A Choice-Modeling Market Information System That Enabled ABB Electric to Expand Its Market Share

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In its third year of existence, ABB Electric was approaching the break-even point when it was confronted with a 50 percent drop in total industry sales of electrical equipment. The only way the firm could survive was to take customers from established major competitors. The firm developed a new type of marketing information system utilizing multiattribute choice modeling. It identified the current perceptions of customers on ABB's products versus various competitor's products. First, ABB used this information on what customers most want from products to devise strategies for taking customers and market segments from competitors. Second, the models' predictive accuracy enabled ABB to organize to meet the customer needs as the low-cost producer. Third, the information guided the firm in selecting new products that were preferred by customers and for which ABB had long-term cost advantages. ABB survived, grew, and now is the dominant firm in its industry.

In March 1970, ABB Electric was incorporated as a Wisconsin chartered corporation with initial capital provided by ASEA-AB Sweden and RTE Corporation. The new firm's management was authorized to operate as an entity independent

0091-2102/90/2001/0006$01.25

INDUSTRIES: ELECTRIC/ELECTRONIC
MARKETING — COMPETITION
UTILITY/PREFERENCES — MULTIATTRIBUTE

of the parent companies. Its mission was to design and manufacture a line of medium power transformers with which to penetrate the North American market. In addition to transformers, the firm produces other electrical equipment such as breakers, switchgear, and relays used in distributing and transmitting electrical energy. There are four major types of customers for this electrical equipment, the largest being investor-owned electrical utilities (IOUs), followed by rural electrification cooperatives (RECs), municipalities, and industrial firms.

Overview

As a new firm in an industry dominated by General Electric, Westinghouse, and McGraw-Edison, ABB had to find a way to win customers from the major competitors or go out of business. To compound the problem, an industry-wide environmental change in 1974 cut industry sales in half.

The emergence of OPEC ended an era of cheap energy. The public service commissions in many areas of the country responded by changing the game rules for utilities; allowable earnings for a utility were now computed as a percentage of kilowatts delivered rather than as a percentage of assets. This change plus the utilities sharply reducing their estimates of the increase in annual electrical energy usage left many utilities with substantial inventories of spare electrical equipment.

The firm at this time (1974) brought in an outside consultant, Dennis Gensch, who helped ABB develop a new type of marketing information system that allowed them to use an emerging class of management science models called multiattribute disaggregate choice models. These models gave ABB Electric insight into current perceptions and preferences of potential customers. These insights guided its marketing strategies in the selection of target segments, the product features to emphasize, and the development of new products, services, and features.

One of the first marketing actions ABB took was to offer a full five-year warranty on all products. To completely warrant a $300,000 item for five years was a dramatic statement of quality assurance. Even today, in 1989, no competitor offers a standard warranty of over one year. In order to develop the extremely high standard of quality control required by a full year warranty at an affordable cost, the firm again developed and applied management science models, this time in the design and manufacturing areas. Over the years, models that integrated the design programs directly into a flexible manufacturing program provided a highly sophisticated concept of manufacturing management that gave ABB the acknowledged highest quality control system in the industry. More remarkably, due to efficiencies gained through the integration of sophisticated management science models, ABB Electric has become the

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low-cost producer in the industry.

Finally, by integrating production information into a new product planning model, ABB Electric can take into account supply side considerations in selecting which new product concepts to develop. This has led to the development of new products in which ABB Electric enjoys significant cost advantages. When ABB Electric introduces such a product successfully, a major competitor is forced to make substantial investments to change or upgrade its basic production process, or leave ABB Electric with a successful product that has no direct competition.

A strength of ABB Electric is that management science techniques have been applied and developed throughout the entire organization, often integrating various functional areas. As with many management science applications, one good model development and application sets the stage for more sophisticated development that uses information generated by the previous stage. A complete description of the breadth and depth of the management science techniques ABB Electric uses are beyond the scope of this paper. We will attempt the following:

First, we will describe the problem situation and the development of the initial approach to modeling customer choice and some more advanced modeling applications to indicate how the evolution of modeling approaches is a dynamic process within ABB Electric. Second, we will provide a nontechnical overview of the models in the production process. Third, we will describe the logic underlying a new product planning model used in developing a major new product.

