J. Eliashberg and G.L. Lilien, Eds., *Handbooks in OR & MS, Vol. 5*

Chapter 1

Mathematical Marketing Models: Some Historical Perspectives and Future Projections

Jehoshua Eliashberg

Marketing Department, The Wharton School, University of Pennsylvania, Philadelphia, PA 19104, USA

Gary L. Lilien

Pennsylvania State University, 113 BAB II, University Park, PA 16802, USA

There is an old cartoon, first published in the *New Yorker* magazine, showing two executives at a cocktail party. One says to the other, 'So you're in marketing. That's funny, in my family, my wife does the marketing'.

The image of the field of marketing has, to this day, retained some of the vague, intuitive flavor that the above cartoon suggests. When the term 'marketing' comes to mind, many people think of 'pet rocks', cans of 'New York City air', and the cyclical movement of hemlines in women's fashions; the analysis of the demand for such items seems well removed from the reliance on mathematical models that characterizes much of the work in operations research and management science (OR/MS).

Indeed, many company executives despair of putting marketing on a more scientific basis. Many see marketing processes as lacking the neat quantitative properties found in production and finance. In marketing, human factors play a large role, marketing expenditures affect demand and cost simultaneously and information to support truly systematic decisions is rarely available. Further, the effects of most marketing actions are typically delayed, nonlinear, stochastic and difficult to measure.

Yet, the OR/MS developments in marketing have been profound and substantial: the chapters of this book describe a significant literature, sketching a broad range of applications of OR/MS in marketing. A major force behind these developments is the battle for markets that has been dictating organizational success and failure in recent years. Sales in many markets are flat or declining while competitors have been growing in number and becoming more desperate. Products are exhibiting shorter life-cycles, and leaner staff organizations have become buried in oceans of new types of data (from bar-code scanners and other sources), demanding rapid comprehension and sound decision making in dynamic and risky environments.

This book represents the state of the art in the OR/MS approach applied to marketing problems. Each of the chapters develops the concepts and describes key mathematical models in specific areas of marketing, leading the reader up to the current state of affairs and projecting future developments. Before proceeding, however, it is appropriate to reflect a bit on the history of this field.

1. Reflections on the past

The OR/MS field emerged during and after World War II, focusing primarily on problems in production, operations, and logistics. Early successes in those areas encouraged analysts to engage in a broader set of problems. The OR/MS literature in marketing began to emerge in a significant way in the 1960s.

At that time, several authors provided classification schemes that were useful in trying to organize the growing literature on marketing models. Several of those schemes were:

-iconic vs analog vs symbolic models [King, 1967],
-descriptive vs predictive vs normative models [Montgomery & Urban, 1969],
-macromarketing vs micromarketing models [Kotler, 1971].

For the purpose of this paper, we will use a classification scheme that focuses purely on the purpose of the model.

There are essentially three purposes for modeling in marketing: measurement, decision-making, and theory-building. We will call the corresponding models measurement models, decision-making models, and stylized theoretical models, respectively (although it may be equally helpful to interpret these 'categories' as classification dimensions for interpreting the multiple purposes of models).

1.1. Measurement models

The purpose of measurement models is to measure the 'demand' for a product as a function of various independent variables. The word 'demand' here should be interpreted broadly. It is not necessarily units demanded but could be some other related variable. For example, in conjoint measurement models, the most crucial variable in determining demand is the individual's preference for a choice alternative. In models of diffusion of new durables, the demand variable is captured mainly through 'sales to first adopters'. In some choice models, the dependent variable is whether or not an individual made a purchase of a given brand on a given purchase occasion.

The independent variables in measurement models are usually marketing mix variables – again interpreted broadly to mean any variables the firm controls – but they could include variables to account for seasonality in employment, GNP, consumer characteristics, and competitors' actions. In conjoint measurement models, for example, the independent variables are usually the attributes of the choice alternatives. Diffusion models typically have 'cumulative sales since introduction' as one of the independent variables. Other choice models have several

independent variables including whether or not the brand was on deal at a given purchase occasion, regular price of the brand, deal price (if any), brand loyalty of the individual, etc. These examples suggest that measurement models can deal with individual (disaggregate) demand or aggregate (market-level) demand.

Once the demand functions have been specified, they are then 'calibrated' to measure the parameters of the function. Calibration reveals the role of various independent variables in determining demand for this product: which variables are more important and which are less. Also, once the demand function has been calibrated, it can be used to predict demand as well as other relevant performance measures in a given situation. A variety of methods have been used to calibrate demand functions: judgment, econometric techniques, experimentation, simulation, etc.

Note that advances in measurement models can be due to better data (scanner data, for example) or better calibration methods and procedures (maximum likelihood methods for generalized logit models, for example).

1.2. Decision-making models

Models are designed to help marketing managers make better decisions. They incorporate measurement models as building blocks, but go beyond measurement models in recommending marketing-mix decision for the manager. The methods used to drive the optimal policies vary across applications. Typical techniques are dynamic programming, optimal control and calculus of variations techniques, static nonlinear optimization techniques, as well as linear and integer programming, and simulation.

Figure 1.1 shows a general framework for a marketing decision-making system. Note the dashed arrow leading from 'marketer actions' to 'competitive reactions'. This is to recognize that, unlike other environmental variables, competitors' actions could be affected by 'our actions' (and even by announcements concerning our *intended* actions).

