

# Management Science at Merrill Lynch Private Client Group

---

Russ Labe

*Management Science Group  
Merrill Lynch Private Client Group  
800 Scudders Mill Road  
Plainsboro, New Jersey 08536*

Raj Nigam

*Management Science Group  
Merrill Lynch Private Client Group*

Steve Spence

*Management Science Group  
Merrill Lynch Private Client Group*

---

Merrill Lynch Private Client Group won the 1997 INFORMS Prize for effective use and impact of management science on the organizational success of the firm. Merrill Lynch established its management science group in 1986. The group's mission is to provide high-end quantitative analysis to support strategic management decisions and to enhance the financial consultant-client relationship. Hallmarks of our approach include objectivity, communication skills, teamwork, and consulting skills in addition to the required technical knowledge. We have developed special expertise in selected areas that are vital to Merrill Lynch's businesses. These include asset-allocation analysis and modeling, financial-planning support and analysis, investment strategies, expert systems, marketing-information technology, prospecting and cross-selling models, and portfolio-performance measurement. The impact and success of the group can be measured in hard dollars, repeat business, the development and analysis of strategic initiatives, and the tools we developed to assist the salesforce.

**M**errill Lynch is a brokerage and financial services firm concentrating on client relationships. In 1997, it had net

revenues of \$15.6 billion, net earnings of \$1.9 billion, and return on equity of 26.8 percent. It has more than 56,000 employ-

---

Copyright © 1999, Institute for Operations Research and the Management Sciences  
0092-2102/99/2902/0001/\$5.00  
This paper was refereed.

---

FINANCIAL INSTITUTIONS—BROKERAGE/TRADING  
INFORMATION SYSTEMS—EXPERT SYSTEMS

ees in 45 countries serving its client base through two primary business units. Merrill Lynch's Corporate and Institutional Client Group serves more than 7,000 corporations, institutions, and governments and has consistently ranked near the top in debt and equity underwriting and overall private placements. The Merrill Lynch Private Client Group (MLPC) serves more than four million households, 225,000 small- to mid-sized businesses, and regional financial institutions, using a planning-based financial-services approach through more than 14,400 financial consultants (FCs) in over 660 branch offices worldwide. Merrill Lynch, through its affiliates and subsidiaries, provides clients with financial advice, banking and brokerage services, insurance, mortgages, financial planning, business financing, and asset management services. It is also among the three largest providers of 401(k) programs, serves over 2.6 million individual retirement plan accounts, and is the most active trading firm on the New York Stock Exchange. In October 1997, Merrill Lynch surpassed \$1 trillion in client assets.

Asset gathering has been Merrill Lynch's core business strategy since the 1980s. Merrill Lynch initiated this strategy to impart a long-term, rather than day-to-day, trading perspective and to encourage clients to consolidate all their assets here. In 1992, it further refined its growth strategy by focusing on three key business drivers—planning, investment performance, and personalized service—to move the firm toward its vision as the “premier, planning-based financial-services firm of choice.” MLPC tries to meet the full range

of financial needs of an individual, including assets, liabilities, transition and retirement needs—what we call “the A/L/T strategy.”

#### **The Management Science Group**

In 1986, Merrill Lynch established its management science group, which currently consists of nine individuals. It has been part of MLPC since 1991.

We provide high-end quantitative analyses and modeling to help management make strategic decisions and to enhance the FC-client relationship. Our implemented models help FCs offer value-added solutions and services to clients. We support MLPC executive management and business units by analyzing data on clients, products, services, and the marketplace. We also identify new marketing technologies and pilot those with high potential.

We focus on the business problem to be solved, paying attention to what the data actually reveal, and employ a broad range of operations research and management science techniques, including optimization, simulation, expert systems, neural networks, and advanced multivariate statistics. To ensure a focus on implementation and business impact, we tackle all aspects of the situation, including collection, maintenance, and validation of data on both mainframe and PC platforms. We have acquired the reputation of an objective, independent, analytical entity that has a can-do attitude.

Our efforts are aligned with Merrill Lynch's strategy of growth through planning, investment performance, and personalized service. We work in a broad range of functional areas including seg-

ment marketing, investment research, finance and credit, product marketing, performance, client satisfaction, human resources, and information systems.

**The Management Science Group's Approach**

Technical expertise and objectivity are necessary in an analytical group such as ours. But they are not sufficient by themselves. Communications skills, proactivity, teamwork, integration of various data, and consulting skills play an equally critical role.