The Marketing Problem and the Application of Multiattribute Choice Models

After losing money in its first three years, ABB Electric faced a real crisis in 1974. Virtually all of ABB Electric's sales were to one type of customer: the IOUs. This group, because of substantial inventories, was projected to decrease sales by up to 80 percent per year for the next two to three years. Figure 1 shows the actual industry sales of transformers from 1965 to 1987. The small ABB sales force had concentrated its efforts on the approximately 250 IOUs who historically had purchased transformers on a regular basis, often in large volume. The sales force had

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little penetration among the over 3,000 RECs and over 100,000 small municipalities and industrial companies who tended to purchase occasionally or one time only. Westinghouse, General Electric, and McGraw-Edison were well-established long-time suppliers of RECs, municipalities, and industrial customers. Customers often purchased new and replacement transformers from a single manufacturer to insure compatibility throughout a system and to standardize periodic testing and maintenance procedures.

It was clear that if ABB Electric were to survive, it needed to win customers away from major suppliers with established relationships, reputations, and product acceptance. ABB Electric realized that

Figure 1: The industry sales (in units) of transformers for years 1965 to 1987. The drop in total sales in 1975 made for an environment that seriously threatened the existence of a new small transformer supplier.

taking established customers from able competitors is a very difficult task. To have any hope of achieving this, it would have to become a consumer-driven company. It would have to do a better job than its competitors of learning and understanding the diverse problems and needs of potential customers. It would have to design products and services to better meet those problems and needs. It would have to communicate to potential customers the existence of those products and why they met their problems and needs better than competitors' products. Finally, ABB Electric would have to monitor customers' responses to both its communications efforts and its products and services in order to make necessary adjustments.

Achieving the Goal

The management science technique ABB Electric used and developed to help it achieve its goal of becoming the most consumer-driven firm in its industry is a new type of marketing information system designed to support multiattribute disaggregate choice models. The concept underlying multiattribute disaggregate choice models is simple and straightforward.

Explaining how individuals make choices among alternatives and providing a theoretic structure for studying the choice process is a fundamental aspect of such basic academic disciplines as economics, sociology, and psychology as well as such applied disciplines as political science, artificial intelligence, and marketing. Obviously considerable differences exist among the disciplines in both jargon and substance. However, one concept that the disciplines seem to agree on is that individuals seldom make actual choices among alternatives by comparing or evaluating them at the totality level, or as psychologists term it, the gestalt. Rather, most individuals make choices by comparing the attributes of the alternatives. For example, most individuals do not choose a car because it is a Ford, Buick, or Honda; rather they make the choice by comparing the price, miles-per-gallon, seat room, and other relevant attributes of the various alternatives.

Now if this is true and we can get individuals to tell us the attribute value (ratings) they currently perceive each alternative as having, and (for some multiattribute choice models) the relative importance of attributes (ranking) in making their decisions, we should be able to put together logical structures or algorithms to combine attribute ratings and rankings in such a way as to enable the researcher to replicate the individual's choice process. The various algorithms or ways of combining the attribute data are the various multiattribute choice models.

A multiattribute choice model is said to be a disaggregate model when it uses a random sample of individuals who provide attribute ratings, and in some cases attribute rankings, and from this sample estimates the parameters of a model that allows the decision maker to predict the response of a population or of individual members of the population who were not in the sample. Because we wanted to predict the choice distribution among alternatives for entire groups of customers (populations) rather than for a specific individual, we were most interested in disaggregate rather than individual level choice models.

In the mid '70s the logit model was just starting to evolve in the economics and marketing literature as a useful disaggregate multiattribute choice model. In 1974, ABB Electric started to survey its various customer segments. Even with the help of a nationally known market research firm, developing a good customer data base involved considerable learning and some setbacks in such things as developing accurate mailing lists and getting adequate response rates.

Our initial surveys had customers rate and rank large sets of product and service attributes. These large sets were factor analyzed and consistently produced

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the same eight to 10 independent dimensions. We selected an attribute that loaded heavily on a dimension to represent the set of attributes loading heavily on that dimension. In this manner, we selected eight to 10 relatively independent and important attributes as independent variables for logit choice models.

The logit model provided us with predictions and diagnostic information as to which attributes were the most salient or key in determining the choice among the various suppliers. Table 1 illustrates the type of output generated by the logit model.