1.3. Stylized theoretical models

The purpose of stylized theoretical models is to explain and provide insights into marketing phenomena; a stylized theoretical model typically begins with a set of assumptions that describes a particular marketing environment. Some of these assumptions are purely mathematical, at best intuitively logical, designed to make the analysis tractable. Others are substantive assumptions with real empirical grounding. They can describe such things as who the actors are, how many of them there are, what they care about, the external conditions under which they make decisions, how they have behaved in the past, etc. It is these latter assumptions that will participate in the explanation being offered. Note that the concept of a model in a stylized theoretical fashion is different from the concept of a decision-making model. A decision-making model is defined as a 'mathematical description of how something works' and it often takes the point of view of one particularly

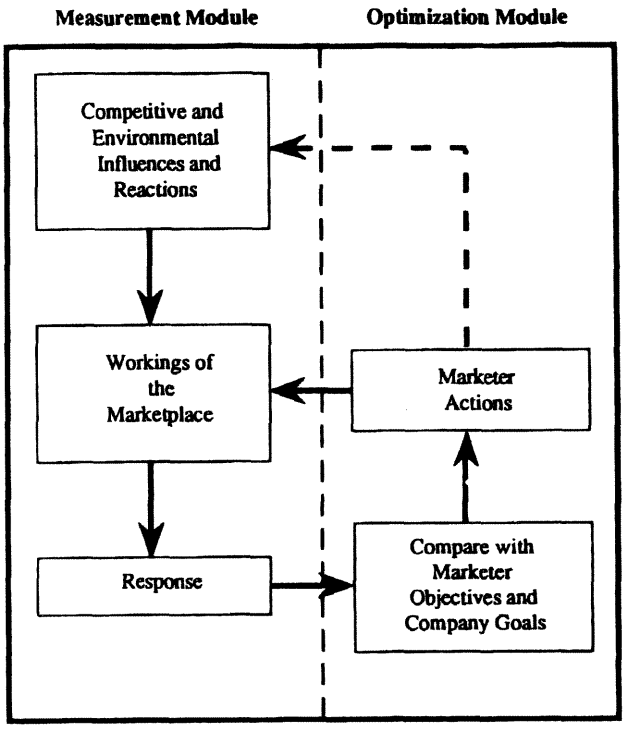

Fig. 1.1. A decision-making system, showing measurement and optimization modules.

interested party. A stylized theoretical model is simply a setting – a subset of the real world – in which 'the action takes place'. It often takes the viewpoint of an outside (objective) third party.

Once a theoretical model has been built, the model builder analyzes its *logical* implications for the phenomenon being explored. Then another model, substantively different from the first, is built – very likely by another model-builder – and its implications are analyzed. The process may continue with a third and a fourth model, if necessary, until all the ramifications of the explanation being proposed have been examined. By comparing the implications of one model with those of another, and by tracing the differences to the different assumptions in the various models, we can develop a theory about the phenomena in question (see Figure 1.2). This is as if a logical experiment were being run, with the various models as the 'treatments'. The key difference from empirical experiments is that, whereas in empirical experiments the subject produces the effects, here the researcher produces the effects by logical argument and (often) mathematical analysis.

The main purpose of theoretical modeling is pedagogy – teaching us how the real world operates – and that purpose is well served by internally valid theoretical experiments. But what about the practical use of such work for marketing managers? Such models are of direct value to managers when they uncover robust results that are *independent* of the unobservable features of the decision-making environment. Under these circumstances the models have two uses:

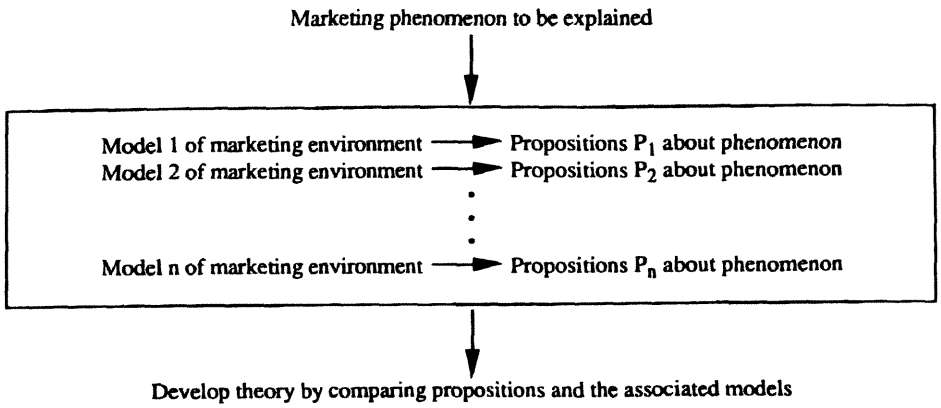

Fig. 1.2. Overview of the theoretical modeling process.

(1) as direct *qualitative* guidance for policy (in our situation, we need low (high) proportions of salesforce compensation in commissions) and
(2) as the basis for specifying operational models and associated decision-making systems that can adapt the theory to a particular environment and generate *quantitative* prescriptions [Moorthy, 1993].

1.4. Methods and applications

Table 1.1 synthesizes a range of OR/MS techniques and the typical problems that they were applied to in the 1960s. Those problems [Kotler, 1971] include product decisions, pricing decisions, distribution system decisions, salesforce management decisions, advertising and mass communication decisions, and promotion decisions. The OR/MS tools that seemed most prevalent in the 1960s and earlier include mathematical programming, computer simulations, stochastic models of consumer choice behavior, response function analysis, and various forms of dynamic modeling (difference and differential equations, usually of first order). Some uses of game theory were reported for competitive situations, but most

Table 1.1
A sample of OR/MS methodology applied to marketing problems prior to 1970

Technique	Typical area(s) of application
• Poisson processes	• Effect of promotional effort on sales
• Differential equations	• Effect of advertising on sales
• Stochastic processes	• Consumer's brand choice
• Decision theory/analysis	• Evaluation of marketing research expenditures
• Mathematical programming	• Advertising decision-making
	• Advertising media selection
	• Warehouse location
• Computer simulation	• Microsimulation of market processes and behavior
• Game theory	• Competitive advertising expenditures