We initiate all major projects with a proposal. After a few face-to-face meetings, we prepare a proposal outlining the background, objectives, approach, resources required, time schedule, and implementation issues. We focus on the business issues and develop solutions that provide significant value and can be easily implemented. During this contracting process, we establish and make explicit the expectations of both parties and the common understanding of the issues, thereby fostering a partnership. We follow this up with frequent meetings with the business groups (our clients), apprising them of our intermediate findings and then presenting a final report. Constant communication is key. We recommend such a process for all major projects. The business issues we face today are so far-reaching and complex that they are beyond the capability of any one group to resolve. Teamwork is essential. We must get along with people of different skills, perspectives, and motivations. We focus on the goals of the firm rather than those of the department. Our group's members have a broad range of multifunctional, multidisciplinary interests

and are motivated to provide solutions. We augment our skills through classes in team approaches, facilitation, and conflict resolution, and we have led several cross-functional teams.

---

**Asset gathering has been Merrill Lynch's core business strategy since the 1980s.**

---

To resolve complex business issues, we integrate data from various sources. To ensure data integrity and cross-validation, we rely on basic-database, exploratory-data-analysis, and computer skills. And after we complete a project, we often do a technology transfer to the business group of the refined data we compiled and the analytical models we built. This enhances the business group's capability, while it allows us to handle new challenges.

In this age of rapid advances in analytical, data, systems, and computer technologies, we estimate that the half-life of our technical knowledge is three to four years. This means that half of what we know and use today will not be relevant three to four years from now. We need to ensure that we will continue to be effective and in demand later. Setting aside 10 percent of our time for acquiring and understanding new material is essential. We attend conferences, publish, read, talk to software and analytical vendors, interact with peer professionals, obtain professional certification, and evaluate new software to keep up our professional competence.

**The Management Science Group's Accomplishments**

While we provide analytic and business assistance in several functional areas, we

have developed special expertise in selected areas that are vital to Merrill Lynch's core strategy and to executive management. These areas are asset allocation, financial planning, investment strategies, expert systems, new marketing technologies, prospecting and cross-selling, portfolio performance, promotions, and pricing.

#### **Asset-Allocation Analysis and Modeling**

Merrill Lynch provides clients with advice and guidance customized to their risk tolerance and financial goals. One aspect of this is recommending an appropriate asset-allocation strategy, typically characterized by a particular mix of equity, debt, and cash percentages. We developed models to help the FC and client determine an appropriate investment strategy and to recommend optimal risk-reward portfolios that help implement the strategy.

In 1991–1992, a team drawn from various parts of MLPC and Merrill Lynch Global Research and Economics participated in discussions to define five asset-allocation strategies that span the risk-return spectrum. Charles Clough, chief investment strategist, led the effort to define five strategies—capital preservation, current income, income and growth, long-term growth, and aggressive growth—ranging from the most conservative to the most aggressive. The percentage of equities runs from 10 percent in the most conservative case to 80 percent in the most aggressive case. The percentages are adjusted as market conditions warrant. An investor holding treasury notes or federally insured CDs would be an example of a very conservative investor, while one holding only technology stocks would be

deemed a very aggressive investor.

We and members of Merrill Lynch's financial-planning-services group developed an expert system that examines a client profile and recommends which of the five asset-allocation strategies is most appropriate. We developed the model through a series of knowledge-engineering work sessions. Inputs to the model include client demographics, risk tolerance, and current investment behavior. The firm implemented this model in 1992 with its original rollout of the Financial Foundation report, its financial-planning service, and it had completed over 500,000 plans by the end of 1997 (Figure 1).

The success of this approach led to development of similar rule-based models for other planning-related tools. We developed a version for the 401(k) market and service-marked it as the Retirement Asset Selector. We provide this tool to 401(k) participants to help them construct an investment portfolio for their retirement assets. Based on a more restricted set of client demographics, it again suggests the most appropriate asset-allocation strategy from among a subset of the same five categories.

