PRODUCTION AND OPERATIONS MANAGEMENT
Vol. 12, No. 1, Spring 2003
Printed in U.S.A.

SERVICE SYSTEM DESIGN FOR THE PROPERTY AND CASUALTY INSURANCE INDUSTRY*

AVI GILONI, SRIDHAR SESHADRI, AND PASUMARTI V. KAMESAM
Sy Syms School of Business, Yeshiva University, 500 West 185th Street, New York, New York 10033, USA
Operations Management Department, Stern School of Business, New York University, 40 West 4th Street, New York, New York 10012, USA
Senior Manager, IBM India Research Lab, Block 1, IIT D Campus, Hauz Khas, New Delhi-110016

This paper describes the changes that are forcing property and casualty insurance firms to rethink their service system design and in particular their distribution strategies. A set of questions related to distribution that are uppermost in the minds of executives in this industry are presented along with a literature survey of models that can be used to answer some of these questions. Based on the survey, a normative framework for designing the distribution system is proposed. Qualitative and quantitative analysis based on the proposed framework is presented along with empirical data to demonstrate the usefulness of the framework. The paper concludes with an agenda for further research.
(INSURANCE INDUSTRY; SERVICE STRATEGY; SERVICE SYSTEM DESIGN; DISTRIBUTION SYSTEM DESIGN)

1. Introduction

In this paper, we examine the service system design problem for insurance firms that serve the property/casualty insurance (P/C) market. Specifically, we first describe how the distribution of insurance products is central to an insurance firm's success within a rapidly changing property/casualty insurance market. We then develop a normative framework for designing the system. We present qualitative and quantitative analysis based on the proposed framework along with empirical data to demonstrate the usefulness of the framework.

In the P/C industry, nearly, 67% of the operating costs are related to distribution channel operations (Berger, Cummins, and Weiss 1997; Cook and Cummins 1996). It is further estimated that over 40% of distribution costs are related to agent commissions (Insurance Advisory Board 1998). Furthermore, a joint study by IBM and the Economist (1996) showed that nearly 60% of the insurance executives surveyed were not confident that their current distribution strategies address the evolving needs of their customers. Firms in the P/C industry carry out a set of activities to distribute products and services that can be broadly classified according to the function performed, e.g., providing information about products and services, providing support for processing claims, answering customer queries, and responding to requests for price quotes. Insurance firms have to decide which channels to use to perform

* Received November 1999; revisions received February 2001, December 2001, May 2002; accepted May 2002.

1059-1478/03/1201/062$1.25

these functions. In Table 1 we show the mix of channels deployed by firms in this industry in 1996 and 2000 based on studies by IBM/Economist (1996) and EIU (2000). The data indicate that firms in this sector use multiple distribution channels.

It seems logical that the customer segments that a firm wishes to target should determine the firm's service system design (Kennickell and Kwast 1997; Bowersox and Cooper 1992). However, to find the optimal service system design, we need to find answers to the following questions: (i) which products and services should be offered, (ii) which subset(s) of the firm's products and services should be made available to different customer segments, (iii) which channels should perform the necessary service functions for each of the various customer segments, (iv) how to optimally allocate resources to the various channels, (v) how to achieve operational efficiency and effectiveness, and (vi) how to use information technologies most effectively for performing the service operations. We define this collection of questions to be the *integrated service system design* problem. Below, we address the modeling of this problem. In Section 2, we discuss how some recent developments have made this problem more significant. In Section 3, we review various models that can be utilized for solving the problem. In Section 4, we present the results from the application of some of the models from Section 3 to the integrated service system design problem. In particular, we show these models can be used to (1) predict the use of the Internet for carrying out various functions, (2) examine the phenomenon of why insurance products are sold direct to customers and also via agents, and (3) determine market segments based upon operational requirements of the distribution system. In Section 5, we discuss our conclusions and directions for further research.

2. Factors Hastening Change in the Distribution of Insurance Products and Services

In the early 1980s, insurance companies offered their products and services to mass market mostly through agents. Competitive advantage in this setup was derived through maintaining and enhancing customer–agent relationships. In stark contrast to the 1980s, today 90% of firms that belong to the P/C industry sector compete for less than 10% of the available premium volume (EIU 2000). The EIU study observes that firms in this industry have to be ultra-sensitive to the evolving requirements of their customers, since nearly 25% of premium revenue in 2005 is expected from products yet to be created. Furthermore, firms need to find ways to improve currently poor shareholder returns, to find ways to deal with consolidation and mergers in the industry, and to determine an effective strategy for responding to changing customer tastes and preferences.

Despite these shifts in the marketplace, the current distribution system operations in many P/C firms are either a legacy of the past or are evolving very slowly and cautiously. Over 80% of respondents to the EIU study recognize that the integration of the Internet, call-centers, as well as interactive television will require insurance firms to redesign their distribution systems. In Table 1, we show the data from both the IBM/Economist study in 1996 and the EIU study in 2000. As was predicted by the IBM/Economist study in 1996, the share of direct writers as a distribution channel has increased and is projected to increase in the future. However, new channels for distribution of products and services are seen to be slow to emerge.

The EIU study cites that some of the important forces that are likely to force insurance firms to rethink their distribution strategies are changing customer preferences, emergence of new channels, advances in technology, and competition from banks. We demonstrate the usefulness of our framework in analyzing how firms should respond to these forces.

In Section 3.4, we present a model that can be used to determine the optimal channel intensities of direct sales operations. In Section 4.1, we discuss the current usage of the Internet by P/C insurance firms. In Section 4.4, we examine both coexistence of independent agency firms with exclusive agents and direct agents and we show that customer preferences

TABLE 1

Mix of Channels in the P/C Insurance Industry

Distribution Channel	Actual Year 1996[1] (%)	Projected 2000 (%)	Actual Year 2000[2] (%)[3]	Projected 2005 (%)
Agents	83	69	72	61
Direct writers[4]	7	17	25	35
Other	10	14	3	4

[1] IBM/Economist (1996).
[2] EIU (2000).
[3] Revenue from net premiums through distribution channels.
[4] Includes Internet and Call Centers.

can be gleaned using rather parsimonious models; thus, data warehouse design can be simplified by applying a suitable modeling framework.

