

# MARKET ANALYSIS AND PRODUCT DESIGN FOR TELECOMMUNICATIONS EQUIPMENT AND SERVICES

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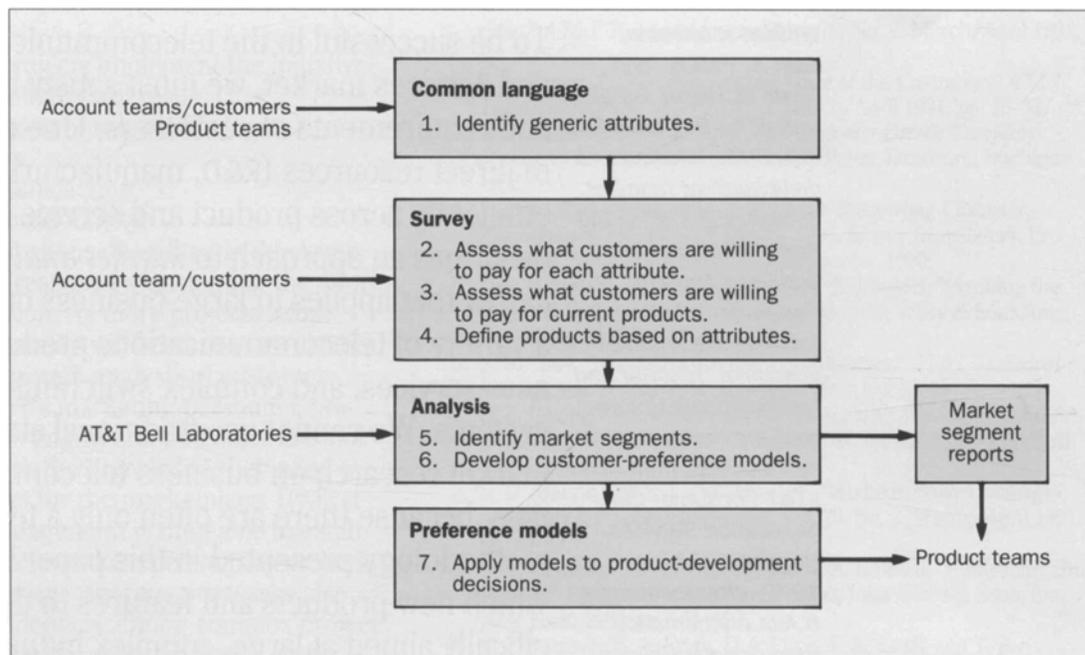
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To be successful in the telecommunications equipment and services market, we must satisfy the diverse needs and requirements of customers. One critical challenge is to direct resources (R&D, manufacturing, and marketing) efficiently across product and service lines. This paper describes an approach to *market analysis* and *product design* that applies to large-business customers who need a variety of telecommunications products, such as business services, and complex switching and transmission systems. We cannot use traditional statistical methods of market research on business telecommunications products, because there are often only a few customers. The methodology presented in this paper helps us determine which new products and features to develop and is specifically aimed at large, complex industrial products. We have applied it successfully to products in switching, transmission, and installation services. Using this methodology, AT&T can design telecommunications products that best meet customer needs and that realize substantial savings in development costs.

## Introduction

As AT&T faces increased competition across all markets, we need to analyze our markets and competitors using systematic and quantitative methods. With those results in hand, we can focus our marketing, manufacturing, and R&D resources efficiently. A major segment of AT&T's customer base is large, industrial customers, whose product and feature requirements are complex and diverse. Often this segment consists of only a few customers, but they account for a large proportion of AT&T revenues. Our challenge is to design, develop, manufacture, and market products and services to satisfy their needs. It is important for AT&T to understand these customers' needs

**Figure 1. The integrated market-analysis and product-design process contains seven steps, by which the product team determines the features and attributes a customer prefers, identifies to whom a product can be sold, and decides which products to develop.**



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completely, because competitors are poised to customize products for this segment. We must often make difficult product and feature design tradeoffs across this varied customer base. We must evaluate these tradeoffs, which result in the creation of a set (one or more) of products, in terms of their revenue and costs.

We need a process that can help us answer such questions as:

- How many different products should we develop?
- Which set of features should we include in the next product release?
- Which market segments should we serve?