We developed another version of the expert system for Merrill Lynch's Mutual Fund Advisor (MFA) program. The MFA program provides customized portfolios of mutual funds, which are actively managed over time. It uses a modified version of the five asset-allocation strategies as a general guideline in establishing portfolios and also considers a client's interest in international investments and tax-exempt funds. MFA was introduced in 1993 and grew to over \$5 billion in client assets by

**Current Asset Allocation**

**Proposed Asset Allocation**

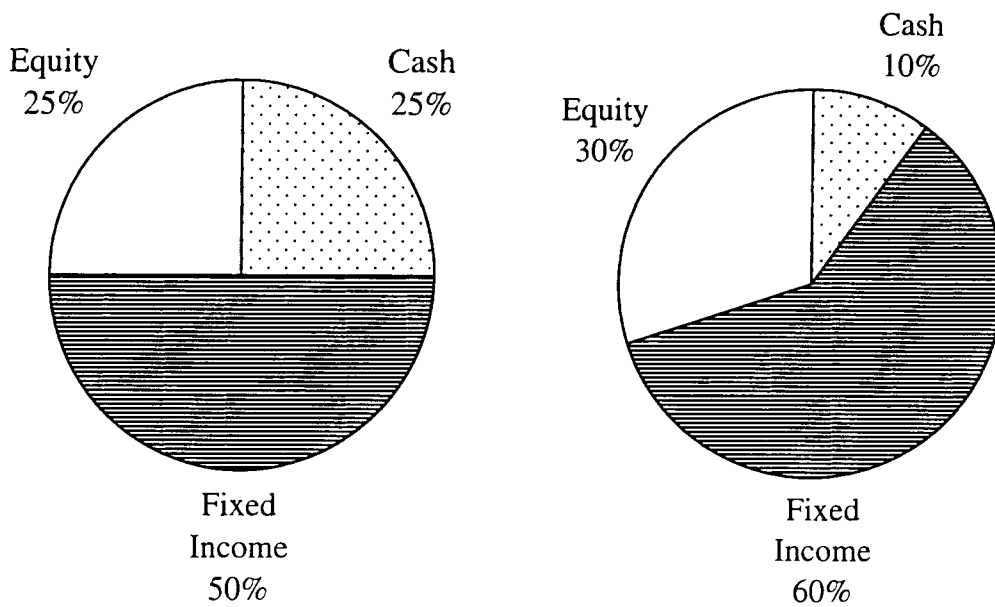


Figure 1: Merrill Lynch uses such a graph in its Financial Foundation report to illustrate a client's current allocation and the allocation the firm proposes based on the client's risk tolerance and other factors. The proposed allocation provides a basis for discussions with the financial consultant.

the end of 1997. A client enrolling in this program fills out a questionnaire. The system feeds data from the questionnaire into our expert system to help determine the client's investor profile and the appropriate asset-allocation strategy. This is then used to select mutual funds for the portfolio.

Portfolio Select is another portfolio management tool that enables FCs to provide guidance to clients on asset allocation. It is also based on the five asset-allocation strategies, but it takes them to the next level, moving below the high-level categories of equity, debt, and cash to address such subcategories as large versus small capitalization and short- versus long-term maturity. We conducted a mean-variance

optimization with nine asset-class indices to construct the model portfolios used as a basis for the Portfolio Select recommendations. This tool was piloted in 1996 and is currently used by 1,500 FCs.

Another area related to asset-allocation analysis is helping the FC to structure and select mutual-fund portfolios. During 1995-1996, we developed a series of optimal mutual-fund portfolios based on a universe of 26 Merrill Lynch funds. The portfolios are based on a Markowitz efficient frontier, which we develop using quadratic programming [Markowitz 1996]. The objective is to create a model portfolio that optimizes portfolio risk and return based on historical performance and the Clough asset-allocation models. We do

this by optimizing portfolio risk subject to a number of mixed-integer constraints. Inputs to the model include historical average monthly return, standard deviation based on the last three years of history, and the covariance matrix across the 26 funds over the same time period. Additional inputs include the percentage of equity and debt in each fund, the percentage of international assets, and the percentage of tax-exempt assets. The mathematical formulation of the model we developed is detailed in the appendix. We constructed different portfolios for each of the five asset-allocation strategies. In addition, we provided alternative solutions depending on the client's preference for international investing and tax minimization. These models were implemented for the first time in 1996 in a CD-ROM, which was provided to about 4,000 FCs. The models are updated and distributed to financial consultants quarterly.

We are now enhancing the model to expand it to a broader universe of about 200 mutual funds covering over 35 fund families. As has been well documented, the Markowitz mean-variance approach begins to break down when there are more than 20 or 30 investment choices. As a result, we had to use a different approach to expand this universe. Our new approach is based on using style analysis at the mutual-fund level to attribute each mutual fund into its underlying asset-class percentages. We then construct the covariance matrix based on the historical correlations among the style-asset classes. The decision variables in the optimization model remain the mix of the individual mutual funds.