We recognize that in addition to being able to address the above questions, the model should take as input the different strategies that are followed in the P/C insurance market. For example, low cost, differentiation, and focusing on a niche market are examples of quite different strategies that are followed in this market. How can the service system/distribution system design problem be structured so that it can address the needs of firms that pursue such different strategies? In this, we embrace the view of Donnelly and Guiltinan (1986) that the difficulties are less with the differences between products and services and more with failing to clearly distinguish between the production and the distribution of services. Thus even though two firms in this industry might use different strategies for reaching customers and have different products and performance standards, their distribution channels are required to perform a similar spectrum of service functions. It is by identifying and classifying these functions that a common approach to channel design can be crafted. From the above discussion, we can identify some of these functions quite clearly. The service functions range from (i) providing product information to gathering information with regard to customer preferences, (ii) selling a product to supporting claim processing, and (iii) creating a brand identity to delivering standardized services.

In the next section, we develop a framework for modeling the distribution system design problem for insurance firms that is centered around two themes: how to further classify these functions and how to combine the functional requirements of multiple customer segments into the design of an efficient and effective distribution system.

3. Models for Distribution Channel Design

3.1. *Introduction*

In this section, we review some of the models that are available for channel design. Four different types of models have been proposed in the literature, namely, behavioral models, economic models, managerial models, and conceptual models. We elaborate upon the managerial models because these models are best suited for formulating and solving the integrated service system design problem.

3.2. *Behavioral Models*

Behavioral models generally focus on the sociological behavior of channel members, covering for example, notions of power, conflict, and satisfaction in channel dyads (Rosenberg and Stern 1971; Hunt and Nevin 1974; Lusch 1976; Etgar 1978). Behavioral models are descriptive as opposed to being normative. For example, models that explain the coexistence of independent agents and exclusive agents (based on hypotheses such as product quality, effect on future sales, and negotiating power of independent agents with insurance firms) have been proposed and tested by Mayers and Smith (1981); Crosby and Stephens (1987); Crosby, Evans, and Cowles (1990); Kim, Mayers, and Smith (1994); Posey and Yavas (1995); and Venezia, Galai, and Shapira (1999).

3.3. *Economic Models*

Extensive work has been done on developing economic models of distribution systems. These models focus on an entire industry rather than on a single firm. For example, the classical assumptions of a competitive market structure have been used to predict the equilibrium number of channel intermediaries by Balderston (1958); Baligh and Richartz (1967); and Naert (1970). More recent work has been carried out within a game theoretic framework in which some of the classical assumptions are relaxed (e.g., the use of contracting theory by Zusman and Etgar 1981, and Moses and Seshadri 2000, the use of quantity discounts to coordinate the channel system by Jeuland and Shugan 1983, the role of implicit understandings in achieving greater profits for all channel members by Shugan 1985, and product differentiation and its relationship to vertical integration by McGuire and Staelin 1983, Coughlan 1985, and Hegde 1986).

3.4. *Managerial/Normative Models*

As opposed to economic models, normative models aim to provide guidance to decision-makers within a firm. These models, when suitably modified, are the most appropriate ones for addressing the channel design problem for insurance. Three models are reviewed in this subsection. Their relevance to solving the distribution channel design problem is discussed at the end of this subsection.

THE MARKET SHARE (MS) MODEL (RANGAN 1987). Rangan proposed a model to determine a channel design that maximizes a firm's market share. Rangan considered firms that were distributing industrial products. He developed his model by classifying the various activities that a firm is required to perform in its distribution of products into service functions. This framework for channel design is an outgrowth of earlier work by Aspinwall (1962), Bucklin (1966), and Lilien and Kotler (1983). In the MS framework a (channel) function is a specialized task that must be performed by the firm and its marketing intermediaries in the process of selling, distributing, and providing after sales support for its products to customers. A list of service functions along with a brief description is given in Table 2. The classification of these functions is based on research by Aspinwall (1962), Bucklin (1966), and McCammon and Little (1965).

TABLE 2
Service Functions

Function	Definition
Product information	Customers require information usually for complex products.
Product customization	Products need to be adjusted to meet the customers' requirements.
Product quality assurance	The emphasis on product integrity and reliability placed by customers due to the customers' operational needs.
Lot size	The customers' monetary spending for the product. Products with high unit values and those which are used extensively represent significant financial decisions.
Assortment	Customers may require a wide range of products.
Availability	The customer requires the immediate availability of products from the firm.
After sales service	Installation, repair, maintenance, and warranty of the product are required by the customer.
Logistics	The transportation, storage, and supply of the product to the customer.

Rangan chose to focus on three aspects of the channel design problem, namely, how to determine the distribution structure (i.e., what are the channels and intermediaries?), the distribution intensity (how much of each type of intermediary to deploy in each channel?), and the distribution management (the service levels to be provided to the customer). The market is partitioned into segments that represent a subset of potential customers and a specific (set of) product(s). The market share in each of the market segments is then represented as a function of the firm's strategy as well as of the channel intensity. A firm's strategy comprises both channel as well as non-channel strategies. A channel strategy is a mapping of the available channels to the market segments. For example, managers might decide that each market segment should be served by only one channel. A non-channel strategy is a combination of the price strategy and the (perfect) prediction of the reaction of the competition in each market segment.

In the model, there are P market segments, K channel strategies, Q non-channel strategies, and n channel functions. Let k_i be the number of levels for channel i. Let T be the planning horizon. The key assumptions in this model are that:

- The current period's market share is influenced by four factors: channel effort, non-channel effort (price), cumulative effect of the past effort (channel and nonchannel), and competition's expected strategy.
- The individual channel functions are assumed to be independent, and thus, the aggregate effect of channel efforts can be determined by the sum of the component effects.
- A concave response function is used to determine the firm's market share as a function of channel efforts. The market share m_{pt}^{qk} at time t for market segment p under channel strategy k and non-channel strategy q is given by

$$m_{pt}^{qk} = (\mu_{pt})^{(\phi^{v_{pt}})(\gamma^{w_{pt}})}\left(1 - \exp\left(-\alpha_{pt} - \sum_{i=1}^{n}\sum_{j=1}^{h_i} \beta_{pij} x_{pijt}^{qk}\right)\right) \tag{3.4.1}$$

where α_{pt} is an estimated parameter which is used to model goodwill;

β_{pij} is an estimated parameter that describes the effects of channel functions performed;

x_{pijt}^{qk} is the amount of channel function i performed by intermediary j and is greater than or equal to zero;

μ_{pt} is the estimated maximum achievable market share that can be achieved (by channel effort alone);

ϕ and γ are estimated parameters describing price strategies and competition, respectively;

v_{pt} is a managerial estimate of price strategy; and

w_{pt} is a managerial estimate of competition.