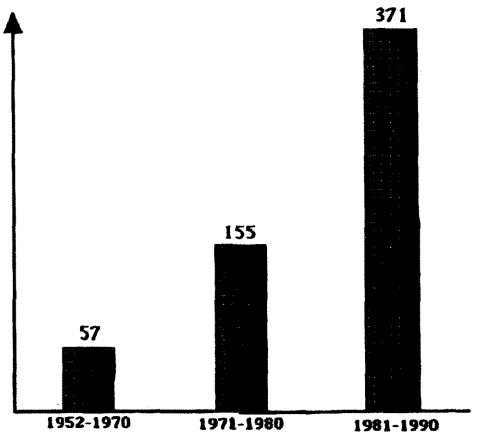

Fig. 1.3. Number of articles on marketing topics published in *Management Science*, *Operations Research*, *Interfaces* and *Marketing Science* for 1952–1990 as reported in the *OR/MS Index*, Volumes 1, 2 and 3.

studies involving competition used decision analysis, risk analysis or marketing simulation games.

Note that most of the models being published in the 1960s era were of the 'measurement model' and 'decision-making model' variety introduced earlier, and that the volume of research was more modest than in recent years (Figure 1.3).

Our impression is that the OR/MS work in marketing in the 1960s and before was largely produced by individuals trained as engineers, scientists or applied mathematicians, applying the OR/MS approach to the field of marketing rather than by individuals from business schools trained in marketing, the more dominant trend in recent years.

2. The 1970s: Early growth period

As Figure 1.3 indicates, nearly three times the number of marketing articles appeared in the 1970s as appeared in the period from 1952 through 1969.

In addition to the increase in numbers of articles, reviews by Schultz & Zoltners [1981] and Lilien & Kotler [1983] reveal that a number of new areas had begun to attract attention in the literature. These included descriptive models of marketing decisions, the impact and interaction of marketing models and organizational design, subjective decision models, strategic planning models, models for public and non-profit oganizations, organizational buying models, and the emergence of the concept of the Marketing Decision Support System (MDSS). In addition, while the number of published articles rose dramatically, the impact on organizational performance did not appear to be equally significant, and issues of implementation began to be stressed. Much of the literature in the 1970s pointed to the need for expanding the domain of application in the next decade and beyond. The limitations sections of some of the literature in the 1970s pointed out that many important phenomena that were being overlooked (such as competition, dynamics and inter-

actions amongst marketing decision variables) were both important and inherently more complex to model. Hence, the level of model-complexity and the insightfulness of the analyses in marketing seemed destined to escalate in the 1980s and beyond.

The 1970s saw growth in the areas of measurement models and decision-making models built on the foundation of earlier work. However, stylized theoretical models were beginning to emerge, foreshadowing their growth in the 1980s.

3. The 1980s, to the present

Figure 1.3 demonstrates the explosive growth seen in the marketing models publications in the 1980s in the OR/MS journals that formed the basis for the analysis. Some of that growth was due to the emergence of the journal *Marketing Science*. However, the journal emerged in response to a need to accommodate the volume of OR/MS papers that were being produced in any case, and its appearance coincided with *Operations Research* closing its publication doors to marketing papers. (We leave the analysis of a feedback effect between the emergence of a new journal and the new papers that that journal may encourage to eager, younger researchers.)

Compared to the earlier decades, the area of OR/MS in marketing saw its greatest growth in the emergence of stylized theoretical models. While it is often difficult to derive direct decision-making guidance from stylized theoretical models, many of those models are well grounded in the thirty-plus years of empirical evidence concerning marketing phenomena.

Hence, we have reason to feel that many of the theoretical marketing models are based on well-founded primitives and axioms. In addition, qualitative guidance for policy decisions that can be derived from theoretical models are often of the contingency variety, and can be used as rules in expert systems, as follows. Many expert systems require decision rules with the structure: if (Condition (Event) A or Condition (Event) B), then (Conclusion (Recommendation) C). Stylized theoretical models (confirmed by empirical observation whenever possible) often provide such contingent guidance.

Stylized theoretical modeling of marketing processes represents an important trend in the area of OR/MS in marketing. Such modeling demands greater mathematical sophistication from both researchers and readers of that research.

Another trend in the 1980s has been a shift from outcome modeling to more process-oriented modeling. The shortening of product life-cycles and the impact of competitive reactions in the marketplace preclude most markets from reaching steady state or equilibrium. Hence such areas as consumer behavior modeling (where the temporal nature of the stimuli that affect consumers' reactions has been the focus of some emerging research), the new-product area (where the moves and counter-moves of competitors keep the marketplace in a constant state of flux), and negotiations (where the offers/counter-offers of one party provide much information to the other party and can determine the future flow of the negotiation) have seen new modeling approaches.

4. Some marketing models comparisons

The following examples illustrate the evolution in complexity and sophistication of marketing models. The first example compares two measurement models; the second, two stylized theoretical models.

4.1. Comparison 1: Parfitt & Collins [1968] vs Blattberg & Golanty [1978]

The Parfitt–Collins [1968] model provides a simple method for obtaining an early prediction of ultimate market share with panel data.

Parfitt & Collins see ultimate brand-share as the product of three factors:

$$s = prb \tag{1}$$

where

s = ultimate brand share,
p = ultimate penetration rate of brand (percentage of new buyers of this product class who *try* this brand),
r = ultimate *repeat*-purchase rate of brand (percentage of repurchases of this brand to all purchases by persons who once purchased this brand),
b = buying-rate index of repeat purchase of this brand (average buyer = 1.00).