The predicted sales are compared to actual sales, and both the magnitude and directions of under and over predictions are observed. Next the logit coefficients of

Supplier	1	2	3	4	5	6	7
Percent of actual sales	10%	30%	15%	3%	7%	10%	25%
Percent of predicted sales	9%	32%	12%	5%	6%	11%	25%
Error	− 1%	+ 2%	− 3%	+2%	−1%	+1%	0%

	Variables	*Logit Coefficient*	*t-value*
1.	Invoice price	3.45	1.45
2.	Energy losses	7.45	3.29**
3.	Appearance	4.32	2.11*
4.	Availability of spare parts	2.45	0.99
5.	Clarity of bid document	1.62	0.36
6.	Knowledgeable salesmen	2.78	1.12
7.	Maintenance requirements	2.64	1.31
8.	Warranty	8.22	4.05**

*Significant at .05 Level
**Significant at .01 Level

Table 1: Actual and logit predicted sales are compared among seven competing suppliers, followed by the independent logit variables, coefficients, and *t*-values used to predict sales.

the independent variables in the logit function are reported along with their *t*-values. The example in Table 1 indicates that warranty and energy losses are the key variables in determining which supplier to purchase from. Often the salient attributes identified by the logit model are quite different from the attributes customers say are most important in their choice. The salient attributes indicate the degree to which actual choices are sensitive to different levels of this attribute.

The ABB marketing staff felt strongly that different segments of customers weighted attributes very differently in their preference functions. Behaviorally, this meant that while the firm considered all the small RECs in the South to be homogeneous in their perceptions of the relative importance of such attributes as price, installation, maintenance, energy losses, and so forth, this group was very different from the large utility companies of the Northeast, both in terms of most important attributes and perception of major suppliers. The reasons for these differences between segments relate to differences in the technical sophistication of the various customers, different salesforce call patterns, and different promotional efforts. For example, a large utility with a sophisticated engineering staff will place different values on product features, initial price, and support services offered by the supplier than a small REC with no engineering staff and little technical sophistication.

Given that we believed the assumption of homogeneity or sameness with respect to one set of logit coefficients was unrealistic, we made an attempt to segment the customers into groups that were reasonably homogeneous with respect to the given set of logit coefficients. A priori the marketing staff indicated three main dimensions underlying heterogeneity: geographic area, type of customer, and size. The size of an electrical company is generally measured in meters served where each customer of the company has an electric meter to measure the consumption of electricity. We initially segmented respondents along these dimensions. The industry broke down into four geographic regions and four types of customers. Utilities were split into three size groups, municipals were split into two size groups, and industrials constituted a single size group. This produced 12 utility segments, eight REC, eight municipal, and four industrial segments for a total of 32 a priori segments to be considered.

We ran logit models on each segment. We combined adjacent segments (segments with two common dimensions, for example, a segment of small RECs located in the Southeast and a segment of small RECs located in the Southwest) if the differences in the set of logit coefficients were not significant at the 0.05 level, using a log-likelihood test on the two sets of logit coefficients.

After we had combined all adjacent segments, we had reduced the number of segments to 10. We then tested the homogeneity with respect to the logit coefficients within each of the remaining segments using both jackknife and bootstrapping techniques. When bootstrapping revealed a heterogeneous segment, we split the segment on dimensions that appeared to be related to systematic differences in the logit coefficients.

We tested the newly formed segments again for adjacent combinations and then for internal homogeneity with respect to the logit coefficients. Eventually we identified 12 segments, and the segment sample sizes ranged from a low of 148 to a high of 464. We analyzed each segment separately, producing 12 different logit models. The respondents were quite homogeneous within a segment, and there were some very significant differences in logit functions between segments. The logit functions yielded good predictions of market share by segment. When they were applied to the actual sales for the year following the surveys, they predicted market share by supplier quite accurately.