In this model, goodwill is expressed as

$$\rho_{pt} = (\mu_{pt})(1 - \exp(-\alpha_{pt})); \tag{3.4.2}$$

i.e., ρ_{pt} represents the cumulative effect of the past effort (channel and nonchannel). The impact of channel effort for this period is captured by modifying ρ_{pt} to

$$(\mu_{pt})\left(1 - \exp\left(-\alpha_{pt} - \sum_{i=1}^{n}\sum_{j=1}^{h_i} \beta_{pij} x_{pijt}^{qk}\right)\right).$$

To include nonchannel effort and competition, two more parameters are used, namely, ϕ and γ. The effects of these factors are modeled by writing the maximum achievable market share through channel effort, nonchannel effort, and reaction by competition as $(\mu_t)^{(\phi^{v_t})(\gamma^{w_t})}$. Here v_t is a scale factor which measures change in nonchannel strategy, i.e., price. This factor is determined by the manager(s) of the appropriate area of the firm. By convention, aggressive moves by the firm are described by negative values in v_t. Similarly, w_t is a scale factor that measures change from the competition's current strategy. Aggressive moves are described by negative values of w_t.

Let Z_{pt} be the market size of segment p at time t. Then the sales response is given by

$$\sum_{p=1}^{P} m_{pt}^{qk} Z_{pt}. \tag{3.4.3}$$

Let the cost of providing the ith channel function at the jth level for segment p at time t, using the qth channel and the kth non-channel strategy be C_{pijt}^{qk}, the gross margin on sales dollars be G_{pt}^{qk}, the fixed cost be FC^{qk}, and the company's cost of capital be r. Then the objective is to maximize the discounted profit given by

$$\max \sum_{t=1}^{T} \sum_{p=1}^{P} m_{pt}^{qk} Z_{pt} \frac{G_{pt}^{qk}}{(1+r)^{t-1}} - \sum_{t=1}^{T} \sum_{p=1}^{P} \sum_{i=1}^{n} \sum_{j=1}^{h_i} C_{pijt}^{qk} \frac{x_{pijt}^{qk}}{(1+r)^{t-1}} - \sum_{t=1}^{T} \sum_{p=1}^{P} \frac{FC^{qk}}{(1+r)^{t-1}}. \tag{3.4.4}$$

This model provides a convenient starting point for solving the distribution system design problem. Additionally, resource and managerial constraints can be incorporated into the model. However, there are three limitations to this model. First, only the channel and non-channel strategies specified by the managers are compared. Thus, there are unspecified combinations of channels that are not considered, even though they might be more profitable than the selected combinations. Second, many of the model's parameters are based on managerial estimates and are therefore difficult to verify. Third, correlation between channel functions cannot be captured because the market share is expressed as a multiplicative function. Significant work is required to change from a multiplicative model to an alternate framework that permits interchannel correlation or the cannibalization of sales.

Other models exist in the literature that can be further developed as extensions of or in addition to the MS model. For example, Corstjens and Doyle (1979) developed a model that allows interaction among the channels as well as cannibalization of sales. Yet, this model contains limitations that make it difficult to apply to P/C insurance because (1) it assumes that demand is independent of marketing strategy, (2) it assumes that demand is aggregate in nature, (3) competition is not considered, (4) intermediaries within channels are assumed to be identical, and (5) it is restricted to a single product or service. Another example is the model developed by Rangan and Jaikumar (1991), in which retailers have the option of either purchasing products from a wholesaler or directly from the producer. Such a model can be used to examine the cost of a customer switching to a direct sales channel from an indirect sales channel.

3.5. *Conceptual Models for Financial Service System Design*

In this section we discuss two issues related to channel design, namely, how does the degree of customization determine the choice of the delivery channel, and how to manage channel conflict.

Customization and Channel Selection. Apte and Vepsalainen (1993) study the design of delivery channels for the financial service industry. They explain that a delivery channel comprises a channel system (level of information technology) and a channel organization (level of human intermediation). They argue that in constructing an efficient service operation every effort should be made to obtain the proper balance between information technology and human intermediation. They propose a model labeled "service channel strategies (SCS)" in which a firm decides not only upon the type of channel system and channel organization, but also the strategy used for customer contact and the type of service contract. Furthermore, they explain that a firm must ensure that the delivery system is configured correctly for the service package being provided. More specifically, the two prototype examples of efficient delivery channels are those that are either human-centered but built on centralized channel systems, or technology-centered channel systems that bypass human intermediation by providing the customer greater connectivity to the channel system. Efficient strategies for creating service packages are generally those that use a transaction-based strategy for customer contact and a relatively simple service contract (little customization) or a relationship-based strategy for customer contact and a more complex service contract (much customization possible). Finally, human-centered delivery channel designs should be matched with service packages that are based on customized service and technology-centered delivery channel designs should be matched with service packages that are based on mass transactions.

Channel conflict. Another issue that firms contend with is channel conflict, namely, friction due to competition between external and internal channels as well as among different external channels. When internal and external channels compete for the same customer segment, the firm may incur additional costs because it uses a larger distribution channel system without increasing its market share. To reduce the dangers of channel conflict, there are two basic strategies.

One strategy is to utilize only the channel(s) that is (are) most appropriate for the market segment(s) the firm is attempting to reach. If a firm wishes to reach only one customer segment, say those customers that are willing to pay for higher quality of service, it may be appropriate to use independent agents as the premier channel and use other channels, e.g., the Internet, only for information retrieval and/or claims processing. Therefore, the dangers of channel conflict are reduced by utilizing only one genre of channel for those service functions where conflict between internal and external channels is detrimental to the firm. Any conflict will take place externally from the firm, i.e., between the various independent agents, which will not incur extra costs, but rather maintain the level of service provided by the independent agents at a competitive level. Similarly, if a firm wishes to reach price-conscious customers, it could utilize various internal channels (and completely eliminate external channels such as independent agents), since conflict can be controlled internally through managerial effort to encourage synergy between the various channels (see, e.g., Friedman and Furey 1999).

On the other hand, if a multiple channel system has to be utilized (which we believe is usually the case for large firms that wish to target different customer segments), i.e., one in which external as well as internal channels are included, then channel conflict can be reduced by varying the service package that each channel distributes. Such a strategy can be useful in more ways than one. By varying the service package (even slightly), customer segments that prefer higher service levels will more likely be attracted to those channels that provide higher service levels, are pricier, as well as cost the firm more. Similarly, customer segments that are more price conscious will be more likely to be attracted to channels that distribute similar services with lower prices and lower service levels (see e.g., Moriarty and Moran 1990).

4. Application of the SCS and MS Models to Insurance

In this section, we apply both the SCS and the MS model to analyze the distribution system of a P/C insurance firm. We first apply the SCS model to determine the service operations that are inherently more transaction-based, that are similar to simple service contracts, and thus, require low human intermediation. We then apply the MS model by first describing the service functions for insurance and qualitatively assess the viability of performing these functions using emerging technologies and alternate channels. Then, we derive structural properties of the MS model. The properties derived by us are new and are helpful in answering some of the questions raised in Section 1. In particular, we examine the phenomenon of why insurance products are sold directly to customers as well as through agents, and we determine market segments based upon the distribution system's operational requirements.