### **Financial Planning Support and Analysis**

Beginning in 1992 with the launch of the Financial Foundation service, financial planning became a core part of Merrill Lynch's business strategy. Financial planning helps the firm to strengthen client relationships and differentiates us from competitors. The management science group has been involved in developing financial planning products and supporting the business since its inception.

---

**We estimate the half-life of our technical knowledge is three to four years.**

---

Prior to 1996, Merrill Lynch used several different methods for evaluating the psychological risk tolerance of clients. It used different approaches to perform the analysis in different products. In 1995, we headed up a cross-functional task force to develop a single, consistent method for assessing risk tolerance. We conducted research on existing risk-assessment tools, both at Merrill Lynch and in the published literature. After several rounds of refinement, we developed a six-question multiple-choice questionnaire. We tested the questionnaire in a series of three validations: first through a sample of employees, second through one-on-one interviews with clients and prospects, and finally with a broad telephone survey of clients and prospects. We used statistical tests, such as Cronbach's alpha, to test for internal consistency across the questions and to identify questions that could be dropped. We used correlation analysis to determine appropriate weights for the individual questions. Since its completion, the risk

test has been implemented for the Financial Foundation report as a supplemental questionnaire to the basic form, the Asset Allocation Planner brochure, the Portfolio Select diskette, and in the Investor Services expert system to support the salesforce. This has brought analytics and consistency to the very critical area of assessing risk tolerance. The FCs and their clients use all of these tools heavily.

From 1993 to 1997, we conducted a series of studies to determine the business impact of MLPC's planning-based strategy and specifically of its Financial Foundation product. We tracked two different samples of Financial Foundation clients for up to 30 months and compared them to a control group. We conducted detailed analyses to examine the impact of this strategy and product on clients' assets, revenues, satisfaction, retention, and breadth of relationships with the firm, and the performance of their investments. These analyses have helped assure management that the financial-planning-based strategy is consistent with and supportive of the A/L/T strategy.

Preparing a financial plan is really just the first step of a more comprehensive planning process. To gain the true benefits of planning, the client and the FC should take action and follow through on the plan. The full planning process consists of the following sequential steps (Figure 2): client profiling, plan preparation, plan implementation, and monitoring progress toward goals. The last step closes the loop in the process and brings the FC and the client back to updating the profile and the goals. Through this dynamic process, Merrill Lynch continues to demonstrate its

commitment to providing planning-based financial services. To enhance the process, we developed a prototype of the Foundation Update report in 1994. This new service was introduced in 1996. It helps clients who completed a Financial Foundation service one to three years ago to monitor their progress. In 1997, we prototyped a Monte Carlo simulation-based approach to take Merrill Lynch's planning methodology to the next level. Stochastic variables include the rates of return of different asset classes and inflation. Using this approach, we can calculate the probability of a client achieving a particular goal by following different saving and investment strategies.

#### **Investment Strategies**

To help clients improve investment returns, we pioneered the development and testing of equity and fixed-income investment strategies based on theoretical justification, empirical validation, product differentiation, risk control, and ease of explanation. By combining Merrill Lynch research with publicly available data, we developed strategies that are appropriate for different segments of client risk tolerance and have demonstrated superior long-term performance.

We have demonstrated the significant practical value of Merrill Lynch research and how combinations of opinions (from such areas as technical, strategy, and fundamental) can be used to develop effective equity strategies. Over the last three years, these results have been presented to over 2,500 senior FCs through seminars, meetings, and advanced training sessions. To achieve this breakthrough, we created an extensive historical database of research

opinions, earnings-related estimates, and financial measures at the individual-security and industry-group levels. We designed, developed, and implemented a software package that utilizes multiple performance measures to assess the risk-adjusted effectiveness of a strategy. We focus on special downside measures of risk as well as more traditional risk measures.

We have also applied nontraditional techniques to the process of selecting securities. We have obtained excellent results by using neural networks to identify overvalued and undervalued stocks. The neural networks use Merrill Lynch research opinions, traditional financial ratios, and technical indicators to develop a predictive model of performance. We have also tested market-neutral portfolios, which combine long and short positions in an effort to eliminate market risk. These portfolios are based on our neural-network results and on more traditional strategies.

Based on our backtested results, we received, in 1997, over \$1 million of firm capital to implement six of the strategies and subject them to real-world, marketplace phenomena.

We also analyzed the historical performance of fixed-income laddered portfolios. Portfolio laddering entails diversifying maturities within fixed-income securities holdings. Using a novel approach, we performed a historical simulation over an 18-year period. Our results showed that the laddered portfolios provided about the same or slightly higher return with less volatility than a single security portfolio with similar average maturity. Portfolio laddering has become a centerpiece of MLPC's short-maturity fixed-income recommendations. Figure 3 shows some of the material that communicates the findings to the FCs.