The model was designed to be used as follows. Assume that a company launches a new brand in an established product field. Its share of new buyers in this product field will rise from zero to some ultimate percentage (*trial*) as weeks pass. The penetration rate generally increases at a decreasing rate beginning at time zero. A curve can be fitted to these data after a few weeks; the authors recommend

$$p(t) = p(1 - e^{-at}) \tag{2}$$

where

$p(t)$ = cumulative trial by t,
p = ultimate (long-run) trial i (from Equation (1)),
a = growth-rate parameter.

The *repeat rate* for this brand will also be monitored as data come in. This rate shows the percentage of repurchases of this brand relative to purchases of all brands by those who have tried the brand. This rate generally falls with the passage of time toward an asymptote (r) and the earlier triers of a new product tend to like it more than later triers.

If purchasers of the new brand buy at the average volume of purchasers of all brands in this product class, then $b = 1.00$; otherwise it should be adjusted.

The key use of this model is to make an ultimate-share prediction as soon as the penetration rate and the repeat-purchase rate curve tend toward clear asymptotic values, which usually occurs before a stable brand share is achieved.

Blattberg and Golanty's [1978] Tracker model extends Parfitt & Collins's work, by developing explicit models for awareness (ignored by Parfitt & Collins), trial and repeat. The method requires three waves of questionnaires of 500–1000 respondents, launched once every 4 weeks, to support estimation of parameters in the awareness, trial and repeat submodels.

Total brand *awareness* is developed as

$$A_t = \frac{\mathrm{UR}_t + \mathrm{AR}_t}{N} \tag{3}$$

where

A_t = awareness at t,
UR_t = unaided recall of new brand,
AR_t = aided recall of new brand given lack of unaided recall,
N = sample size.

The model also relates the change of awareness at time t to advertising spending as

$$\ln\left[\frac{1 - A_t}{1 - A_{t-1}}\right] = a - b(\mathrm{GRP}_t) \tag{4}$$

where

GRP_t = gross-rating points of advertising at t,
a, b = parameters.

In this model, *trial* rates are estimated with two separate populations: the newly aware and those aware for more than one period. In particular, the authors specify trial rates as

$$T_t - T_{t-1} = c\underbrace{(A_t - A_{t-1})}_{\text{newly aware}} + d\underbrace{(A_{t-1} - T_{t-1})}_{\text{past aware but not yet trying}} \quad \text{for } 0 < d < c < 1 \tag{5}$$

where

T_t = cumulative percentage of triers by period t,
A_t = percentage aware in period t,
c = probability of trial by consumers who become aware this period,
d = probability of trial by consumers aware last period or earlier but who have not yet tried.

Here the model postulates a greater conversion rate among the newly aware. The trial rate in Equation (5) is adjusted for relative price:

$$(T_t - T_{t-1})^* = (T_t - T_{t-1})\mathrm{RP}_t^{\gamma} \tag{6}$$

where

RP_t = relative price at t,
γ = price-elasticity parameter.

Similarly, an error term is added to Equation (5) for estimation; it is both auto-correlated and heteroscedastic (where the heteroscedasticity is related to relative price). Parameters of the model are assumed constant in a product class and are estimated by a nonlinear procedure, pooling data for a number of products in the class.

The projection model for market share or sales is based on tracing the percentage of triers who become first-time users, second-time users, and so on. Triers or repeat users who discontinue use are classified as non-users. Triers are assumed to have a constant, average purchase rate TU, and repeaters are assumed to have a different use rate RU. Total sales per potential trier is then given as

$$TS_t = (T_t - T_{t-1})TU + \sum_{i=1}^{t-1} UC_{it}RU \tag{7}$$

where

TS_t = total sales per potential trier during period t,
T_t = new triers during period t,
TU = trial-use rate,
RU = repeat-use rate,
UC_{it} = percentage of new triers in period i who are still users during period t.

To model UC_{it}, the authors use a depth-of-repeat model. For simplicity they assume that

$$UC_{t-1,t} = r(T_t - T_{t-1}), \tag{8}$$

that is, that the percentage (r) of triers who repeat at least once is independent of time. The rest of the structure of $UC_{t,t+i+1}$ is developed as $k_i(UC_{t,t+1})$, where k_i is the percentage of triers in period t who continue to purchase after period $t+i$. Note that the $\{k_i\}$ are also assumed independent of time.

According to the authors, r and RU can be estimated with telephone surveys, while the $\{k_i\}$ are estimated subjectively with product-satisfaction data from the questionnaires; the trial-use rate TU is set equal to one by definition. The reason for the subjective estimates of the $\{k_i\}$ is that no quantitative long-term, depth-of-repeat information is available; this problem exists in all cases where a short purchase history is used to project future sales.

As this comparison shows, Blattberg & Golanty [1978] build on the rather spare structure of the Parfitt & Collins model by (i) adding an awareness model (tying in advertising), (ii) relating (change in) trial to conversion of the newly aware group and to aware-but-not-trying group separately, and (iii) modeling the repeat rate among triers in each period separately. That structure also ties in with

a measurement procedure, providing a complete decision-modeling system, with projections and policy diagnostics on advertising, pricing, and other marketing variables.

4.2. Comparison 2: Farley [1964] vs. Basu, Lal, Srinivasan & Staelin [1985]

The two papers we compare here are of the stylized-theoretical-model variety. The papers deal with salesforce compensation: how can the firm develop a compensation plan for its salesforce so that while the salesperson is operating in his or her best interest, he or she is maximizing profit for the firm?