4.1. *Application of the SCS model*

We apply the SCS approach to P/C insurance by determining which service functions are inherently more transaction-based, are similar to simple service contracts, and thus, require low human intermediation. We measure these three dimensions in one aggregated criterion that we refer to as the level of customization. We claim that the Internet is better suited as a distribution channel for those service operations that require low levels of customization. Furthermore, we follow the theoretical framework developed by Apte and Mason (1995) to determine guidelines for the global disaggregation of information-intensive service activities. We consider the levels of information intensity, customer contact need, and physical presence need (see Apte and Mason 1995 for their precise definitions) for each of the service functions that firms within the P/C insurance industry must perform. In Table 3, these three criteria along with the level of customization (custom level) are used to determine the Internet potential for each service operation. For example, a service operation whose performance requires (1) little customization (low customization level), (2) a lot of information (high information intensity), (3) customers to have easy and frequent access (high customer contact need), (4) little contact between customers and employees of the firm (low physical presence need) is assessed as having high Internet potential. In the same table, we show the current use of the Internet by major players within the automobile insurance market for those channel functions. Our findings support the predictions of the SCS model but more importantly in the context of the MS model validate the classification of service functions in Table 2.

4.2. *Service Functions for an Insurance Firm*

In Table 4, the eight functions described previously in Table 2 are redefined with regard to the insurance industry. For example, the need to determine product preferences for different customer segments is an "important and necessary" function, whereas (except for the case of the Internet) the logistics function does not appear to carry over to insurance.

The framework shown in Table 4 can be used to analyze whether a direct agent or an indirect agent or an entirely new media will be preferred for performing the function. The predictions made in this table with regard to the preference for independent agents are examined in Section 4.4. Many successful uses of new media in this industry are based on the factors favoring the use of alternative channels as shown in the table. For example, the Internet and around the clock call centers are very good choices for performing the function of product information (at least for some customer segments). On the other hand, agents are a good choice for those policies that require greater product customization, availability, product quality assurance, and lot size. These inferences are supported by the use of the Internet shown in Table 3. The classification scheme shown in Table 4 finds further use in

TABLE 3

Current Usage of the Internet within the Auto Insurance Industry

Channel Function	Custom Level	Information Intensity	Customer Contact Need	Physical Presence Need	Internet Potential	Percentage of Firms[1]
Product information	Low	High	High	Low	High	100
Product customization	High	Medium	Medium	Low	Medium	45
Quality assurance	High	Low	Medium	Medium	Low	0
Lot size	High	Low	Low	Low	Low	0
Assortment	Low	Medium	Medium	Medium	Medium	75
Availability	High	Low	Low	Medium	Low	0
After sales service	Medium	Medium	High	Medium	Medium	40

[1] Based on a sample of 20 websites for insurance firms.

TABLE 4
Service Functions Adapted to P/C Insurance

Function	Application to Insurance	Factors Favoring the use of Direct or Exlusive Agents	Factors Favoring the use of Independent Agents	Factors Favoring the use of Alternative Channels
Product information	Policies, prices, comparisons	Centralization of sources for policies	Comparisons between different firms easier	Convenience, 24 hour service, automated service
Product customization	Match customer preferences	Has greater knowledge of product	Has greater knowledge of customer	
Product quality assurance	Claim processing time, conversant with policy details	Firms can standardize processes	Has greater leverage with firms	
Lot size	Group policies, extra-high protection	Centralization of sources for policies		Corporation wide and affinity group sales
Assortment	Multiple policy needs	Discounts for multiple policy holders	Can search for the best deal for each policy	
Availability	Speed	Direct agent is connected to firm	Has greater leverage, i.e., can move business elsewhere	Very short transaction time
After sales service	Claims processing, change (renewal) of policy	Direct agent is connected to firm	Has greater leverage. Easier to anticipate and meet customer's changing needs	
Logistics	Customer receives policy and updates			Automation and new communication channels increase efficiency and speed

market segmentation, as explained in Section 4.4. However, some theoretical properties first need to be addressed which will be helpful within the discussion in Section 4.4.

4.3. *Some Theoretical Properties*

PROPOSITION 1. *The objective function shown in equation* (3.4.4) *is a joint concave function in the* x_{pijt}^{qk}*'s.*

Proof. First consider a simplified version of the objective function in which $r = 0$, $T = 1$, $P = 1$, $Z = 1$, $G = 1$, and let $h_i = 1$ for all i. Then the objective function can be expressed as

$$\max_{x_1, \ldots, x_n} \left\{ K\left(1 - \exp\left(-\alpha - \sum_{i=1}^{n} \beta_i x_i\right)\right) - \sum_{i=1}^{n} C_i x_i \right\}. \tag{4.3.1}$$

It is easily seen that the Hessian matrix of this function has the form of a covariance matrix multiplied by the constant $-K \exp(-\alpha - \Sigma_{i=1}^{n} \beta_i x_i)$. By definition, covariance matrices are positive semi-definite; thus the Hessian matrix is negative semi-definite. This implies that the objective function is jointly concave in x_{pijt}^{qk}'s even in the general case, since the only changes are the inclusion of additional indices for channel levels, multiple time periods, and multiple strategies. □

Remark. The propositions that follow, although based on the MS model, will hold if the objective function is jointly concave in the decision variables, namely, the x_{pijt}^{qk}'s.

PROPOSITION 2. *Assume that there are no constraints in the MS model. Then in the profit maximizing solution to* (3.4.4), *for a given non-channel strategy q and a channel strategy k in each segment p, for each time t, for each* $x_{pijt}^{qk} > 0$ *in the optimal solution, the marginal revenue from increasing* x_{pijt}^{qk} *is equal to its marginal cost. For all* $x_{pijt}^{qk} = 0$ *in the optimal solution, the marginal revenue is strictly less than the marginal cost.*

Proof. Again we use the simplified form of the objective function (4.3.1). We know that the objective function is jointly concave in the x_i and the direction of optimization is maximization. Since we are restricting the channel functions x_i's to be greater than or equal to zero, if the gradient with respect to x_i in the optimal solution were negative, then the optimal value of x_i should equal zero (because the marginal revenue $K(\beta_i \exp(-\alpha - \Sigma_{i=1}^{n} \beta_i x_i^*)) - C_i$ is strictly smaller than the marginal cost C_i at the optimal solution). On the other hand, if x_i were greater than zero in the optimal solution, then the marginal cost should be equal to the marginal revenue. □

4.4. *Customer Preferences, Demographics, and Market Segmentation*

We first show based on the above propositions that there exist at least two customer segments for P/C insurance products. This will help us establish why insurance products are sold directly to customers as well as via agents. We do this by examining the coexistence of exclusive agency firms, direct agents, and independent agency firms, following which we demonstrate that the segmentation of the market can be done by parsimonious use of demographic variables and the operational considerations given in Table 4.