By applying this marketing information approach to a particular segment, we identified the main competitors and ran logit analyses of ABB versus these competitors to determine the salient attributes determining choice. In light of this analysis, we examined current perceptions of ABB and the major competitors on the salient attributes. We then determined a marketing strategy for the segment. We also suggested specific models and transformer features to emphasize and possible new products or product modifications. Using the mailing lists painstakingly developed to survey this segment, ABB initiated a direct mail campaign emphasizing the salient product features in which it had an advantage. In many cases within a segment, we performed logit analyses to predict the choices of individual customers and to guide us on the key features that determined these choices. Thus ABB's marketing response to two similar requests for bid documents (requests by customers that ABB Electric make a detailed bid to

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meet given sets of specifications), even for customers of the same type, is often quite different, depending upon whether we view General Electric, Westinghouse, or some other supplier as ABB's major competitor for this order.

We implemented marketing strategy sequentially one segment at a time. Two years elapsed between the direct mail campaigns to the first segment and to the last segment.

As shown in Figure 1, industry sales dropped dramatically during this period. Nineteen seventy-five sales dropped 70 percent from 1974. Nineteen seventy-six industry sales were going even lower. During this period, in the year following the first direct mail campaign to a segment, ABB Electric was able to maintain or increase its sales level in each segment. More important, over 50 percent of all orders during this first year were from new customers. ABB's market share in the modeled segments was three times that in the nonmodeled segments. In dollar terms this increase in sales was over three million per year for each of the first two years direct mail was used. Since ABB Electric tends to convert most new customers to repeat customers, a conservative estimate of the dollar value over time, from the initial use of the marketing strategies based upon choice modeling, is well over 50 million dollars. It is clear to the management of ABB Electric that few of these sales would have occurred without the information developed from the choice modeling analysis.

Following the initial application of choice modeling, a number of more sophisticated advancements in the methodology evolved. The first major innovation allowed ABB Electric to identify the more switchable of its competitors' customers, allowing it to concentrate its resources on these customers. In a similar manner, we identified which of ABB's customers were most likely to switch to a competitor and again concentrated its resources on this group in an effort to prevent their doing so. A complete and detailed write-up of this procedure was published by Gensch [1984]. We will summarize this approach here:

Identifying Switchable Customers

The methodology was to extend the multinomial logit choice model to determine the statistical significance of the differences in the choice probabilities generated by the basic logit model. The electrical customers have, through personal interactions and past experiences, developed varying degrees of loyalty to various suppliers. Conceptually, ABB wanted to identify the switchable and competitive segments of current customers. A *switchable* customer is one who currently perceives our firm to be very close to its first choice supplier; a *competitive* customer is one who, while he currently perceives our firm as his first choice, perceives other suppliers as being very close to our firm. These two segments of customers are believed to be the most responsive to the marketing efforts of suppliers.

The logit model estimates for each individual the probability of selecting each of the alternatives in the choice set. Consider two individuals, designated as individual 1 and individual 2. Assume that for individual 1 the logit model estimates the following choice probabilities for three suppliers: 90 percent for supplier A, five percent for supplier B, and five percent for supplier C. For individual 2 the estimated choice probabilities are 40 percent for supplier A, 30 percent for B, and 30 percent for C. If one were asked to predict which supplier individuals 1 and 2 would select, the maximum probability indicates supplier A is most likely for both. However, given the above probabilities it is clear that individual 2 is much more likely to choose supplier B or C than is individual 1. We developed a methodology to compute the statistical significance of the difference in the probabilities for each individual between their first and second choices [Gensch 1984].

We identified four groups of customers based upon this analysis: loyal ABB Electric customers, competitive customers, switchable customers, and competitor loyal customers.

The segment labeled *loyal ABB customers* is defined as that segment in which ABB is currently perceived as vastly superior to all competitors. The loyal customer has a very high probability of purchasing his next transformer from ABB. This segment consists of respondents whose probability of purchasing from ABB is highest and is significantly (at the 0.05 level) above the second highest probability.

The *competitive* segment consists of customers who have a slight preference for ABB Electric over other suppliers. These are respondents whose probability of purchasing from ABB is highest, but the differences between the highest probability and one or more of the other probabilities is not statistically significant at the 0.05 level. The *switchable* group consists of respondents whose probability of purchasing from one or more other suppliers is higher than their probability of purchasing from ABB, but the difference between the probability of purchasing from ABB and the firm with the highest probability is not statistically significant. This customer's first preference is for a competitor, but it perceives ABB Electric as relatively close to its first choice.