Given the diversity of customer requirements, we may choose not to serve certain market segments so we can concentrate on other, potentially more profitable, market segments. However, we need to understand precisely where we are making these tradeoffs and what their financial impact may be. This knowledge enables us to

coordinate our marketing, distribution, manufacturing, and R&D plans for customer requests and product lines.

This paper describes an integrated market-analysis and product-design process to support the work of the *product team* (i.e., the representatives from market management, product management, sales management, and R&D responsible for the success of the product) in designing and marketing complex products for large, industrial customers. The goal of the process is to bring timely market intelligence to the product-design process and to help team members communicate with each other—in short, to support the product-realization process.

In this paper, we describe:

- Some key industrial-design and market-analysis issues
- The common marketing and R&D language we have developed to facilitate an integrated market-analysis and product-design process

- An overview of the integrated market-analysis and product-design process
- Some details of the process, including questionnaire design, market segmentation, and multi-attribute customer-preference models
- An application of the process
- The automated support systems we have developed to implement the process.

#### **Industrial-Product-Design and Analysis Issues**

The goal of the industrial-product-design process is to create a set of products that are well matched to customer needs and that provide the supplier with a reasonable profit. To achieve this goal, the supplier must be able to:

- Segment the market
- Test new product concepts
- Guide feature development
- Price new and existing products
- Target the market for new and existing products
- Respond to competition.

When designing methods to analyze the industrial market, we face several issues, including:

- Complex products and features
  - Few customers for a given product
  - Customers who have more than one decision maker.
- Statistical methods that rely on large sample sizes (i.e., thousands of respondents) may not provide a reliable assessment of responses when applied to fewer than 100 customers. In particular, unlike the case for consumer products, we cannot rely on statistical tests to select the initial set of customer-decision variables.

#### **A Common Marketing and R&D Language**

To help the members of the product team communicate with each other, the integrated market-analysis and product-design process described here uses a common marketing and R&D language. The language groups a product line into sets of attributes and features that summarize the individual products along broad,

functional lines.

*Attributes* represent major generic categories on which customers base their purchase decisions. For example, "operations and administration" would be an attribute of a transmission product. Ideally, the set of attributes used to describe a product should satisfy two properties. The set should be complete, that is, it should capture every major purchase-decision variable. It should also be orthogonal, that is, independent and not overlapping. As such, a judgment about one attribute should have no effect on another.

For each attribute, we specify a pair of "anchors," which define the attribute. The pair of anchors is a description of the "features" that correspond to the best and the worst levels of the attribute. The set of features constitutes the difference between the anchors. Note the distinction between attributes and features: attributes consist of features. A product situated at the lower anchor contains *none* of the features of the attribute, while a product at the upper anchor contains *all* of the features of the attribute. For example, the operations and administration features for a transmission product include:

- Extensive customer control
- Automated restoration
- Automated provisioning
- Automated record keeping
- Remote plug-in inventory.

In general, we define the lower anchor as the worst level of the attribute that is currently available and acceptable in the marketplace. The upper anchor is the expected level that the attribute will reach within a five-year time frame.

#### **Overview of Methodology**

The integrated market-analysis and product-design process illustrated in Figure 1 includes seven steps:

1. *Identify a generic set of attributes.* As members of the product team identify a set of attributes, they automatically develop a common marketing and R&D language. The attributes must be generic enough to cover both

- existing and future products. They must be unambiguously defined and cover the complete set of criteria by which customers make their purchase decisions.
2. *Assess how much customers are willing to pay for each attribute and its underlying features.* We base these assessments on customer responses to a formal questionnaire. The questionnaire asks customers how they would trade attributes for price. (The questionnaire is described later in this paper.)
  3. *Assess how much customers are willing to pay for current products.* We also derive these assessments from the formal questionnaire. We use these assessments to adjust (i.e., calibrate) the attribute assessments to ensure that they accurately predict product preferences.
  4. *Define current and proposed products based on the attributes.* We use these product characterizations to calibrate the attribute assessments and to forecast how much customers would be willing to pay for proposed products.
  5. *Identify market segments.* Using graphical techniques, we pinpoint groups of customers who have similar attribute preferences and thereby identify market segments.
  6. *Develop customer-preference models.* A customer-preference model is a mathematical formula used to predict which product on a list of arbitrarily defined and priced products a customer is likely to prefer. The formula defines products according to their attributes. The parameters of the model are estimated from the customer's answers to the questionnaire. The model is described later.
  7. *Apply preference models to product-development decisions.* Later in this paper, we give examples of how we use the customer-preference models to help make decisions about product pricing and development.