Berger, Cummins, and Weiss (1995) examined the coexistence of exclusive agency firms and direct agents with independent agency firms in the P/C industry. (This reference will be denoted as BCW.) Researchers had previously established that independent agencies have higher costs than exclusive ones and thus they perhaps should not coexist with exclusive agency firms and direct agents. Two different hypotheses have been advanced to explain their coexistence. The product quality hypothesis explains the coexistence by arguing that independent agency firms provide better service and thus are able to generate higher revenues in return. Such revenues offset their higher costs. On the other hand, the market imperfection hypothesis suggests that the coexistence is due to imperfections such as price regulation, slow diffusion of information, or high search costs. Unlike the product quality hypothesis, the market imperfection hypothesis implies that exclusive and independent agents provide the same level of service. BCW show that independent agency firms are less (cost) efficient than exclusive agency firms. (Cost efficiency is defined as the ratio of the lowest achievable cost to produce a given output to the actual cost of producing the same output.) Even though the independent agency firms have lower profit efficiency, the difference between exclusive and independent agency firms is much smaller and is not statistically significant. (Profit efficiency is defined as the ratio of actual profits to potential profits.) They conclude that these findings are in keeping with the product quality hypothesis, viz., the extra costs incurred by independent agency firms are a result of the higher service levels provided to their customers, who in turn pay more for better service.

We now show that the models and propositions presented in this section together with aggregate data about the industry can be used to *re-create* BCW's conclusions. We also show that the industry data contain strong evidence that there are at least two market segments of customers: a segment in which customers prefer lower price and another in which customers prefer higher service levels. Therefore, the P/C market can and actually should be segmented based on customer preferences. Before we state the proposition, we draw attention to an important fact that is highlighted in the BCW study: Most insurance firms use either only exclusive agents or only independent agents. Firms that use a combination of the two are in the minority. The 472 property-liability insurers studied by Berger, Cummins, and Weiss represent almost 90% of industry assets over the period between 1981 and 1990. Only 26 of those firms switched from one distribution system to the other during the 10-year study and only 53 had systems which were either a combination of both direct and indirect agents or whose characteristics were indeterminable.

PROPOSITION 3. *The coexistence of two types of distribution systems with different cost structures and the decision of most firms to use either one or the other type of distribution system together indicate that there are at least two (distinct) market segments for P/C insurance products: One in which customers prefer to deal directly with an insurance firm's agent (possibly one in which price is the primary factor) and a second one in which customers prefer to deal with independent agents (possibly a segment in which service quality is very important as well).*

Proof. Assume that there is only one market segment that is served by both types of firms. Then, Proposition 2 suggests that if two "pure" channel strategies, such as the exclusive use of direct agents and the exclusive use of independent agents, are both optimal for serving this market, then any convex combination of the two strategies will yield equal profit. It is therefore surprising to find that the majority of firms use either one or the other type of agents. Thus the assumption of a single market segment must be incorrect. Channel conflict alone cannot explain the firms' choice. As we show below some states have greater share of direct writers than others—which goes to show that demographic factors favor the use of direct writers in some states. Geographic boundaries can be established to exploit this so that a firm uses direct writers in some states and independent ones in others, thereby keeping channel conflict to a minimum. We additionally show that the state-to-state variation in the market share of direct writers can be completely explained by demographic variables that in turn are related to the preference for higher or lower service requirements. Moreover, the data in Table 5 and the statistics shown in Table 6 indicate that different lines have significantly different ratios of net premiums written through exclusive agency firms. Thus, if preferences of customers are (relatively) homogeneous across states as well as across product lines, then such variation in the market share of direct writers cannot be explained based on rational

TABLE 5

Net Premiums Written (NPW) and Net Premiums Earned (NPE) by Direct Writers

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
					Fire					
NPW	35.70%	36.77%	38.37%	36.90%	36.72%	41.29%	42.45%	44.40%	44.16%	43.02%
NPE	35.26%	36.70%	37.61%	36.60%	37.05%	41.22%	41.85%	42.95%	43.47%	45.43%
					Commercial Auto Liability					
NPW	21.15%	21.36%	21.68%	20.66%	20.19%	26.29%	26.87%	25.97%	26.80%	28.14%
NPE	20.96%	21.17%	21.58%	20.56%	20.15%	26.94%	26.69%	27.10%	27.09%	27.65%
					Private Passenger Auto Liability					
NPW	68.72%	68.78%	68.34%	68.40%	68.53%	67.99%	67.22%	66.62%	67.16%	67.93%
NPE	68.72%	68.92%	68.50%	68.51%	68.67%	68.06%	67.79%	67.07%	66.70%	68.06%
					Private Passenger Automobile					
NPW	69.02%	69.36%	69.17%	69.00%	68.75%	68.01%	67.58%	68.01%	68.36%	68.53%
NPE	68.93%	69.42%	69.39%	69.13%	68.72%	68.81%	68.53%	67.99%	67.62%	68.67%
					Homeowners Multiple Peril					
NPW	58.24%	61.82%	63.33%	63.62%	64.00%	64.79%	64.77%	65.78%	67.26%	67.98%
NPE	57.21%	60.24%	62.43%	63.19%	63.78%	64.88%	64.52%	65.75%	66.06%	68.21%

TABLE 6

Net Premiums Written by Exclusive Agency Firms

Line	Mean	Std Deviation	Lower[1]	Upper[2]	Min	Max
Fire	28.76%	7.83%	27.52%	30.00%	13.87%	47.70%
Auto[3]	68.84%	10.99%	67.09%	70.58%	26.01%	84.64%
Home[4]	60.75%	14.41%	58.48%	63.02%	17.02%	82.53%

[1] Lower limit of a 95% confidence interval for the mean percentage of NPWs by exclusive agency firms.
[2] Upper limit of a 95% confidence interval for the mean percentage of NPWs by exclusive agency firms.
[3] Private passenger auto physical damage.
[4] Homeowners multiple peril.

decision making by firms. It therefore follows that demographic factors that account for customer preferences (and other factors such as state regulations) and the variations in the service requirements across lines of insurance must not only significantly influence firms to concentrate on different customer segments but also compel them to use different distribution strategies to reach different market segments. □

Remarks. (1) Based on the analysis presented above, it is more reasonable to expect that firms that attempt to reach multiple market segments find it difficult to focus their strategies. In other words, such firms must not only be able to provide the extra service to a segment of its customers but also must be able to maintain a reputation as a provider of high-quality service. Achieving these dual objectives is more of a problem for firms that try to sell in (both) multiple market segments since it is already known that they provide no-frills service to other customers for a (significantly) lower price. Therefore, we hypothesize that signaling better quality or better price, and preventing customers that prefer personalized service from buying the low cost product, is a much more severe problem for insurers than it is for a seller of industrial products.