The *competitor loyal* group consists of respondents whose probability of purchasing from one or more of the competitors

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is higher than the probability of purchasing from ABB, with a statistically significant difference between these probabilities. It is unlikely that members of this segment will purchase their next transformer from ABB.

ABB Electric has divided the US market into three geographic sectors, each with a district manager in charge of a sales and promotion budget. The keys to getting any new methodology adopted, especially if it uses advanced statistical or mathematical programming, are to make sure the managers who must implement it understand it, and that they actually believe it will be an improvement on the status quo. One manager stated he didn't really understand the proposed "number crunching" and preferred to manage his territory without using the statistical models. The remaining two managers were responsive to the choice-modeling approach and derived the following strategy: Cut back on the general promotional advertising in trade journals. Reduce the field sales-force's call pattern over all customers, with the greatest reduction targeted at competitor-loyal customers. With the money and personnel time saved they formed "missionary" sales forces to operate out of district headquarters.

The strategy developed by these managers concentrated on the competitive and switchable groups in their territories. They relied heavily on direct mail, supported by the missionary sales force. The direct mail emphasized the particular attributes and products of greatest interest to the particular customer. The attributes and products to emphasize were indicated by the logit analysis on the particular segment to which the prospect belonged. The missionary sales force also emphasized the attributes and the products identified as most salient by the logit analysis and of most interest to respondents of a particular segment. Essentially, the strategy was to reduce the marketing effort to ABB's and the competitors' brand loyal segments and to expand it to consumers for whom ABB was competitive. The strategy assumed that it is within the competitive and switchable groups of customers that changes in market share are most likely. While the services provided to the firm's brand loyal customers were not reduced, the repetition of the same message was. The marketing effort to other firms' brand loyal customers was substantially reduced. Thus these two managers, guided by the modeling, reallocated their marketing budgets to concentrate more resources on the customers most likely to switch to ABB.

The third district manager, who had spent his entire career in sales and had a very limited background in statistics and modeling, did not feel comfortable with the modeling approach. He chose to continue with the existing marketing strategy.

Results

After a full year of implementation, the strategies yielded these results: Total transformer sales for the industry were down 15 percent. Total industry transformer sales appeared to be down in all three districts, with the decline in district two greater than that in the other two districts. ABB sales in the two districts using the choice model segmentation approach were up 18 percent and 12 percent. Sales in the territory using traditional marketing methods were down 10 percent.

Table 2 presents the change in sales per group of customers by sales district. Districts One and Two used the choice-modeling segmentation strategy while District Three used the conventional approach. Sales are measured in terms of contracts awarded rather than shipments made. It is clear that major increases in the first two districts occurred because of substantial increases in the competitive segment supported by increases in the switchable group.

In 1980, the year preceding the one described above, industry sales were down about eight percent from the previous year, and district sales were up two percent for District One, down seven percent for District Two, and down three percent

	District		
Consumer Group	One	Two	Three
ABB's brand loyal	+ 2%	+ 3%	+ 3%
Competitive	+26%	+18%	− 9%
Switchable	+16%	+ 8%	−18%
Competitors' brand loyal	− 4%	− 3%	− 4%
Total	+18%	+12%	−10%

Table 2: The annual changes in sales by district and by consumer group for 1981 reveal the effectiveness of concentrating marketing efforts on competitive and switchable customers. Districts One and Two followed the new strategy, while District Three continued its traditional sales tactics.

for District Three. Thus it does not appear that the results in Table 2 can be explained principally as a function of different sales trends in the different sales districts.

In an attempt to obtain some estimate of what sales might have been if the supplier segmentation approach had not been implemented, we multiplied the total sales in each of the 12 customer segments by the aggregate choice probabilities estimated by the logit function for that segment. This approach produced the following estimates of sales results for our three districts: District One (−9 percent), District Two (−8 percent), and District Three (−11 percent).

If we convert to dollars the percentage change in sales in each district from what happened using the modeling approach versus what most likely would have happened without modeling, we find the 25 percent to 30 percent increase in sales to be worth 8 to 30 million in sales depending on the year. In the first two years this approach was used (1981-1982), ABB estimated a $17 million increase in sales revenue. At the end of the first year all three sales districts adopted this approach, and it is still in use today. The sales gains from the competitive and switchable segments, while still double the sales gain in the loyal segments, are not as impressive as in the first year.