**Expert Systems**

Our group developed an expert system

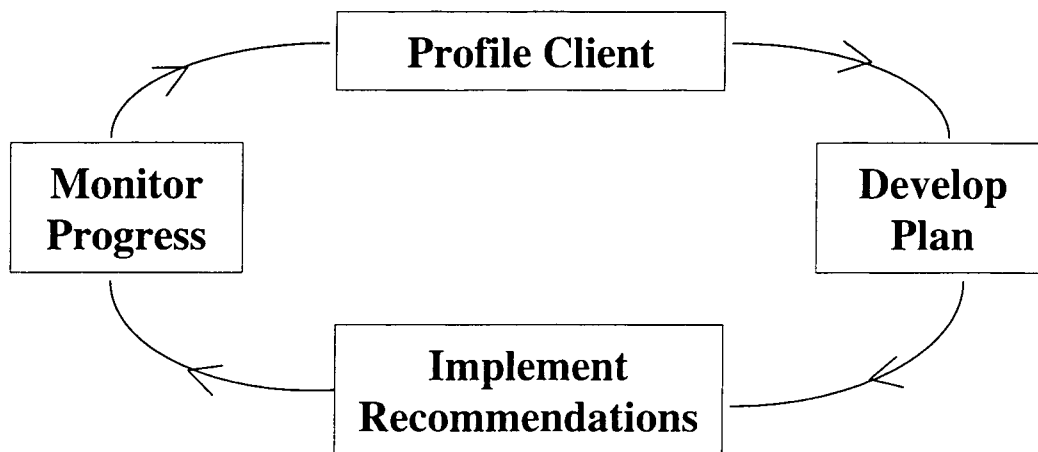


Figure 2: Financial planning at Merrill Lynch is a full-fledged process that goes far beyond running some numbers through a software package. It starts with understanding the client's goals, risk tolerances, time horizons, demographics, and other factors. The financial consultant then develops a comprehensive financial plan and makes recommendations to the client for his or her consideration. The financial consultant then monitors the progress toward the client's goals and the changes in the client's financial and personal situation.

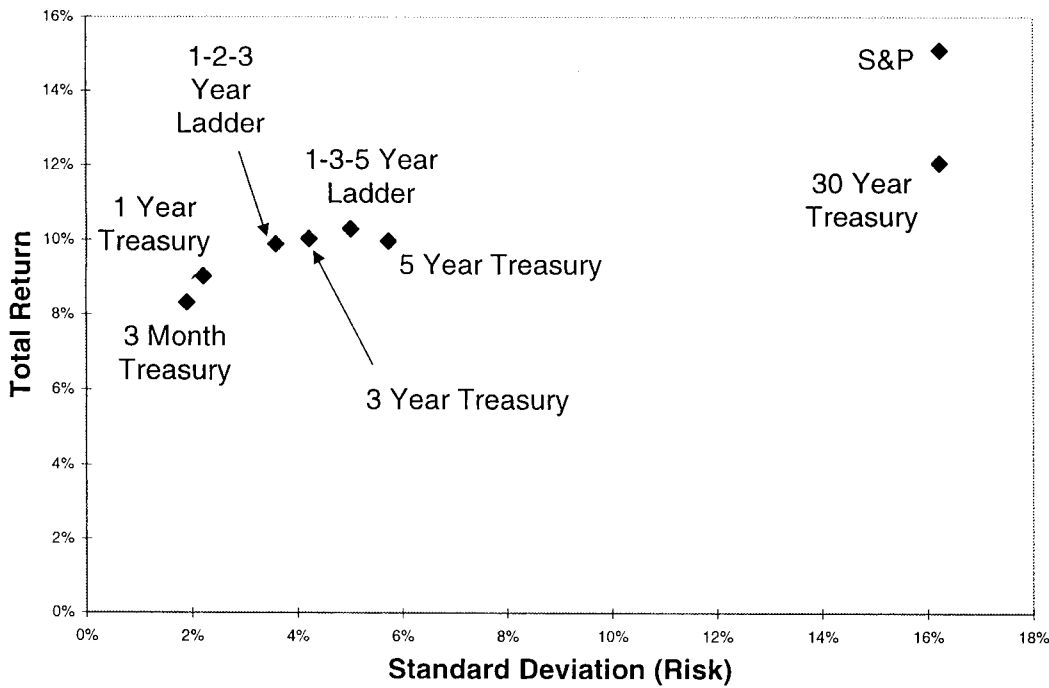


Figure 3: Various treasuries and specific treasury ladders show different trade-offs between return and risk (standard deviation of return). The 1-3-5 year ladder has an average maturity similar to that of a three-year security. To get a higher return, the client must accept more risk in the form of volatility of return. Standard deviation is only one of the ways to measure risk.