(2) In BCW's analysis, the data on all states and all lines were pooled together for examining the product quality hypothesis. The pooled data were used to construct non-parametric estimates of cost and profit efficiency. As we show below, the disaggregated data are so heterogeneous that analysis based on aggregate data cannot be easily used for answering many of the questions posed by executives in this industry and is summarized in Section 1.

MARKET SEGMENTATION. We now show how the market can be segmented using distribution-specific operational considerations. We demonstrate that the classification of service functions in Table 4 provides the necessary guidelines.

LINE-TO-LINE VARIATION. In Table 5, the percentage of net premiums written (NPW) and net premiums earned (NPE) by exclusive agency firms with respect to the total NPW and NPE for each line are shown for five lines of P/C insurance for the years 1991 to 2000 (A. M. Best 1996, 2001). We first observe that for each line, the variation of this percentage is relatively small from year to year. In contrast, there is a tremendous difference between personal and commercial lines of insurance. We tested this conjecture using the null hypothesis that the market share of direct writers were equal for all five lines versus the alternative hypothesis that at least one pair differs. The results of this test are shown in Appendix A and confirm that there is significant difference in the market share of direct writers among lines.

STATE-TO-STATE VARIATION. The variation in the percentage of net premiums written by exclusive agency firms is not only among different lines. There is also substantial variation from state to state within any line. This is documented by data (drawn from A. M. Best tapes) that contain the percentage of net premiums written by exclusive agency firms for each of the separate lines of fire, homeowners multiple peril, and private passenger auto physical damage for each of the 50 U.S. states and the District of Columbia for the years 1995–1997. Some summary statistics as well as confidence intervals for the population mean percentage of net premiums written by exclusive agency firms over the 50 states are shown in Table 6. From the fact that the confidence intervals for each of the three means are so different (there is no overlap of the ranges), we conclude that there exists significant line-to-line variation. Also, from the fact that standard deviation as well as the range of the percentage of net premiums written by exclusive agency firms within each line is large, there is evidence of state-to-state variation as well.

Demographics and service functions. The state-to-state variation suggests that demographics provide a basis for segmenting customers and creating data warehouses. The contribution of this section is that through the use of a few variables and the classification of service functions in Table 4, we explain a significant amount of the variation in the market share data. We observed that the percentage of direct agency NPW was correlated with several demographic variables, such as household income, population density, unemployment level, percentage of population living in a metropolitan area, and industrial concentration. These relationships can be explained via the classification of the service functions listed in Table 4.

The first set of service functions we consider are *product customization* and *quality assurance*. Accordingly, states with higher unemployment rates and lower disposable income should see a larger fraction of premiums written by direct writers. To test this, we formulated the following set of propositions: (A) We expect to see a positive linear relationship between the unemployment rate in a state and the market share of direct writers (DW) for auto insurance. (B) We expect a negative linear relationship between the per capita income in a state and the market share of DW for fire insurance. (C) We expect to see a negative linear relationship between the per capita income in a state and the market share of DW for home insurance. The statistical test results are shown in Appendix B. In all three cases we find evidence of a linear relationship in the hypothesized direction.

The next service function we consider is *lot size*. In general, commercial and/or corporate customers have larger insurance needs and thus a more pronounced lot size effect. As suggested in Table 4, independent agency firms should have an advantage when the average policy sold for a particular line is large and expensive. Thus we expect to see a smaller share of fire insurance by direct writers. (D) The mean market share through direct writers of personal auto, home, and fire are not equal. The market share of direct writers should be lower for fire insurance. The result of this hypothesis test is shown in Appendix C. From the coefficients of the regression model, we see that the most pronounced difference in market share is between fire and either home or auto.

General linear model. Given the strong relationships with demographic variables and the market share of direct writers, it seems reasonable to attempt to explain the variation in market share of direct writers for *all* lines using a single model. To develop a single model, we used the different states as levels of the qualitative variable describing customer preferences and demographics, and the different lines of insurance as levels for the qualitative variable describing product-specific preferences. Using the data that were available to us, we are able to explain over 99% of the variation in the market share through direct writers using only the variables line, state, and their interaction, which were all statistically significant (see Appendix D for the analysis of variance from the general linear model). The predicted market share through direct writers (fitted values) of the general linear model along with the true market share through direct writers (actual market share) are displayed in Figure 1. We conclude that there is strong evidence that a parsimonious model can be created for segmenting a P/C insurance firm's market.

In fact, we may infer from the general linear model that on a macro level just a few demographic variables can describe the variation in the market share of direct writers. This we hope will serve as a starting point for future work on creating more specific

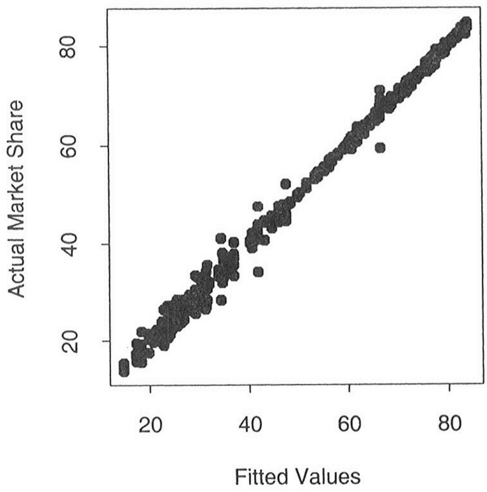

FIGURE 1. Market Share of Direct Writers, General Linear Model Results.

models. For example, to create a firm-specific and/or line-specific model, one would require demographic variable data on a much finer granularity, for example, at the level of towns or counties. In such a case, one would also want to include data on variables that represent the service functions shown in Table 4. Similarly, competitive activities within the region in question will need to be described to use our framework. Furthermore, not all of the levels of the qualitative variables nor all of their interactions should necessarily be used in creating a model. Since we are interested in describing the variation in the market share data on a macro level, we use a general linear model (i.e., we use all levels of the qualitative variables and all interaction terms) as opposed to a regression model with only the most significant levels of both the qualitative variables and their interactions.