The 1980s

With the success of the early choice-modeling projects at ABB, it was natural that applications grow in sophistication. Many of the innovations in choice modeling made at ABB in the early 1980s were detailed in the management science literature [Gensch 1984, 1985, 1987a, 1987b; Gensch and Javalgi 1987; Gensch and Svestka 1984].

The leading choice models in the late '70s were logit, probit, and tobit in which the probability of choosing a particular alternative was a linear or nonlinear combination of the attribute values. Herbert Simon, a Nobel laureate in economics and artificial intelligence, and Amos Tversky, a psychologist, supported with empirical evidence their argument that many decision makers used a decision process with a completely different structure than that assumed by the logit-type choice models. They argued that decision makers simplified the decision process by using a hierarchical decision structure which evaluated and eliminated alternatives on an attribute by attribute basis. The first practical disaggregate multivariate choice algorithm assuming a hierarchical decision variable capable of estimating population parameters from a sample of individuals was published by Gensch and Svestka [1979]. In applying this algorithm to the segments at ABB Electric, we found that the hierarchical type of choice structure did a much better job of representing the actual choices of some populations (segments) than the logit structure. In other segments, the logit structure seemed more appropriate. There were strong patterns here. It soon became clear that certain types of decision makers could be more accurately represented by one decision structure than another. Research on sets of decision makers suggested that the reason one type of decision structure gave better predictive fits than others was that it probably more closely replicated the decision structure actually being used. We found a number of a priori variables that indicated the individual or organization would be better analyzed by one type of decision model than another. For example, Gensch [1987a] reports that the more knowledgeable and experienced a buyer of electrical equipment is, the better a simultaneous compensatory (logit) model fits. More knowledgeable customers tend to consider more attributes and make more trade-offs on the attributes, particularly invoice price. Less knowledgeable purchasers, for example, many smaller REA or industrial customers, are better represented by a hierarchical decision structure; they seldom compare alternatives on more than three attributes. For less knowledgeable buyers, choices are usually determined on invoice price and the perceived reputation of the supplier. Relative differences on other attributes seem to have little influence on their choices.

Within the competitive and switchable groups, changes in market share are most likely.

Thus not only do we have segments of customers who have different evaluations of important or salient attributes in decision making, but we also know that various individuals or organizations tend to use different decision structures for evaluating their perceived ratings of suppliers' attributes in making a choice. As Gensch [1987b] indicates, we can now predict the chosen supplier for each sale of a transformer or other major piece of equipment with 60 to 70 percent accuracy. These rates are substantially above chance levels for decision sets containing four to eight alternatives. When we estimate market share for a segment, we average out some over- and underpredictions for a particular supplier, thus making the supplier's market share per segment very accurate, especially for the main suppliers. The averaging process of combining market shares for all segments tends to further cancel out individual mispredictions, yielding very accurate aggregate market share predictions for ABB as well as other suppliers.

We have attempted to conservatively estimate the sales impact of some of the various stages in choice modeling used by the firm. The cumulative impact of this methodology is best summed up in a 1988 statement at the board of directors meeting by Daniel Elwing, president of ABB Electric, who observed that for a firm whose total sales had grown to over $100 million: "Without the insights from our marketing models, it is unlikely we would have current sales of $25 million; in fact, without the use of these models, it is unlikely we would be here at all."

Operations and Production

The production layout and the operations procedures were designed to meet the customer orientation required by the firm. Choice modeling indicated the features of each product that had to be included and emphasized. Production layouts were evaluated with the feature goals clearly in mind. The feature goals for each product constrained the possible production layouts and focused creative attention on these goals.

For example, the high premium many customers placed on specialized paints for their transformers required that the production process permit a change of paints for each transformer. The standard process for doing this was time consuming and expensive, costing approximately $5,000 per change. Consequently, ABB's competitors tended to limit their flexibility in providing specialty paint colors. Insistence that this be part of the production process gave birth to an innovative method which simply called for replacing $100 worth of hoses after each job. Thus the production process used the marketing information to plan the plant layout, the machines needed, and the labor skills required so as to most efficiently produce the products and features that customers would desire 18 to 24 months in the future. The accuracy of the marketing forecasts underlies the production functions' ability to be responsive and efficient in producing to meet customer demands.