to help the credit-administration department set and review credit limits on margin loans over \$250,000. The department bases these limits on a careful evaluation of the securities in the account. These limits are in addition to the firm's standard margin limits and New York Stock Exchange rules that determine the maximum allowed debit for such accounts.

The system has two primary modules: an account analyzer and a scanner. The account analyzer allows the credit analyst to review one account at a time and interactively assess the impact of proposed changes. For example, the client may wish to purchase additional shares of a stock on margin. Based on the system's evaluation of the liquidity, quality, and volatility of

the positions and the overall portfolio diversity, it warns the credit analyst about problems in the account and proposes a credit limit. Each morning, the scanner reviews the entire database of large debit accounts that has been updated to reflect the previous day's pricing and position changes. It identifies problem accounts and prioritizes them for review by the credit analysts. Once the firm recognized that the expert system's evaluations of portfolios were accurate, it deployed the scanner function to augment the account analyzer. The credit administration department finds it the most valuable feature in the system.

We installed the production version in March 1989. It is used daily and has been

updated continually. Using the system, credit administration, without increasing staff, has reduced credit exposure, increased the number of accounts under review six-fold, and increased the amount of debt under review from \$1 billion to nearly \$4.5 billion [Beshinske 1995].

We have also developed three expert-system models that help the salesforce assess client risk tolerance and recommend portfolios from selected mutual funds. We began implementing these models in late 1996. We are developing additional expert-system models to help the salesforce by suggesting follow-up calls, identifying potential new services or features that may be suitable for the client, and assisting clients to make mutual-fund-pricing decisions (front-load, rear-load, or level-load share classes).

#### **New Marketing Technologies**

We also provide MLPC with a technology oversight function called new marketing technologies. Communicating with and providing information to our clients and prospects has evolved from monthly statements, direct mail, and print, radio and TV advertising to phone and fax technologies. We identify and monitor new technologies that are likely to have an impact on the way we market and deliver our products and services to our clients and prospects over the next two to five years. We make recommendations to senior management about pilot testing new technologies with quantitative and qualitative learning objectives. The pilot tests are normally sponsored by a segment- or product-marketing manager. Our current focus is on intelligent agents (a new category of software, which enables one to

search the web for specific information) and on using the web for a one-on-one customized interaction (using specialized software that adapts and provides responses that are appropriate and meaningful to each web user).

---

### **The group's impact can be measured in hard dollar terms.**

---

In 1994, we began to emphasize that MLPC should evaluate how the Internet would affect relationships with clients and prospects. We based our argument on many factors, primarily the emergence of the browser technology, the growth of public online services, and the development of online relationships and communities (through e-mail, chat rooms, and forums). We realized that the Internet would become a ubiquitous network affording companies a highly interactive extension to client relationships. Because the personal relationship our FCs have with clients and prospects is the cornerstone of our strategy, the Internet loomed as both a potential threat and an aid to this relationship.

In 1995, in partnership with several MLPC areas, we comanaged a multidisciplinary team to develop a Merrill Lynch presence on the Internet. The executive committee approved a plan to create an MLPC web site. Our primary objectives were to learn about the effectiveness of online prospecting and to understand what organizational impacts this new medium would have. We helped to develop the site's storyboard, navigational flowcharts, and a design metaphor. To help the

firm acquire new clients, we included a prospect-evaluation model in the site that evaluated a prospective client's future business potential. It ranked leads and provided data on those that were highly qualified to a central lead-distribution system. The model helped the FCs to focus on prospects with high potential, resulting in almost double the closure rate of other direct-marketing promotional campaigns. This work was of critical value to the firm. Management recognized that it would need a new organizational paradigm to create complementary content for the online world. The success of the pilot led Merrill Lynch to create a separate organization within MLPC to focus and lead further efforts in developing an online presence.