### Questionnaire Design

The questionnaire contains four types of different, but related, questions. Panel 1 gives a sample of each type of question.

*Attribute questions* assess a customer's willingness to pay for individual product attributes. The ques-

tions are written in terms of the high and low anchors, to ensure a common understanding of the meaning of each attribute. In Panel 1, the high anchor for the operations and administration attribute is a system with extensive customer control, automated restoration, automated provisioning, automated record keeping and remote plug-in inventory. The low anchor is a system with none of these features.

The *feature questions* disaggregate the willingness to pay for the attributes into the willingness to pay for the specific product features that define the attributes.

The *product questions* ask respondents to position existing products between the lower and upper attribute anchors, and the *preference questions* ask them to indicate their preferences among these products at alternative prices. The product and preference questions help us calibrate the responses to the attribute questions. In this way, we ensure that the individually assessed attributes accurately reflect product and price preferences when combined to form a whole product.

After we calibrate the model, we compare the results of the product and price questions with the preference-model predictions to measure the accuracy of the preference model.

### Market-Segmentation Application

All customers do not have the same preferences. If their preferences are diverse, a product that is designed to satisfy the "average" customer may satisfy none of the customers. To maximize customer satisfaction under these circumstances, more than one product or product option may be needed. Segmentation analysis helps product designers determine if multiple products or options are needed, and what those products or options should be.

Figure 2 shows customer preferences for a single attribute—the level of system integration—plotted for a number of customers. There are two levels of system integration: custom and modular. Custom systems are delivered assembled by the vendor, whereas modular systems must be put together by the customer.

Each bar in the plot represents a different

**Panel 1. Excerpts from a Questionnaire**

We used the excerpts that follow in a questionnaire about a transmission product.

**Attribute Questions**

1. Which of the following operations and administration options do you prefer, assuming all other variables, including price, are equal?
  - ( ) A system that has all the following features: extensive customer control, automated restoration, automated provisioning, automated record keeping, and remote plug-in inventory.
  - ( ) A system with none of the above features.
2. By what percentage would we have to discount the price of the less preferred option for you to be equally likely to purchase either option? \_\_\_\_\_

**Feature Questions**

Imagine that you could buy each operations and administration feature separately.

1. Which of the following features would you be willing to pay the most to have? Give it a rating of 100 in the following table.
2. For the remaining features, assign ratings between 0 and 100 to indicate how the feature compares to the top-rated feature on willingness to pay. (For example, if your willingness to pay for a given feature is 80% of the top feature, give it a rating of 80).

Feature	Willingness to Pay Rating
Extensive customer control	_____
Automated restoration	_____
Automated provisioning	_____
Automated record keeping	_____
Remote plug-in inventory	_____

**Product Question**

Rate Product X with respect to operation and administration on the scale from 0 to 10 below.

None of the Above O&A Features	All the Above O&A Features
0	10
1	9
2	8
3	7
4	6
5	5
6	4
7	3
8	2
9	1

**Preference Questions**

1. Which of the following products do you prefer, assuming their prices are equal?
2. By what percentage would we have to discount the price of the less preferred product for you to be equally likely to purchase either product?