Implications of the Five-Year Warranty

The ABB five-year warranty was made standard on all products; it was a given, something a customer did not have to bargain for. At the time, those competitors who gave warranties limited them to one year. Even today ABB Electric's competitors still offer a standard warranty of only one year. From the marketing side, the five-year warranty gave ABB an instant quality reputation, particularly among customers who had regularly dealt with a competitive supplier. Five years later Chrysler did the same thing in the auto industry. The production and quality control system built to support this quality pledge required a series of management science models integrated throughout the design, manufacturing, and testing of products.

Economic Implications

It turns out that the high quality designs required by the five-year warranty have actually reduced the total quality cost to the firm. Total quality cost has four components: (1) in-house failures, (2) warranty costs, (3) inspection and testing costs, and (4) prevention (quality control engineering) costs. Ten years ago the total quality cost was approximately 3.90 percent of gross sales; today it has dropped to 1.78 percent. ABB's major competitors indicate warranty costs alone of between 2.50 percent and 6.00 percent.

The production planning models have also had a dramatic effect on the factory throughput time (TPT). Factory TPT is measured from day of first production operation to day of shipping. Eight years ago factory TPT was 38 days. Today TPT is 21 days (subsequently reduced to 19 days in June 1989); this gives ABB Electric the shortest TPT in the transformer industry, worldwide by a factor of between two and five. The industry average TPT for power transformers is approximately 60 days.

ABB's short TPT results in less investment in facilities and equipment, and it reduces work-in-process and material inventory for equivalent product shipments. The average number of inventory turns for job-shop type manufacturing is between two and four. Last year, thanks to accurate data for planning and material forecasting, ABB had nine inventory turns. Accurate sales forecasting by the marketing division is the key that enables us to use complex, sophisticated scheduling models. It allows us to make long-term decisions about machines, work stations, and new personnel assignments. And over time, it allows us to smooth out material orders. Our ability to be a steady customer has helped our vendors provide higher quality materials, delivery consistency, and better service. It also gives us sufficient lead time so that we can create the right mix of machines, plant layout, and employees to meet the boundary conditions for the optimal scheduling models mentioned above. These boundary conditions shift over time as a function of theproduct mix to be manufactured.

Finally, the employees all have access to and contribute to one integrated data base for the firm. It is difficult to get current industrial data on productivity per employee. The latest industry data we have access to is from the 1983 US Bureau of the Census under the SIC code 3612 which covers manufacturers of distribution and power transformers. The dollar sales, value added, and the million volt amperes (MVA) manufactured per employee is much higher for ABB than the industry average (Table 3). All three of these employee productivity ratios have improved substantially at ABB since 1983.

After 18 years, ABB Electric is the only North American supplier that has never had a through-fault failure on one of its transformers. This outstanding quality record is now known throughout the industry, and ABB Electric is recognized as the industry's product quality leader. Information and advanced statistical-planning techniques have made ABB the low cost producer with a quality reputation and warranty that lead the industry.

New Product Development

A new methodology for generating new product concepts was developed and implemented. The key innovative feature of our new product model, over those current in the marketing science literature, is

	Industry — 1983	ABB — 1983	ABB — 1988
Sales per employee	$81,000	$128,000	$207,000
Value added per employee	$42,000	$ 58,000	$ 98,000
MVA per employee	2.3 MVA	11.7 MVA	15.6 MVA

Table 3: The sales, value added, and million volt amperes (MVA) per employee for ABB and for the industry in 1983 and for ABB in 1988 show that ABB's productivity is substantially above that of the industry.

that it incorporates supply side considerations directly into the analysis, suggesting new product concepts for which ABB Electric has significant long-run cost advantages over our competitors. Results from an initial application have been very profitable, as predicted by the methodology.

Most of the existing marketing literature on new product models concentrates on estimating demand-side implications for new products. Our methodology retains this emphasis but expands the analysis to include supply side differences

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among competing firms. As previously described, we have knowledge of the basic attributes that most influence a sale, and segmentation analyses for customers. We also know the basic plant size, types of machines, and general technological capabilities at the main production facilities of other major suppliers — features that strongly influence the cost efficiency of a facility. With different size plants and technologies, various suppliers will be more or less cost-efficient depending on the size and type of product involved.