5. Conclusions and Directions for Future Research

A framework was presented for the design of distribution systems for the P/C insurance industry. Empirical data were used to validate this framework and to verify its consistency. Both the qualitative and the quantitative analysis presented in this paper suggest that this framework is potentially useful to managers for designing their service operations.

Our main finding is that it is no longer a 0/1 choice whether a direct or an indirect channel is to be used by firms to distribute their insurance products. Rather, firms must determine which functions their customers prefer to have performed through which channels. Moreover, the classification scheme for channel functions that was proposed in the context of physical products appears to carry over nicely to the distribution of a service. It would be interesting to see whether similar conclusions could be drawn with respect to the design of service systems other than insurance.

The integrated service system design problem can be divided into three parts. The first task is to create segments that have similar service requirements. We have identified a list of channel functions that can be used to describe these service requirements, which in turn form a basis for segmenting the market. The second task is to design the distribution system itself. The MS model can be used for this purpose. However, the third and hardest task, as described in Section 3.5, is to determine how a firm should deliver its services with various service levels using multiple channels while creating the least channel conflict. This should be taken into consideration when a firm-specific model is to be developed.

Appendix A: Testing of Line to Line Variation

To perform this hypothesis test, we regressed the percentage of NPW by direct writers against the qualitative variable *line of insurance*. The regression was performed by using dummy variables for the various levels of the qualitative variable with commercial auto liability as the base level. The results are shown below. Note that the various levels (not including the base level) of the qualitative variable *line of insurance* are fire, private passenger auto liability (PPAL), private passenger automobile (PPA), and homeowners multiple peril (HME).

Predictor	Coefficient	Standard Deviation	*T*	*P* Value
Constant	23.9114	0.7758	30.82	0.000
Fire	16.067	1.097	14.64	0.000
PPAL	44.058	1.097	40.16	0.000
PPA	44.667	1.097	40.71	0.000
HME	40.248	1.097	36.69	0.000
S = 2.453	R-Sq = 98.3%	R-Sq(adj) = 98.2%		

Analysis of Variance

Source	*df*	SS	MS	*F*	*P*
Regression	4	16,069.9	4017.5	667.57	0.000
Residual error	45	270.8	6.0		
Total	49	16,340.7			

Appendix B: Testing of Propositions A–C

To test propositions A–C described in Section 4.4, we conducted a hypothesis test for each proposition. In each case, ρ refers to the true correlation coefficient between the variables in question. In Proposition A, the variables were unemployment rate and market share of auto insurance. In Proposition B, the variables were per capita income and market share of fire insurance. In Proposition C, the variables were per capita income and market share of home insurance. In the table below, the column titled Correlation Coefficient corresponds to the sample or observed correlation coefficient.

Proposition	Hypothesis Test	Correlation Coefficient	*T*	*P* Value
A	H0: $\rho = 0$, HA: $\rho > 0$	0.311	2.314	0.012
B	H0: $\rho = 0$, HA: $\rho < 0$	−0.433	−3.397	0.001
C	H0: $\rho = 0$, HA: $\rho < 0$	−0.529	−4.408	<0.001

Results of t tests where $t = (r\sqrt{n-2})/(\sqrt{1-r^2})$.

Appendix C: Testing of Proposition D

To perform this test, we regressed the market share through direct writers for any state and any line against the qualitative variable *line* with levels home (the base level), auto, and fire.

Predictor	Coefficient	Standard Deviation	*T*	*P* Value
Constant	60.799	1.590	38.24	0.000
Auto	8.142	2.249	3.62	0.000
Fire	−31.084	2.249	−13.82	0.000
S = 11.47	R-Sq = 68.9%	R-Sq(adj) = 68.5%		

Analysis of Variance

Source	*df*	SS	MS	*F*	*P*
Regression	2	44,567	22,283	169.52	0.000
Residual error	153	20,112	131		
Total	155	64,679			

Appendix D: Analysis of Variance of General Linear Model

To explain the variation in the market share in direct writers, we ran a general linear model using the qualitative variables *line* and *state*. The variable *line* had three levels corresponding to the three lines of insurance studied and the variable *state* had 51 levels corresponding to the 50 states in the U.S. along with the District of Columbia. The interaction between these two qualitative variables was considered as well (see Line*State in the Analysis of Variance section). The most significant variable was *line* followed by *state* and then their interaction.

General Linear Model

Factor	Type	Levels
Line	Fixed	3
State	Fixed	51

Analysis of Variance

Source	*df*	Seq SS	Adj SS	Adj MS	*F*	*P*
Line	2	137,421.9	137,421.9	68,710.9	2.5E+04	0.000
State	50	40,341.2	40,341.2	806.8	294.62	0.000
Line*State	100	18,046.1	18,046.1	180.5	65.90	0.000
Error	306	838.0	838.0	2.7		
Total	458	196,647.1				

References

A. M. Best Company (2001), *Best's Aggregates and Averages*, ed., Oldwick, NJ.

A. M. Best Company (1996), *Best's Aggregates and Averages*, ed., Oldwick, NJ.

Apte, U. M. and R. O. Mason (1995), "Global Disaggregation of Information-Intensive Services," *Management Science*, 41, 7, 1250–1262.

Apte, U. M. and A. P. J. Vepsalainen (1993), "High Tech or High Touch? Efficient Channel Strategies for Delivering Financial Services," *Journal of Strategic Information Systems*, 2, 1, 39–54.

Aspinwall, L. (1962), "The Characteristics of Goods Theory," *Managerial Marketing: Perspectives and Viewpoints*, Lazer, W. and Kelley, E. J., (eds.), Richard D. Irwin, Homewood, IL, 633–643.

Balderston, F. E. (1958), "Communication Networks in Intermediate Markets," *Management Science*, 4, 1, 154–171.

Baligh, H. H. and L. E. Richatz (1967), *Vertical Market Structures*, Allyn and Bacon, Boston.

Berger, A. N., J. D. Cummins, and M. A. Weiss (1997), "The Coexistence of Multiple Distribution Systems for Financial Services: The Case of Property-Liability Insurance," *Journal of Business*, 70, 4, 515–546.

Bowersox, D. J. and M. B. Cooper (1992), *Strategic Marketing Channel Management*, McGraw-Hill, New York.

Bucklin, L. P. (1966), "A Theory of Distribution Channel Structure," *IBER Special Publications*, CA, 7–16.

Cook, D. O. and J. D. Cummins (1996), "Productivity and Efficiency in Insurance: An Overview of the Issues," paper 96-57, Wharton Financial Institutions Center, The Wharton School, University of Pennsylvania, PA.