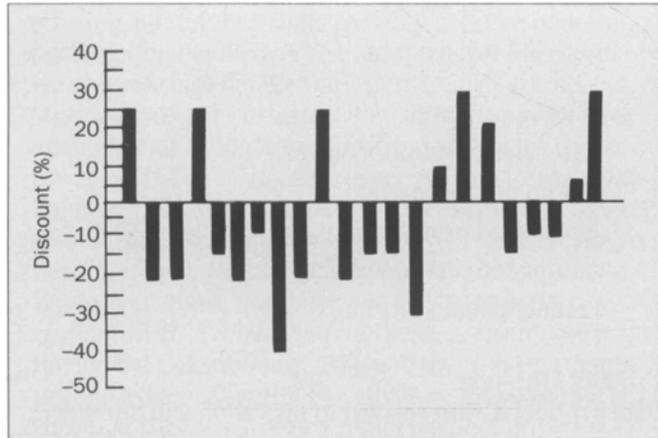
Product X	_____
Product Y	_____

customer. The bars that point up represent customers who prefer modular systems. These customers do not want to buy fully integrated systems; they prefer to do the integration themselves. The bars that point down represent customers who prefer custom systems—systems that are already fully integrated by the vendor. The length of each bar shows the minimum price discount (relative to the price of a system at the preferred level of integration) that the customer would require to buy a system that is not at his or her preferred level

of integration.

In this example, when all other attributes are identical, customers appear to fall into at least two groups: those that prefer modular systems, and those that prefer custom (i.e., vendor-assembled) system solutions.

Examining attributes one at a time, as we can in Figure 2, is just the first step in segmentation analysis. We must also examine correlations in customer preferences among the attributes. For example, suppose that the customers who prefer modular systems also differ in



**Figure 2.** This graph shows how customers differ in their preferences regarding a single attribute, the level of system integration. Custom systems are delivered fully assembled by the vendor, whereas modular systems are put together by the customer. Each bar pointing up represents a customer who prefers modular systems, while each bar pointing down represents a customer who favors custom systems. The length of each bar shows the minimum price discount the customer would require to buy a system that is not at his or her preferred level of integration. Thus, the length of each bar shows how much the customer wants his or her preferred level of system integration. When all other attributes are identical, these customers appear to be segmented into two groups: those who prefer custom systems and those who prefer modular systems.

their preferences for other attributes from the customers who prefer custom systems. Then, the product designer may build features into the modular product that are not in the custom product, and vice versa.

### Scatter Plots

One method of displaying correlations in preference between pairs of attributes is the scatter plot. Scatter plots show the tradeoffs customers are willing to

accept between pairs of attributes.

Figure 3 shows a sample scatter plot. Each point (i.e., letter) represents a customer plotted against the x and y axes. The x axis shows the discount that the customer would require for a product whose system interfaces are nonstandard. The y axis shows the discount that the customer would require if a product did not have a desired new option. The 45-degree line through the origin divides the market into customers who have a stronger preference for the new option than for standardization, and vice versa.

In the initial assessment of the new option for the product (i.e., before market research), product management rejected the alternative of offering the new option with nonstandard system interfaces. After examining the customer preferences, they reconsidered the decision, because some customers (A, C, D) who have strong preferences for the new option also have a weaker preference for standard system interfaces in this product type. Furthermore, some of the customers who indicated that standard system interfaces are essential also expressed little interest in a product with the newly proposed option.

Scatter plots, such as the one in Figure 3, allow us to examine simple correlations in preference between pairs of attributes. Levels of correlation that involve more than two attributes are harder to identify. However, advanced techniques<sup>1</sup> such as multidimensional scaling and cluster analysis may help identify such correlations and the corresponding market segments by displaying and enhancing graphical views of customer preferences in multi-attribute dimensions. A more detailed discussion of these techniques is beyond the scope of this paper.

### Multi-Attribute Preference Model

To support the industrial product-design process, we have developed a multi-attribute customer-preference model. The model helps the product team forecast how customers would rank proposed and/or existing products at alternative prices. The product team creates the

forecast by entering each product's attributes, features, and price into the model. This makes the model flexible, because it lets the product team evaluate *any* product that can be defined in terms of the model's attributes and features. The model can be used to examine the potential for new products and, therefore, to guide new product development, one of our major objectives.