### **Prospecting and Cross-Selling Models**

Beginning in 1990, we advocated and implemented the use of database marketing techniques within Merrill Lynch to support both prospecting and cross-selling efforts. The objective is to identify and prioritize the best prospects or clients for a particular product or particular service, or for a broader relationship (including assets, liabilities, transition, and retirement needs) with the firm. Focusing marketing efforts on the best prospects increases MLPC's effectiveness, better aligns its resources, and enhances its performance while meeting clients' needs. In our initial efforts in 1990, we relied primarily on discriminant analysis, but we now rely largely on logistic regression and neural-network modeling.

In our first project, conducted during 1990 and 1991, we focused on identifying prospects that share characteristics with

Merrill Lynch's most valued clients. We developed and field tested a discriminant model. Over a six-month period, we demonstrated that the model significantly outperformed the baseline, generating 167 percent higher assets, 39 percent higher revenues, and 43 percent more conversions (from prospects to becoming clients). These results convinced Merrill Lynch to adopt the new model in its ongoing prospecting efforts in 1991 [Labe 1994]. The model selects approximately five million names annually, which are provided to the salesforce. We have enhanced the model several times since 1991.

The success of this project led to additional initiatives, including separate models for the IRA market and the small-business market, an online model for use on Merrill Lynch's public web site on the Internet, and a cross-selling model for municipal bonds.

### **Portfolio Performance Measurement**

Our group has played an integral role in a number of efforts within MLPC to measure and report the performance of our clients' investments. Determining investment performance at the account and relationship level in a full-service context is not simple, and financial services firms have not traditionally done it. We helped develop a methodology to accomplish this that was consistent with published standards and to verify the accuracy of its implementation through independent, thorough testing. Merrill Lynch rolled out the basic internal measurement system to the FCs for high-asset client accounts in 1994. We chaired a cross-functional steering committee that managed the expansion of the system to all accounts and enhanced it

to include additional risk and return measures. We have also played a role in the team that is designing and implementing an annual investment performance statement for clients. The first version of this report was successfully piloted in early 1998.

### **Promotions Analyses**

During the period of 1991 through 1995, we conducted a series of case studies examining the effectiveness of various internal and external promotional campaigns. We studied more than a dozen campaigns, ranging from fairly small, focused direct-mail efforts, to large, national advertising campaigns. In some cases, we conducted controlled tests to evaluate the relative contributions of internal versus external promotions and of the various advertising media (radio, national and regional print, and TV). In some of the studies, we developed a unique modeling approach to permit a detailed attribution analysis of the campaign components. We constructed state-space models using daily trading information. This allowed us to estimate the contribution of individual ads or promotion events to the total incremental business generated by a campaign. Based on the results observed across several studies, we identified critical success factors and promotion-design principles and used this information to modify MLPC's campaigns. Several campaigns were discontinued or refocused. The impact of these decisions was in the tens of millions of dollars.

### **Pricing Analyses**

During 1994, we conducted an analysis of pricing and projected demand for mutual funds that led to the introduction of level-load "C-shares" pricing. We esti-

mated the cannibalization from other mutual funds sales. Our analyses, along with marketing research among clients and FCs, led management to adopt this level-load pricing. More recently, we analyzed the pricing of equity trades, leading the firm to pilot a new salesforce discount-sharing plan. Our analysis also showed the impact that equity pricing has on the total client relationship. In recent work, we have also examined the implications of incentive fee pricing for high-net-worth clients.

### **Summary**

The management science group's impact on and its integration in the organization can be measured in hard dollar terms, in our pioneering and sustained efforts, in repeat business, in the development and analysis of strategic initiatives, in the tools we provide to the salesforce, and in our involvement in most business units. Keeping up with analytical and systems technology and paying attention to basic processes have enabled us to add value to the firm. Our focus on the firm's strategic and executive initiatives and on implementation has led to many successes.

### **Acknowledgments**

Several people and factors have contributed to the success of the management science group at Merrill Lynch. At Merrill Lynch, the people are very entrepreneurial, there is a lot of management by fact, and there is a built-in appreciation of analytics. Launny Steffens, vice chairman of Merrill Lynch and Company, and other senior executives deserve the credit for creating an environment that focuses on people and solutions.

We extend our sincere thanks to Allen

Jones, senior vice president and director of marketing, and Bill Henkel, first vice president for market planning, for constantly challenging and guiding us to ensure that our solutions can be implemented; to Mitch Farkas, John Michel, and Mike Thompson, first vice presidents in the marketing group, for their support over many years; to Gail Farkas for her leadership; and to Newt Garber and Franz Edelman for being long-time mentors. We also acknowledge the contributions of Larry Berman, a former member of our group; and Ray Beshinske, a long-time member of the group who passed away in early 1997. And last, but not least, we thank the rest of our team in management science—Stuart Altschuler, Jukti Kalita, John Longo, Gretchen Marsh, Je Oh, and Steven Sheerin—for having a can-do attitude and for insisting on excellence on a daily basis.