Coughlan, A. T. (1985), "Competition and Cooperation in Marketing Channel Choice: Theory and Application," *Marketing Science*, 4, 2, 110–129.

Corstjens, M. and P. Doyle (1979), "Channel Optimization in Complex Marketing Systems," *Management Science*, 25, 10, 1014–1025.

Crosby, L. A., K. R. Evans, and D. Cowles (1990), "Relationship Quality in Services Selling," *Journal of Marketing*, 54, 68–81.

Crosby, L. A. and N. Stephens (1987), "Effects of Relationship Marketing on Satisfaction, Retention, and Prices in the Life Insurance Industry," *Journal of Marketing Research*, 24, 404–411.

Donnelly, J. H. and J. P. Guiltinan (1986), "Selecting Channels of Distribution for Services," in *Handbook of Modern Marketing*, V. P. Buell (ed.), McGraw-Hill, New York.

EIU (2000), *Property and Casualty: Mapping the Future*, The Economist Intelligence Unit and Pricewaterhouse, Coopers.

Etgar, M. (1978), "Interchannel Conflict and the Use of Power," *Journal of Marketing Research*, 15, 2, 273–274.

Friedman, L. D. and T. R. Furey (1999), *The Channel Advantage*, Butterworth-Heinemann, Oxford.

Hegde, G. (1986), "Market for Product Support," Ph.D. Dissertation, University of Rochester.

Hunt, S. D. and J. R. Nevin (1974), "Power in a Channel of Distribution: Sources and Consequences," *Journal of Marketing Research*, 11, 2, 186–191.

IBM/Economist, Global Insurance to the 21st Century (1996), The Economist Intelligence Unit, and IBM Insurance Solutions.

Insurance Advisory Board (1998), CEO Briefing: A Call to Arms, The Mandate for Distribution Innovation in the Shrinking Life Insurance Market, Insurance Advisory Board, The Watergate, 600 New Hampshire Ave., N. W., Washington, D.C. 20037.

JEULAND, A. P. AND S. M. SHUGAN (1983), "Managing Channel Profits," *Marketing Science*, 2, 3, 239–272.

KENNICKELL, A. B. AND M. L. KWAST (1997), "Who Uses Electronic Banking? Results from the 1995 Survey of Consumer Finances," Proceedings of the 33rd Annual Conference on Bank Structure and Competition, Federal Reserve Bank of Chicago, May, 56–75.

KIM, W. J., D. MAYERS, AND C. W. SMITH, JR. (1996), "On the Choice of Insurance Distribution Systems," *Journal of Risk and Insurance*, 62, 207–228.

LILIEN, G. L. AND P. KOTLER (1983), *Marketing Decision Making: a Model-Building Approach, Harper and Row*, New York.

LUSCH, R. F. (1976), "Sources of Power: Their Impact on Intrachannel Conflict," *Journal of Marketing Research*, 13, 4, 382–390.

MAYERS, D. AND C. W. SMITH, JR. (1981), "Contractual Provisions, Organizational Structure, and Conflict Control in Insurance Markets," *Journal of Business*, 54, 407–434.

MCCAMMON, B. C. AND R. W. LITTLE (1965), "Marketing Channels: Analytical Systems and Approaches," *Science in Marketing*, G. Schwartz (ed.), Wiley, New York, 321–385.

MCGUIRE, T. W. AND R. STAELIN (1983), "An Industry Equilibrium Analysis of Downstream Vertical Integration," *Marketing Science*, 2, 2, 161–191.

MORIARTY, R. AND U. MORAN (1990), "Managing Hybrid Marketing Systems," *Harvard Business Review*, November-December.

MOSES, M. AND S. SESHADRI (2000), "Policy Mechanisms for Supply Chain Coordination," *IIE Transactions*, 32, 3, 245–262.

NAERT, P. A. (1970), "Mathematical Models of Vertical Market Structures," Ph.D. Dissertation, Cornell University.

POSEY, L. L. AND A. YAVAS (1995), "A Search Model of Marketing Systems in Property Liability Insurance," *Journal of Risk and Insurance*, 62, 4, 666–689.

RANGAN, V. K. (1987), "The Channel Design Decision: A Model and an Application," *Marketing Science*, 6, 2, 156–174.

RANGAN, V. K. AND R. JAIKUMAR (1991), "Integrating Distribution Strategy and Tactics: A Model and an Application," *Management Science*, 37, 11, 1377–1389.

ROSENBERG, L. J. AND L. W. STERN (1971), "Conflict Measurement in the Distribution Channel," *Journal of Marketing Research*, 8, 4, 437–442.

SHUGAN, S. M. (1985), "Implicit Understandings in Channels of Distribution," *Management Science*, 31, 4, 435–460.

VENEZIA, I., GALAI, D., AND SHAPIRA, Z. (1999), "Exclusive vs. Independent Agents: A Separating Equilibrium Approach," *Journal of Economic Behavior and Organizations*, 40, 443–456.

ZUSMAN, P. AND M. ETGAR (1981), "Marketing Channel as an Equilibrium Set of Contracts," *Management Science*, 27, 3, 284–302.

Avi Giloni is an Assistant Professor of Business Statistics and Operations Research at the Sy Syms School of Business, Yeshiva University in New York. He received a Bachelor of Arts degree in Mathematics in 1994 from the College of Arts and Science, New York University, a Master of Science degree in 1997 and a Ph.D. in Statistics and Operations Research in 2000 from the Stern School of Business, New York University. His areas of research are optimization, robust forecasting, and stochastic system design.

Sridhar Seshadri is an Associate Professor of Operations Management, Leonard N. Stern School of Business, New York University. He received his Bachelor of Technology degree from the Indian Institute of Technology, Madras, his Post Graduate Diploma in Management from the Indian Institute of Management, Ahmedabad, and his Ph.D. degree from the University of California at Berkeley. He is a Fellow of the Institution of Engineers (India). His current research interests are in the area of risk management for supply chains and performance measurement and optimization of stochastic service systems. He serves as an Associate Editor for *Naval Research Logistics*, *Telecommunication Systems Journal*, and the *Production and Operations Management Journal*. He is the current Area Editor for Inventory, Reliability and Control for *Operations Research Letters*.

Pasumati V. Kamesam is currently a Senior Manager in the IBM Research Laboratory located in New Delhi, India. He obtained his Ph.D. in Operations Research from the University of Wisconsin at Madison. He served as an Assistant Professor at the University of Maryland in Baltimore. He has been a Research Staff Member at the IBM Watson Research Center since 1986. He worked in the areas of Logistics, Manufacturing Research, Supply Chain Management, Mathematical Optimization, VLSI physical design and a number of other areas. He served as an Associate Editor of *Operations Research*.