The first paper we deal with [Farley, 1964], addresses the problem in a deterministic environment where the salesperson tries to maximize his or her commission and the firm wants to maximize its revenue.

We use the following notation here:

π = company's gross profit in dollars,
S = salesperson's commission income in dollars,
B_i = commission rate (in percent) paid on product i,
t_i = time devoted to selling product i,
Q_i = quantity of product i sold in units,
P_i = selling price per unit of product i,
K_i = variable non-selling cost per unit of product i,
M_i = gross margin (contribution to overhead and profit) of product i in dollars per unit (equals $P_i - K_i$),
C = total time the salesperson devotes to selling in some appropriately defined time period (month, quarter, etc.).

Farley assumes

$$Q_i = f_i(t_i) \quad \text{and} \quad \frac{\mathrm{d}f_i(t_i)}{\mathrm{d}t_i} > 0, \tag{9}$$

i.e., sales response, Q_i, is an increasing function of t_i (selling effort *only*), and is deterministic.

The firm's problem is:
find $\{B_i\}$ to

$$\text{maximize} \quad \pi = \sum_{i=1}^{n} Q_i[(P_i - K_i)(1 - B_i)] \quad \text{(the firm's gross profit)}, \tag{10}$$

$$\text{subject to} \quad C \geqslant \sum_{i=1}^{n} t_i \quad \text{(the constraint on the salesperson's time)}. \tag{11}$$

Inserting constraint Equation (10) into Equation (9) via Lagrange multipliers, yields an expression that can be maximized by calculus.

The salesperson's problem is to
find $\{t_i\}$ to

$$\text{maximize} \quad S = \sum_{i=1}^{n} m_i Q_i B_i \quad \text{(the commission)}, \tag{12}$$

$$\text{subject to} \quad \text{constraint Equation (11) again.}$$

Equations (11) and (12) can again be combined via a Lagrangian operation, and the resulting pair of equations are solved simultaneously to yield the general result that each optimal $B_i = B = \text{constant}$ will maximize both the firm's and the salesperson's objective functions. In other words, a compensation scheme based on a constant percentage of gross margin across products is optimal for the problem formulated by Farley.

Farley's result does not specify, however, what level B should be, although it seems evident that if B doesn't compensate the salesperson more than his or her opportunity cost of time, the salesperson would leave the firm.

There have been many key developments expanding upon and qualifying Farley's results. Most of the more recent work has employed the agency theory framework, where three basic assumptions hold: (a) response to salesperson's effort (sales) is only known stochastically, (b) the firm can only observe salesperson's effort imperfectly (if at all), and (c) the firm and the salesperson are assumed to be expected-utility maximizers, with the salesperson typically risk-averse and the firm risk-neutral.

The paper by Basu, Lal, Srinivasan & Staelin (BLSS) [1985] uses this framework with the following assumptions: one salesperson selling one product, and selling time is related to sales volume x via $f(x|t)$ which is a density function of sales, conditional on effort. Specifically, BLSS consider $f(x|t)$ as either gamma or binomial.

The salesperson's objective is to maximize expected utility, which is specified as:

$$W(s,t) = U(s) - V(t) \tag{13}$$

where

W = total utility,
s = total income,
t = selling time,
$U(s), V(t)$ = utility of income and (dis)utility of effort (selling time) respectively.

The salesperson requires some minimum level of utility, m, to be willing to work for the firm.

Other assumptions include:

- c, marginal cost, is a constant fraction of price,
- the firm knows $f(x|t)$ but cannot observe t.

The firm's problem is to find $s(x)$ to

$$\text{maximize} \quad \pi = \int_0^\infty [(1-c)x - s(x)]f(x|t)\mathrm{d}x \tag{14}$$

$$\text{subject to} \quad \int_0^\infty [U(s(x))]f(x|t)\mathrm{d}x - V(t) \geqslant m, \tag{15}$$

$$\int_0^\infty [U(s(x))]\frac{\partial f(x|t)}{\partial t}\mathrm{d}x - \frac{\mathrm{d}V(t)}{\mathrm{d}t} = 0. \tag{16}$$

Equation (14) has the firm looking for a compensation package, $s(x)$, to maximize its expected profits. (Recall the firm is risk-neutral.) Constraint (15) requires the compensation package, $s(x)$, to be at least as attractive as the salesperson's outside alternative, m. Constraint (16) has the salesperson choosing a level of sales effort, t, to maximize his/her expected utility.

The optimization problem characterized by Equation (14) with constraints, Equations (15) and (16), can be solved using calculus of variations or optimal control methods [Holmstrom, 1979]. To obtain specific insights, BLSS study the case of a constant relative risk-aversion salesperson having a utility function

$$U(s(x)) = \frac{s(x)^\delta}{\delta}, \quad \delta < 1 \tag{17}$$

and show that for $f(x|t)$ either gamma or binomial, the optimal compensation scheme is

$$S^*(x) = [A + Bx]^{1/(1-\delta)}, \quad A \geqslant 0, B > 0. \tag{18}$$

Note that Equation (18) has a salary component, A, and a commission component, B. BLSS go on to show how changes in risk-aversion, uncertainty, marginal cost, or minimum expected utility can lead to a range of possible compensation plans, including straight salary, straight commission, progressive sliding commission, salary plus commission, and salary plus commission beyond a sales target. (See Coughlan, Chapter 13, for a complete discussion of this area.)

The comparison of these two papers reflects an evolution in model sophistication. Farley posits a simple model and obtains a simple, but non-intuitive result. The world is more complex, however; BLSS deal with a richer, more realistic set of assumptions and provide some more satisfactory explanations for the more complex set of compensation arrangements we normally observe in practice.