A preference model is a mathematical formula that characterizes a customer's preferences among generic product attributes. For example, if  $x$  is the top speed of a sports car, and  $p$  is its price, then a simple example of a preference model applied to these two attributes might be  $V = ax + bp$  where  $a$  and  $b$  quantify customer preferences, which are combined to provide a measure for customer value,  $V$ . If  $(x_1, p_1)$  and  $(x_2, p_2)$  represent two sport cars, then car 1 is preferred to car 2 when

$$V_1 = ax_1 + bp_1 > V_2 = ax_2 + bp_2$$

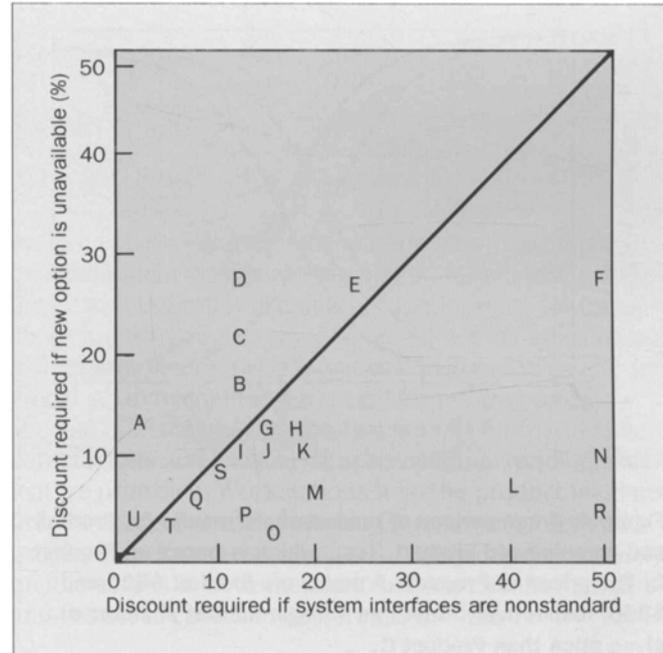
The initial steps in our model development are similar to the method described recently by Keeney and Lilien.<sup>2</sup> Products are characterized by a set of  $N$  attributes, which are assumed to be complete. The attributes are defined in terms of their upper and lower anchors. The upper anchor is a list of features that are considered incremental additions to the features represented by the lower anchor.

The multi-attribute value model:

$$V_{jk} = \prod_{i=1}^N \left[ 1 - d_{ik} + \sum_{l=1}^{L_i} \omega_{ikl} \delta_{ijl} \right] \quad (1)$$

gives customer  $k$ 's assessment of product  $j$ 's value,  $V_{jk}$ . The attribute discount parameter,  $d_{ik}$ , is an estimate of the relative value between attribute anchors, and  $\omega_{ikl}$  is a measure of the relative importance of feature  $l$  associated with attribute  $i$  for customer  $k$ . The parameter  $\delta_{ijl}$  equals one if product  $j$  has feature  $l$  associated with attribute  $i$ ; otherwise, it equals zero.

The model in eq. (1) looks more complicated than that of the sports car example, but the basic idea is



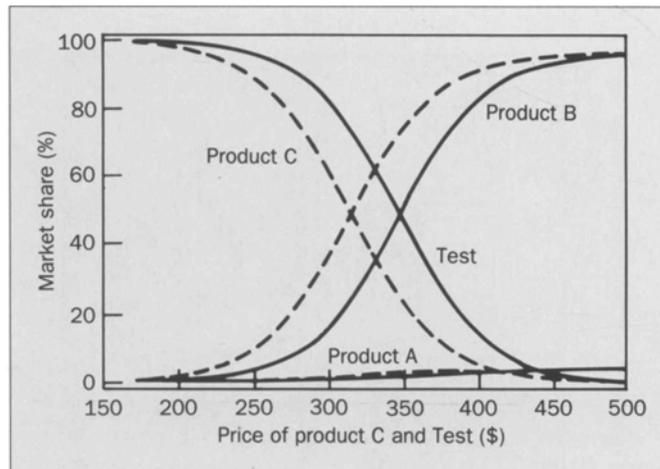
**Figure 3. A scatter plot displays correlations in preference between pairs of attributes. The 45° line through the origin divides the market into customers who have a stronger preference for the new option than for standardization, and vice versa.**

the same: The value of a given product to a customer is a function of what features the product has and how much the customer values each feature.