**APPENDIX**

**Markowitz Portfolio Model for Mutual Fund Selection**

In 1952 Harry Markowitz published his pivotal paper on portfolio selection, which would eventually earn him the 1990 Nobel Prize for economics. The Markowitz mean-variance model is used to construct a set of portfolios that comprise an efficient frontier for a set of risky assets. In the mutual-fund-selection model, the underlying risky assets are mutual funds representing a diverse set of equity, fixed-income, balanced, international, and tax-free funds as well as a proxy (30-day T-bill) for a money market cash fund.

The overall efficient frontier for these  $n$  funds (with return  $r_i$  and standard deviation  $\sigma_i$ ) is constructed by solving the standard quadratic-programming problem that determines the weight ( $w_i$ ) for each fund to minimize the variance for a given

return  $R$ :

$$\text{Minimize } \sigma_p^2 = \sum_{i=1}^n w_i^2 \sigma_i^2 + \sum_{i=1}^n \sum_{\substack{j=1 \\ j \neq i}}^n w_i w_j \text{Cov}(r_i r_j) \tag{1}$$

$$\text{subject to } \sum_{i=1}^n w_i r_i \geq R \tag{2}$$

$$\sum_{i=1}^n w_i = 1 \tag{3}$$

$$0 \leq w_i \leq 1 \quad \forall i = 1 \text{ to } n \tag{4}$$

Note that constraint (4) prevents the inclusion of short positions in these portfolios. In addition to the overall frontier, five subfrontiers are constructed for different levels of risk tolerance (capital preservation, current income, income and growth, long-term growth, and aggressive growth) by adding constraints to rebalance the proportion of fixed income ( $FI_i$ ) and equity ( $EQ_i$ ) assets.

$$\sum_{i=1}^n w_i EQ_i = \text{TOTAL\_EQ} \tag{5}$$

$$EQ_i + FI_i = 1 \quad \forall i = 1 \text{ to } n \tag{6}$$

In general, higher proportions of equities ( $TOTAL\_EQ$ ) result in higher risk levels with capital-preservation portfolios being the least risky with nominal equity levels, and aggressive-growth, with over 80 percent equities, having higher risk levels. In general, the efficient frontiers of the five risk categories fall below the overall efficient frontier due to the additional constraints.

In addition to constructing portfolios for target risk levels, we construct international and tax-free portfolios by adding constraints, similar to (5) and (6), to control the level of international and tax-free funds included in the portfolios. We construct portfolios quarterly for various com-

binations of risk levels, number of funds, and international and tax-free content by adjusting the appropriate constraints.

---

In accepting the 1997 INFORMS Prize, Launny Steffens, vice chairman of Merrill Lynch and Company, Inc., made the following comments.

"After Merrill Lynch Private Client formalized financial planning as the basis of our business strategy, Management Science developed the asset allocation models which facilitated the implementation of that strategy to over 13,000 financial consultants. This strategy has set Merrill Lynch apart in becoming the premier, planning-based financial services firm of choice.

"Management Science has also helped us obtain significant insights. Analytical models developed by them have been used in investment strategies, client investment performance measurement, retention analysis, mutual funds optimization, credit evaluation, cross-selling and prospecting, incentive compensation, and client-satisfaction measurement, to name a few. I have thrown many challenges to Raj, Russ, Steve, and the rest of the Management Science Group, and they have repeatedly risen to the occasion. They accept the hard problems and pioneer new solutions."

#### Note

Financial Foundation and Retirement Asset Selector are registered trademarks of Merrill Lynch & Co., Inc. © Merrill Lynch, Pierce Fenner & Smith Incorporated, member, Securities Investor Protection Corporation (SIPC).

#### References

- Markowitz, Harry M. 1996, *Portfolio Selection: Efficient Diversification of Investments*, Blackwell, Malden, Massachusetts.
- Beshinske, Ray and McCarthy, Walter 1995, "Credit evaluation systems," chapter 25 in *Artificial Intelligence in the Capital Markets*, eds. Roy S. Freedman, Robert A. Klein, and Jess Lederman, Probus Publishing, Chicago, Illinois.
- Labe, Russell P. 1994, "Database marketing increases prospecting effectiveness at Merrill Lynch," *Interfaces*, Vol. 24, No. 5 (September-October), pp. 1-12.