the financial services industry. Motivated by the results that work organization matters and that cross-selling is not necessarily profit enhancing if it is not implemented properly, a major retail bank performed a study of its own cross-sell program after the forum. Even though the bank's analysis did not use the model described herein, its results confirmed the major qualitative result of this article, namely, that work organization matters. In this case, the bank found that a work organization in which each department has its own sales agents and a small sales department that deals only with occasional cases (the nonspecialization scenario) is superior to one in which service representatives try to generate leads that they then forward to a sales department (the specialized scenario). The existing sales paradigm at the

FIGURE 3
Profits for Second Base Case



bank, at the time of this study, was the specialized work organization. Based on its results, this bank's call centers now are restructuring. A new information system accompanying this restructuring is being built.

A close scrutiny of cross-selling further demonstrated to management that one could make a distinction among types of sales transactions. In particular, it was observed that certain sales transactions that are counted as revenue enhancers in the current system actually were diminishing revenue potential for the bank, whereas others induced customers to deepen their relationships with the bank even further. An example of the former type could be overdraft protection in a checking account, resulting in forgone penalty fee earnings for the bank. This observation led to the idea of focused cross-selling, where the congestion costs would be minimized by targeting only profitable sales opportunities. The new system is designed to prompt agents for profitable sales opportunities. This is an additional insight obtained by the bank's study. It indicates that an analysis similar to the one performed in this study raises awareness, resulting in a deeper understanding of certain phenomena well beyond the capabilities of the model itself. In future work, the revenue dimension of different sales efforts will be investigated to capture the difference between sales attempts that are a success and those that are not.

It is instructive to briefly focus on the details of this bank's study and how it was performed. Using data available for the current operation and some projections for the case with the different work organization, the study estimated costs and revenues generated by each cross-sell scenario. On the cost side, these estimates account for differences in training expenses, additional telecommuni-

cation expenses incurred due to increased talk times, additional representative space due to differences in staffing requirements (estimated using current staffing policies), additional representative personnel expenses due to differences in staffing, and additional allocation expenses. Thus, it is clear that the results reported in this article underestimate the cost dimension of cross-selling given that only staffing costs in terms of salary were incorporated into the current analysis. The differences in profits reported earlier would be more dramatic if these additional costs were included. On the revenue side, the bank's study accounts for differences in the percentages of leads that are successfully converted to sales in each of the two work organizations. This could be a source for another difference compared to the analysis performed herein because the framework in this study does not account for differences in leads-to-sales conversion percentages. Once again, incorporating these into the analysis could dramatically increase the difference in the revenue potential between the two work organizations.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The preceding analysis uses a plausible example from a retail banking phone center to demonstrate that cross-selling is a costly endeavor. In addition to its visible costs such as training and technology costs, cross-selling is shown to have detrimental effects on customer service due to the additional load it creates on the system. With a move to more selling, capacity needs will increase in terms of both customer service representatives and information processing resources. One should note that the capacity implications of cross-sell programs can be easily overlooked because these are less visible than what one expects to see on the revenue side. The analytical approach suggested in this article is capable of quantifying the capacity implications of cross-selling and, in this sense, constitutes an important tool to aid decision making.

The preceding examples show that by restaffing, the center can overcome its congestion-related problems induced by additional sales activity. A need to determine the appropriate staffing levels after such an increase in call traffic has been experienced is apparent from this discussion. The restaffing problem constitutes a natural next step for this research. The authors currently are working on using the performance model outlined herein in conjunction with an optimization model to determine economically optimal staffing levels for call centers (Akşin and Harker 1998b).

Although restaffing does alleviate congestion-related problems at a center experiencing a transition to more

sales activity, the contrast between the two sales scenarios that were analyzed suggests that staffing is not the only factor that needs to be considered. Designing the right process and adopting human resource practices that support this design are equally important in determining the success of a cross-sell program. The examples, as well as the independent study performed by the bank reported earlier in this article, emphasize the claim that adoption of the proper work organization to support cross-sell activities in retail banking phone centers constitutes a critical success factor.

APPENDIX A

Description of the Data Collection Process

The retail banking study is an interdisciplinary research effort aimed at understanding the drivers of competitiveness in the industry, where competitiveness means not simply firm performance but also the relationship between industry trends and the experiences of the retail banking labor force. Following an initial exploratory phase consisting of open-ended and structured interviews with industry informants, the second phase of the study was launched, entailing a detailed survey of technology, work practices, organizational strategy, and performance in 135 U.S. retail banks. The team sought to survey a group of banks that could yield the broadest coverage of the trends in human resources, technology, and competitiveness in the industry. The survey was not intended as a random sample of all U.S. banks; rather, the focus was on the largest banks in the country. In the end, the approach gained the participation of banks holding more than 75% of the total assets in the industry in 1994. A list of the 400 largest bank holding companies (BHCs) in America at the beginning of 1994 was compiled. Merger activity, and the fact that a number of BHCs had no retail banking organizations (defined as entities that provide financial services to individual consumers), reduced the possible sample to 335 BHCs.