We calibrate this value model to customer-stated preferences among actual products and prices to obtain the following customer-preference model: Customer  $k$  is likely to prefer product  $A$  to product  $B$  if:

$$\frac{V_{Ak}^\alpha}{p_A} > \frac{V_{Bk}^\alpha}{p_B}$$

where  $p_A$  and  $p_B$  are prices and  $\alpha$  is the fitted calibration factor for transforming the assessed attribute values to



**Figure 4. A comparison of market-share results for Product C and an enhanced product, Test, which is based on Product C. The prices of Products A and B are fixed at \$500 and \$350, respectively. Test has a larger market share at a given price than Product C.**

**Table I. Sample Product Data for a Market-Share Model**

Attribute	Product			Attribute Discount
	A	B	C	
OA&M*	9.3	9.0	9.0	0.32
Capacity	10.0	9.5	7.0	0.25
Durability	8.8	8.7	8.2	0.25
Standards	9.3	7.9	7.7	0.13
⋮				
Price	\$500	\$350	\$350	

\* Operations, administration, and maintenance.

the features of the upper anchor the product contains. If a product has all the features of the upper anchor, it is defined to have an attribute rating of 10 and the corresponding term for that attribute in eq. (1) is 1. If the product has none of the features of the upper anchor of attribute  $i$  (i.e., it is at the lower anchor), then it has an attribute rating of 0 and the corresponding attribute term in eq. (1) is  $1 - d_{ik}$ . Ratings between 0 and 10 show that the product has some of the attribute's features. The higher the rating, the more features the product has. The customers' attribute ratings of the products shape the market-share models.

Table I presents the average attribute ratings for three products—A, B, and C—across all the customers. Products A, B, and C could be AT&T or competitors' products, or they could be new product concepts. To get the average, the individual customer preferences have been combined and weighted by the relative addressable market for each customer for the product type that includes products A, B, and C.

When the model is run, it calculates individual market shares for each customer, shown on the left side of Table II. Customer-level estimates are then combined to determine a total market share, where each customer's addressable market is incorporated in the total market-share prediction.

Figure 4 shows how price variations of Product

reflect customer-stated preferences accurately among actual products and prices.

We have also developed a model to quantify the likelihood that product A is preferred. The resulting model for the probability that product A is preferred to all other products is:

$$P(A) = \left[ \frac{V_{Ak}^\alpha}{p_A} \right]^c \div \sum_j \left[ \frac{V_{jk}^\alpha}{p_j} \right]^c$$

where  $c$  is a fitted parameter related to the precision of the customer-preference model, that is, the higher the value of  $c$ , the more the probability function  $P(A)$  approaches a step function with values near zero and one.

#### Applying the Preference Model

Each product is characterized by attribute ratings. An attribute rating is determined by how many of

**Table II. Calculating Market Shares**

Customer	Products			Products		
	A \$500	B \$350	C \$350	A \$500	B \$350	Test \$350
Customer 1	0.02	0.49	0.48	0.02	0.43	0.55
Customer 2	0.03	0.63	0.34	0.02	0.54	0.44
Customer 3	0.04	0.81	0.15	0.02	0.55	0.43
Customer 4	0.02	0.75	0.23	0.02	0.67	0.31
Customer 5	0.03	0.78	0.19	0.03	0.71	0.26
Customer 6	0.05	0.63	0.32	0.02	0.32	0.66
Customer 7	0.03	0.71	0.66	0.02	0.45	0.53
Customer 8	0.02	0.67	0.31	0.01	0.39	0.60
Customer 9	0.02	0.64	0.33	0.02	0.32	0.66
Customer 10	0.03	0.79	0.18	0.02	0.65	0.33
Total Market Share	0.03	0.74	0.23	0.02	0.51	0.47

C affect the market shares. The prices of Products A and B are held fixed at \$500 and \$350, respectively. The dashed lines show the market shares of Products A, B, and C as the price of Product C varies. This also helps us to understand the market-share implications of varying the feature content of the products.

Consider the example shown in Table I. We enhance the feature content of Product C to form a new product, Test, while we hold the feature content of A and B constant. Test has additional features, so the attribute ratings for the first four attributes—OA&M, capacity, durability, and standards—now are 10. The other attribute ratings remain the same as for Product C.

The right-hand side of Table II shows the results of running the market-share model; the solid lines in Figure 4 depict the new price-sensitivity curves, in which the price of Test is varied. Figure 4 shows that the enhanced product, Test, has a larger market share at a given price than Product C, on which it is based.

Taking into account these new market-share results and a knowledge of the product costs, we can decide whether enhancing Product C is a workable, profitable decision.