5. OR/MS in marketing today

Everyone has different impressions about what issues are topical and where the frontiers are or should be in any field. We do not claim that what follows is any

more than personal impressions, but we will summarize some reasoning before making any prognostic projections and statements.

(1) Marketing models are having an important impact both on academic developments in marketing and on marketing practice. During the 1980s two new and important journals started: *Marketing Science* and the *International Journal of Research in Marketing* (*IJRM*). Both are healthy, popular, and extremely influential, especially among academics. And both reflect the developments of marketing models. In addition, on the practice side from 1980 to 1990, the Edelman Prize Competition (held annually to select the best example of the practice of management science) selected seven finalists in the field of marketing and two winners.

(2) New data sources are having a major impact on marketing modeling developments. One of the single, most influential developments of the 1980s has been the impact of scanner data on the field of marketing models. There are typically two or more special sessions at national meetings on the use of scanner data, a special-interest conference on the topic was held recently, and a special issue of *IJRM* was devoted to the topic. Scanner data and the closely related single-source data (where communication consumption data are tied into diary panel data collected by means of scanners) have enabled marketing scientists to develop and test models with much more precision than ever before. Relatedly, the Marketing Department in *Management Science* and *Marketing Science* have initiated editorial actions to encourage behaviorally oriented submissions. Such papers provide substantive evidence based on which new marketing theories can be developed and new marketing decision-making models can be further improved.

(3) Stylized theoretical modeling has become a mainstream research tradition in marketing. While the field of microeconomics has always had a major influence on quantitative model developments in marketing, that influence became most profound in the 1980s. The July 1980 issue of the *Journal of Business* reported on the proceedings of a conference on the interface between marketing and economics. In January 1987, the European Institute for Advanced Studies in Management held a conference on the same topic and reported that "the links between the two disciplines were indeed strengthening" [Bultez, 1988]. Key papers from that conference were published in issue 4 of the 1988 volume of *IJRM*. Issues 2 and 3 of the 1990 volume of *IJRM* on salesforce management provide several examples of how agency theory (a microeconomic development) is being used to study salesforce compensation. Other major theoretical modeling developments, primarily in areas of pricing, consumer behavior, product policy, promotions, and channel decisions are covered in detail in Lilien et al. [1992]; the impact on the field has been dramatic.

(4) New tools and methods are changing the content of marketing models. The November 1982 issue of the *Journal of Marketing Research* (*JMR*) was devoted to causal modeling. A relatively new methodology at the time, causal modeling has become a mainstream approach for developing explanatory models of behavioral phenomena in marketing. New developments have also occurred in psychometric modeling. As the August 1985 special issue of *JMR* on competition

in marketing pointed out, techniques like game theory, optimal control theory, and market share/response models are essential elements of the marketing modeler's toolkit. And finally, the explosion of interest in and the potential of artificial intelligence and expert systems approaches to complement traditional marketing modeling approaches has the potential to change the norms and paradigms in the field. (See the April 1991 special issue of *IJRM* on expert systems in marketing.)

(5) Competition and interaction is the key marketing models game today. The saturation of markets and the economic fights for survival in a world of relatively fixed potential and resources has changed the focus of interest in marketing models, probably forever. A key word search of the 1989 and 1990 volumes of *Marketing Science*, *JMR* and *Management Science* (marketing articles only) reveals multiple entries for 'competition', 'competitive strategy', 'noncooperative games', competitive entry', 'late entry' and 'market structure'. These terms are largely missing in a comparable analysis of the 1969 and 1970 issues of *JMR*, *Management Science* and *Operations Research* (which dropped its marketing section when *Marketing Science* was introduced, but was a key vehicle for marketing papers at that time).

6. Marketing models in the future

As we have tried to show above, the marketing models area has had important impact on the practice of marketing as well as on the development of an understanding of the nature of marketing phenomena. That trend will continue – the area is healthy and growing. Let us take a crack at a few extrapolations that we think (and hope) will have a dramatic impact on developments in the marketing models area in the next decade.

6.1. *Interface modeling*

Marketing is a boundary-spanning function, linking the selling organization with buyers and channel intermediaries in some way. To operate most effectively, its activities must be coordinated with other functional areas of the firm. An area that has begun to see research is the marketing–manufacturing interface. In this case, the firm is suboptimizing by looking at the marketing function, given a manufacturing decision; the coordination of efforts allows for significant savings in many situations. We expect this area to be explored both theoretically and empirically in the next decade.

6.2. *Process modeling*

Models of competition and models of bargaining and negotiations have generally focused on identifying equilibrium (steady-state) outcomes. Yet markets rarely reach such equilibria; indeed, even the equilibria that are obtainable are often determined by the 'transient' part of the analysis. We expect that such models will

be built and tested. Those tests will become more doable given the ability of interactive computer networks to capture the dynamics of moves and counter-moves in negotiation contexts, for example.

6.3. *Models of competition and coordination*

The markets of the 1990s will be characterized by strategic competition. This means that our models will focus on those situations (like the tit-for-tat solutions to repeated prisoner's dilemma games that induce cooperation; see, for example, Axelrod [1984]) that induce price coordination in low-margin markets, that allow for mutual 'understandings' about permitting monopolies or near monopolies in small market niches and the like. Competitive signaling represents one major paradigm in this direction. This is in contrast to most of the current models of competition that focus on the 'warfare' aspects of competition.

6.4. *Marketing generalizations*

Meta-analysis must become the norm for the development of operational market response models in the 1990s. It is absurd to analyze data on sales response to price fluctuations, for example, and ignore the hundreds of studies that have previously reported price elasticities. The 1990s will see such 'generalizations' become formal Bayesian priors in estimating response elasticities in marketing models. The grouping of our knowledge in this way will allow the discipline to make direct use of the information that it has been accumulating.