Participation in the study required substantial time and effort on the part of organizations. Commitment to participation was sought, and the 70 largest BHCs were approached directly. A total of 47 BHCs agreed to participate with at least 1 retail banking entity. In addition, 7 BHCs engaged the participation of 2 or more retail banks, giving a total of 64 participating retail banks in the sample. Multiple questionnaires were delivered to each organization in the sample. For this group of banks, questionnaires were delivered to four top managers: the head of the retail bank, the top finance officer, the top marketing officer, and the top manager responsible for technology and information systems. These banks received questionnaires for one manager of a bank telephone center, one branch manager, and one customer service representative (CSR) in the bank's "head office" branch (defined as the branch closest to the bank's headquarters). In addition, a researcher on-site in this branch gathered data about business process flows for checking and small business loans. Identical questionnaires were mailed to five more branch managers and to CSRs in those branches. In these questionnaires, the CSRs themselves mapped processes associated with home equity loans,

checking accounts, certificates of deposit, mutual fund accounts, and small business loans.

In late 1994, surveys were mailed to the next largest 265 BHCs and were followed up with telephone calls. A total of 64 of these BHCs agreed to participate in the study, with 4 of these engaging the participation of 2 or more retail banks in the BHCs, so that a total of 71 participating retail banks constituted the sample of the mailed survey. For this group of banks, the head of the retail bank was surveyed. Many of the questions directed to other top managers were consolidated into this survey. For this sample, questionnaires also were mailed to one telephone center manager, one branch manager, and one CSR in the head office branch.

APPENDIX B

Overview of the Analysis of the Performance Model

To formalize the analysis of the proposed model, one must introduce some additional notation. Define $\pi(\mathbf{n})$ as the equilibrium probability of being in state \mathbf{n} (i.e., of having n_k customers of class k in the system). Define the sets $\mathbb{A} = \{\mathbf{n} \in \mathbb{Z}^K : n_k \leq T_k\}$ and $\mathbb{A}_k = \{\mathbf{n} \in \mathbb{A} : n_k < T_k\}$, where \mathbb{Z}_+ denotes the nonnegative integers. Let $\psi: \mathbb{A} \rightarrow \mathbb{R}_+$ be a function, satisfying $\psi(\mathbf{0}) > 0$ and

$$\frac{\lambda_k(\mathbf{n})}{\mu_k(\mathbf{n} + \mathbf{e}_k)} = \frac{\psi(\mathbf{n} + \mathbf{e}_k)}{\psi(\mathbf{n})} \quad \forall \mathbf{n} \in \mathbb{A}_k, k = 1, \dots, K. \quad (3)$$

Finally, \mathbf{e}_k is a K -dimensional vector of zeros with a 1 in its k th position, and $\mathbf{0}$ is a K -dimensional vector of zeros.

The time that a customer waits in queue k is assumed to be an exponential random variable with rate α_k . Customers are assumed to renege only when they are on hold and will not renege once they start talking to a customer service representative. This implies a renege rate of $r_k(n_k) = \alpha_k(n_k - S_k)1(S_k < n_k \leq T_k)$ for $k = 1, \dots, K$.

To characterize the performance of the phone center, one must establish the behavior of the system in the steady state. To this end, one first must determine the equilibrium distribution, $\pi(\mathbf{n})$. The derivation of this result can be found in Akşin and Harker (1998a). In this appendix, the expressions for the equilibrium distribution and then for blocking and renege probabilities are stated without proofs.

For notational simplicity, let $\tau_k(j, \mathbf{n}) = \mu_k \min(j, S_k) + r_k(j)(\sum_{k=1}^K \min(n_k, S_k))$. It can be shown that

$$\pi(\mathbf{n}) = \left(\sum_{k=1}^K \min(n_k, S_k) \right)! \prod_{k=1}^K \frac{\lambda_k^{n_k} \left(\sum_{k=1}^K \min(n_k, S_k) \right)^{(n_k - S_k)^+}}{\prod_{j=1}^{n_k} \tau_k(j, \mathbf{n})}. \quad (4)$$

Using Equation 3, the equilibrium distribution is given by

$$\pi(\mathbf{n}) = \frac{\psi(\mathbf{n})}{\sum_{\mathbf{n} \in \mathbb{A}} \psi(\mathbf{n})}.$$

The performance measures can be obtained using the equilibrium distribution. In general, blocking probability in channel k is given by

$$B_k = 1 - \frac{\sum_{\mathbf{n} \in \mathbb{A}_k} \pi(\mathbf{n})}{\sum_{\mathbf{n} \in \mathbb{A}} \pi(\mathbf{n})}.$$

Denote the long-run probability of renege for a customer of type k by R_k . Then,

$$R_k = \sum_{\mathbf{n} \in \mathbb{A}} \pi(\mathbf{n}) \frac{r_k(n_k)}{\lambda_k(1 - B_k)}. \quad (5)$$

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O. Zeynep Akşin is an assistant professor of operations management at INSEAD, France, and a senior fellow at the Wharton Financial Institutions Center, University of Pennsylvania. She received her B.S. in industrial engineering from the Middle East Technical University, Ankara, in 1990, and an M.S. and Ph.D. in operations management from the Wharton School of the University of Pennsylvania in 1994 and 1996, respectively. Her research interests are mainly in the areas of service operations management, call center design and management, service delivery in financial services, and the design and analysis of stochastic networks.

Patrick T. Harker is the UPS Transportation Professor for the Private Sector at the University of Pennsylvania, chairman and professor of operation and information management at the Wharton School, and senior fellow at the Wharton Financial Institutions Center. He received his B.S.E. and M.S.E. in civil engi-

neering in 1981 and an M.A. in economics and a Ph.D. in transportation planning and economics from the University of Pennsylvania in 1983. He previously served as chair of the Systems Engineering Department in Penn's School of Engineering and Applied Science.