#### **Automated Data Collection and Market Analysis**

In our work program, we emphasize an automated set of tools that support the product team in both data collection and data analysis. Figure 5 illustrates how we automated the data-collection process. A laptop computer enabled us to take surveys that used interactive questioning and data verification. Because we collected the data in electronic form, it was ready for analysis.

Figure 6 illustrates an on-line decision-support

system that was constructed to help the product team in two major activities: analyzing exploratory data and creating customer-preference models. Exploratory data analysis includes market-segmentation studies, as well as graphical representations of customer willingness to pay for individual attributes and features and for existing products. We use the customer-preference models for market-share comparisons and for analyzing competition, pricing, and feature priorities. Workstations help the product team not only to execute models but also to generate tables and graphs in business-case analyses. The product team has on-line access to both the market-research information and the set of customer-preference models.

#### **Conclusion**

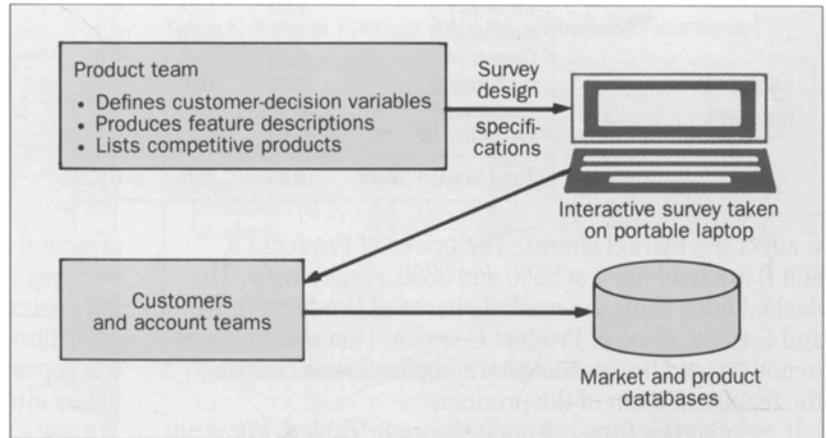
In this paper, we described an integrated market-analysis and product-design process. The process specifically supports the planning and marketing of complex industrial products, any one of which may have only a few customers. As part of the process, we:

- Identify generic product attributes
- Design a set of customer-survey questionnaires
- Create a set of market-segmentation schemes
- Develop sets of multi-attribute preference models.

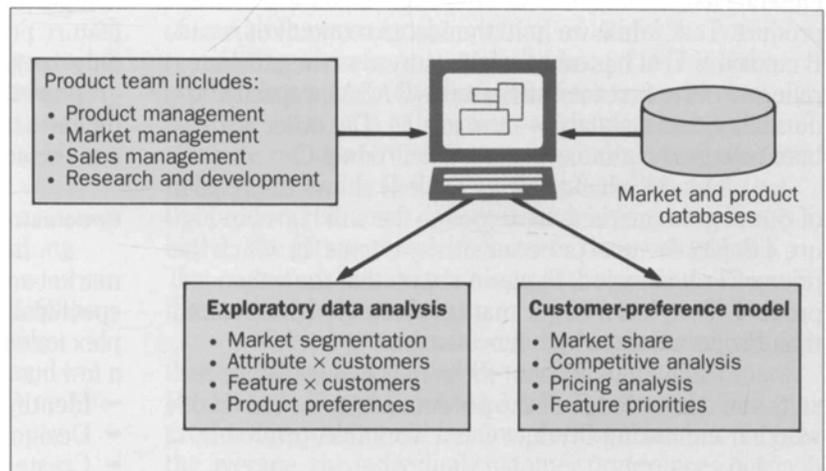
This process has been successfully applied to numerous products and services across a wide variety of markets. It has enabled us to:

- Segment the market
- Test new product concepts
- Guide feature development
- Price new and existing products
- Target the market for new and existing products
- Respond to competition.