6.5. *New measurement technologies*

Single-source data will boost our ability to tie advertising and communications variables into consumer choice models. The increasing and expanded use of electronic forms of communications, data entry, order entry, expanded bar-coding, and the like will provide explosions of data that will stimulate the development of marketing models parallel to those that resulted from the introduction of scanner data. For example, it is feasible to capture the complete set of computer screen protocols facing a travel agent when making a client's booking. The implications of such technology for model development, experimentation and testing are enormous.

With more emphasis on incorporating the voice of the customer in designing new products, we also expect to see more measurement work related to yet unexplored aspects of consumer behavior processes such as consumption/usage experiences as well as post-purchase attitudes and feelings. This would entail, among other things, close examination and understanding of moods and emotions in addition to the more traditional examinations of judgment and decision-making. Given the inherent complexities of constructs such as consumer emotions, we expect to see explicit recognition of measurement errors in such contexts.

6.6. New methodologies

The impact of logit and related choice models had tremendous impact on both marketing model development and applications in the 1980s. (For a striking example of the effect such modeling had at one firm, resulting in an application that won the 1989 Edelman Prize, see Gensch, Arersa & Moore [1990].) We see a similar impact of Bayesian procedures in calibrating marketing models in the 1990s. For example, advances in elicitation of subjective judgments as well as in computation will increasingly allow analysis to exploit coefficient similarity across equations relying on similar data (perhaps from different regions or different market segments) to produce more robust estimates.

6.7. Intelligent marketing systems

The 1970s and early 1980s saw the explosion of decision support systems (DSS) in marketing. A DSS can be very powerful but, used inappropriately, can provide results that are either worthless or, possibly, foolish. The 1990s will see the development of a generation of intelligent marketing systems (IMS) that will have the 'autopilots' on board the marketing aircraft (the DSS) to take care of the routine activities and focus the analyst's attention on outliers.

6.8. More impact on practice

Even several decades after the earliest operational marketing models were first introduced, their impact on practice remains far below its potential. Shorter life-cycles, more competitive (and risky) decisions, better theory, faster computers, new technologies, and the convergence of the developments outlined above will permit marketing models to impact marketing practices in a way that approaches their impact in the academic realm.

6.9. New areas of application

Most reported applications of marketing models have been to consumer products, both for frequently purchased packaged goods and for consumer durables. Yet the business-to-business and services marketplaces have seen only limited modeling activity in spite of the fact that more than twice the dollar volume of transactions takes place between businesses than in the consumer marketplace; and service industries including telecommunications, food, lodging, education, health care, entertainment and the like, account for about 70% of US national income. To take one under-modeled area, the film industry generated revenues of over US $13 billion in 1990 and has seen almost no attention from the marketing modeling community. These observations suggest that there are many under-researched and under-modeled domains available for development of new marketing models and for adaptation of existing models.

7. Organization and content of the Handbook

This book brings together leading marketing scientists with an OR/MS orientation, each of whom has developed a state-of-the-art review of his or her area of expertise. The material spans the marketing discipline and represents excellent coverage of what is known and what problem areas present themselves as ripe for further development.

Each chapter was written with a mathematically sophisticated reader in mind. But that reader is not expected to be an expert on marketing. In each chapter, the authors discuss the motivation – the behavioral foundations or key assumptions – leading to the development of the important models and methods that they review.

We have organized the book around four main areas following this Introduction: Models of Market Phenomena, Tools and Methods for Market Analysis, Elements of the Marketing Mix and, finally, Interactions, Strategy and Synergy.

7.1. Part II. Models of market phenomena

Market phenomena can be addressed at different levels of aggregation: the individual consumer, the dyad (family or bargaining pair), the group (or organizational decision-making unit), or the market as a unit. In this part, Roberts & Lilien (Chapter 2) provide a taxonomy of individual-consumer behavior phenomena that have received modeling attention. They then show how these models can be used and combined to solve managerial problems. Corfman & Gupta (Chapter 3) focus on choice and decision-making models when the decision must be made by a group, defined as a collection of people united by bonds of common interest. Their definition of a group encompasses market phenomena that include: group choice (based on normative models as well as models derived from the literature in social psychology), family decision-making, organizational decision-making, buyer–seller negotiations and interdependent decisions in marketing channels. Finally, Moorthy (Chapter 4) reviews key developments when the actors under analysis are organizations involved in price, product, advertising and distribution decisions in a competitive framework. His review indicates the type of factors that one must consider when analyzing competitive market situations.

7.2. Part III. Tools and methods for market analysis

The marketing scientist's toolkit includes methods developed in OR/MS, psychometrics, econometrics and statistics. These methods have often been adapted to the particular circumstances of marketing problems.

In this part, DeSarbo, Manrai & Manrai (Chapter 5) show how competing products or brands can be represented so that substitution patterns among them can be better understood. They review primarily deterministic and stochastic non-spatial tree models that originated in the psychometric area. Cooper (Chapter 6) also addresses competitive and market structures, but focuses on the relationship between the aggregate concept of market share and disaggregate choice models, relying on methods derived primarily from mathematical psychology and econo-

metrics. Urban (Chapter 7) describes methods designed to develop pre-test market assessments for new products, primarily consumer packaged goods and durables. These methods provide useful diagnostics as well as market penetration forecasts and provide tools for management to assess the likely market response to various marketing plans. Mahajan, Muller & Bass (Chapter 8) focus on diffusion models, dealing with the rate of penetration of new products into the market. In addition to describing and predicting the dynamic patterns of penetration for such products, these models provide normative guidance for pricing policies, advertising strategies, entry timing decision and the like. Hanssens & Parsons (Chapter 9) conclude this part with an econometrics-based review of aggregate (both static and dynamic) sales response functions, i.e. functional relationships between marketing actions and the resulting sales seen by the firms in the marketplace.