**Figure 5. The product team automated the data-collection process using a portable laptop computer to take an interactive survey and to verify data. First, the product team designs a survey. The answers provided by the customers and/or account teams are used to produce market and product databases.**



**Figure 6. The product team uses an on-line decision support system and the market and product databases derived from the interactive survey to analyze the exploratory data and create a customer-preference model.**



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To execute this approach, we needed a formal structure to collect and analyze data relating to customer needs. To support this formal structure, we have formed product teams from the areas of market management, product management, sales management, and R&D. Within this formal structure, we have developed a common language to describe and evaluate products and features. To support the market-analysis process, we have designed and developed an automated set of

support systems for collecting survey data and helping us make marketing decisions.

**For More Information**

The modeling of customer preferences among multi-attribute alternatives has been a major activity in consumer market research for many years. A popular technique for modeling consumer preferences is conjoint analysis.<sup>3</sup> Green and Srinivasan<sup>4</sup> discuss the advantages

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and disadvantages of various implementations of conjoint analysis. Urban and Hauser<sup>5</sup> provide a more general discussion of the application of quantitative methods to the design and marketing of new consumer products.

Industrial markets, however, have several characteristics that make the straightforward application of consumer techniques difficult to implement. These characteristics include complex products, few customers, and complex organizational buying processes. These issues are discussed in Webster,<sup>6</sup> and in Choffray and Lilien.<sup>7</sup>

The methodology described in this paper draws on the literature of decision analysis,<sup>8</sup> as well as traditional market-research sources. In that sense, our methodology is similar in spirit to that described in a paper by Keeney and Lilien.<sup>2</sup> It also resembles the quality-function deployment (QFD)<sup>9</sup> process, described by Brown,<sup>10</sup> King,<sup>11</sup> and Akao,<sup>12</sup> in that our methodology starts with high-level customer requirements (attributes) and translates those requirements into more detailed, measurable features. This hierarchical multi-attribute approach enhances communication among members of the product team and ensures that design tradeoffs take into account customer satisfaction.

#### Acknowledgments

The initial process structure and model formulation described in this paper were developed by William J. Infosino and Eric Sumner, Jr. Later model applications and extensions were developed by Blaise Heltai, Laura Polisson, Simon Tse, and Lynn Wilson. We have benefited greatly not only from the modeling examples and results, but also from the many hours of stimulating discussion with this industrial marketing team.

#### References

1. J. D. Carroll, "Models and Methods for Multidimensional Analysis of Preferential Choice (or Other Dominance) Data," *Similarity and Choice*, E. D. Latermann and H. Jeger (Eds.), Hans Huber Publishers, Bern, Stuttgart, Vienna (1980), pp. 234-289.
2. R. L. Keeney and G. L. Lilien, "New Industrial Product Design and

- Evaluation Using Multiattribute Value Analysis," *Journal of Product Innovation Management*, Vol. 4, September 1987, pp. 185-198.
3. P. E. Green and Y. Wind, "New Way to Measure Consumers' Judgments," *Harvard Business Review*, Vol. 53, July-August 1975, pp. 107-117.
4. P. E. Green and V. Srinivasan, "Conjoint Analysis in Consumer Research: Issues and Outlook," *Journal of Consumer Research*, Vol. 5, September 1978, pp. 103-123.
5. G. L. Urban and J. R. Hauser, *Design and Marketing of New Products*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1980.
6. F. E. Webster, Jr., "Management Science in Industrial Marketing," *Journal of Marketing*, January 1978, pp. 21-27.
7. J. Choffray and G. Lilien, *Market Planning for New Industrial Products*, John Wiley and Sons, New York, 1980.
8. R. L. Keeney and H. Raiffa, *Decisions With Multiple Objectives: Preferences and Value Trade-Offs*, John Wiley and Sons, New York, 1976.
9. J. R. Hauser and D. Clausing, "The House of Quality," *Harvard Business Review*, May-June 1988, Vol. 66, No. 3, pp. 63-73.
10. P. G. Brown, "QFD: Echoing the Voice of the Customer," *AT&T Technical Journal*, Vol. 70, No. 2, March/April 1991, pp. 18-32.
11. B. King, *Better Designs in Half the Time: Implementing QFD Quality Function Deployment in America*, GOAL/QPC, Methuen, Massachusetts, 1987.
12. Y. Akao, *Quality Function Deployment: Integrating Customer Requirements into Product Design*, G. H. Mazur (translator), Productivity Press, Cambridge, Massachusetts, 1990.

#### Biographies (continued)

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