7.3. *Part IV. Elements of the marketing mix*

Marketing management controls a wide range of decisions that affect market response. While many of these decisions interact (as we see in Part V) much research has addressed the impact of these elements in isolation.

The part begins with a review by Green & Krieger (Chapter 10) of the impact of product design on market response. The authors emphasize the role of conjoint analysis, a widely adopted method to assess the relationship between product attributes and consumer preferences and choices. Pricing is perhaps the most frequently mentioned variable under the control of the marketing manager. Rao (Chapter 11) deals with the many complexities of pricing behavior, including the role of competition, the dynamics of price, pricing a line of products and the like. He also examines such behavioral phenomena as the price–quality relationship, as well as measurement issues such as willingness-to-pay and elasticity. Sales promotion is another key marketing-mix element. Blattberg & Neslin (Chapter 12) address that role that consumer promotions such as coupons and deals, as well as trade promotions such as dealer allowances, have on demand and profitability. They discuss both descriptive and normative models of promotional phenomena.

The salesforce consumes the largest share of the marketing budget for most firms and we have two chapters dealing with important issues of salesforce management. Coughlan (Chapter 13) examines models of salesforce compensation, reflecting indirect control of the salesforce. The types of models she reviews are deterministic relationships between salesforce effort and sales, agency-theoretic models of salesforce management, and decision support systems for salesforce compensation. Vandenbosch & Weinberg (Chapter 14) address the direct control of the salesforce through territory design models, call-planning models, and salesforce sizing models.

7.4. *Part V. Interactions, strategy and synergy*

The models in this part take a broader view of marketing problems, looking at the effect of multiple marketing-mix elements, at using other types of models (like

expert systems) to aid decisions, and at larger issues such as marketing strategy and decisions that cross functional boundaries.

Gatignon (Chapter 15) reviews models of the marketing mix. He discusses estimation issues as well as models that permit an optimal allocation of resources across marketing-mix elements. Rangaswamy's focus (Chapter 16) is on marketing decision models more generally, with a particular emphasis on approaches using expert systems and artificial intelligence. Such systems rely on a specific synthesis and representation of knowledge rather than the more concise summarization that more traditional, explicit mathematical models afford. Wind & Lilien (Chapter 17) begin by providing an overview of the accomplishments and limitations of marketing models, moving from models of individual elements of the mix to more general models of marketing strategy. They discuss portfolio models and resource allocation models as well as some more non-traditional approaches (morphological analysis, benchmarking) and assesses their potential to aid marketing practitioners. The part and the book conclude with Eliashberg & Steinberg's discussion (Chapter 18) of cross-functional coordination between marketing and production. Marketing actions affect production and inventory costs, and such costs in turn affect the relative profitability of marketing actions. This final chapter shows the benefit of coordinating efforts in the firm and opens a window onto the type of cross-functional modeling that must take place in the fully integrated firm of the 21st century.

The careful reader will note that we do not have coverage of advertising models, channel models, models dealing specifically with scanner-data environments, product line models or models of the R&D–marketing interface. Our original plans *did* include chapters in these areas. Sadly, such plans did not result in completed chapters that we could include here. Happily, we have an excellent set of papers, written by a stellar group of authors. We hope that our readers will agree that in, at least, a significant domain of the space of OR/MS in marketing, these chapters will define the state of the art for at least a few years to come.

References

Axelrod, R. (1984). *The Evolution of Cooperation*, Basic Books, New York.

Basu, A., R. Lal, V. Srinivasan and R. Staelin (1985). Salesforce compensation plans: An agency theoretic perspective. *Marketing Sci.* 4 (Fall), 267–291.

Blattberg, R.C. and J. Golanty (1978). Tracker: An early test market forecasting and diagnostic model for new product planning. *J. Marketing Res.* 15 (May), 192–202.

Bultez, Alain (1988). Editorial for Special Issue on Marketing and Microeconomics, *Inter. J. Res. Marketing* 5(4), 221–224.

Farley, J.U. (1964). An optimal plan for salesmen's compensation. *J. Marketing Res.* 1 (May), 39–43.

Gensch, D., N. Arersa and S.P. Moore (1990). A choice modelling market information system that enabled ABB Electric to expand its market share. *Interfaces* 20(1) (January/February), 6–25.

Holmstrom, B. (1979). Moral hazard and observability, *Bell J. Econom.* 10, 74–91.

King, W.R. (1967). *Quantitative Analysis for Marketing Management*, McGraw-Hill, New York.

Kotler, P. (1971). *Marketing Decision Making: A Model Building Approach*, Holt, Rinehart and Winston, New York.

Lilien, Gary L. and Philip Kotler (1983). *Marketing Decision Making: A Model Building Approach*, Harper and Row, New York.

Lilien, Gray L., Philip Kotler and K. Sridhar Moorthy (1992). *Marketing Models*, Prentice-Hall, Englewood Cliffs, NJ.

Montgomery, D.B. and G.L. Urban (1969). *Management Science in Marketing*, Prentice-Hall, Englewood Cliffs, NJ.

Moorthy, K.S. (1993). Theoretical modeling in marketing, *J. Marketing* 57 (April), 92–106.

Parfitt, J.H. and B.J.K. Collins (1968). Use of consumer panels for brand share prediction, *J. Marketing Res.* 5 (May), 131–146.

Schultz, R.L. and A.A. Zoltners (1981). *Marketing Decision Models*, North-Holland, New York.