The data we analyzed was the entire bid document file for the market from 1978 through 1980. Almost all utilities, municipalities, government agencies, and most REAs require formal bid documents from each supplier involved in a specific sale. In the bid document the supplier indicates the various product features and materials he will use to meet the buyer's specifications, as well as the price, terms, and conditions. This information is generally made available by public utilities at the time of the final selection. ABB has made a concerted effort to collect this data.

The methodology is an extension of the well-known Rosen's competitive-market equilibrium model [Rosen 1974]. For a full description of the application of this new product model to ABB's data that attempts to be rigorous, detailed, and complete, see Gensch [1989].

Through an econometric analysis of bid data, we estimate utility choice functions for each segment of buyers along with the seller's isoprofit supply functions. An *isoprofit supply function* is all of the various combinations of product attribute levels that produce the same profit for the supplier; for example, putting more labor hours and less copper into a given transformer to meet the same specifications. Choice functions indicate the trade-offs on attribute levels that produce the same utility for the buyer segment. The supply functions indicate the various combinations of attributes a supplier is capable of producing currently for a given profit (price) level. Each buyer wishes to buy a brand located on the lowest possible choice function, whereas each seller attempts to market a brand consistent with the seller's highest attainable supply function. The market achieves its steady state once the choice functions are just tangent to the supply functions, and the loci of all resulting tangencies constitute the market hedonic price function (Figure 2). A major advantage of this technique is that the supply functions for each seller are estimated by the econometric model

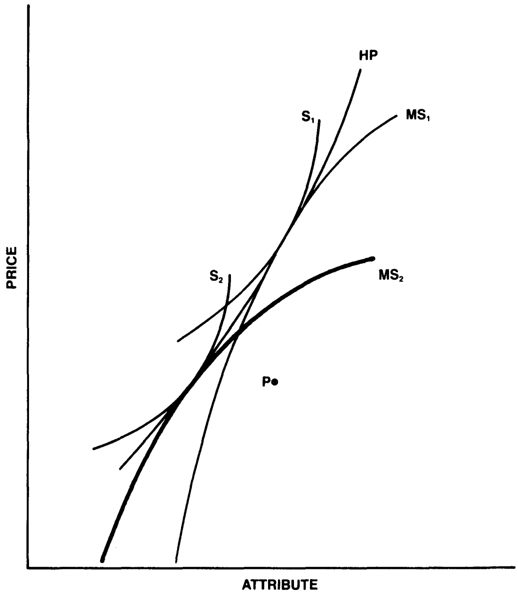

Figure 2: A special illustrative case of Rosen's market equilibrium shows one attribute with two market-segment-preference curves and two supplier-cost curves.

of the actual purchase data.

The theory is that due to the prevailing state of technology, firms cannot profitably offer products below the existing hedonic price function. If they could have done so, they would have during the period the data was collected. Then a new product offered below the hedonic price function will dominate (be preferred to all existing products) by the members of market segments with current preference functions passing between the new product's location and the current hedonic price function. The point P in Figure 2 indicates this type of new product concept. But to offer a new product below the hedonic price function, each firm must invest in its current state of technology in order to reduce the firm's current supply function sufficiently and in the prescribed manner so as to be able to produce the given product profitably. The investment may be in terms of research and development to develop new technology, changes in plant size or layout, purchase of new machines, hiring new employees with certain skills or any other methods of reducing the current production cost curve.

Empirically we have estimates of the utility choice functions and the supply cost function of ABB and the other suppliers in the industry. We used this mapping to, in effect, look at where new product concepts would tend to be placed. We used management estimates of the product features and mapped these relative to the estimated choice functions. We then looked for product concepts that would dominate a number of market segments and for which our investment would be less than that which we estimated competition would have to make. We also identified regions on these maps that looked attractive in relation to the above two criteria, and management speculated on various product feature combinations that would place a new product in this area.

Based upon this evaluation, ABB decided to develop a new completely integrated and self-contained substation, called a power delivery system (PDS). This product offered substantial improvements in safety, maintenance, ease of installation, and required space over existing substations. ABB already had and was using very expensive total-system testing equipment that most other manufactures would have to purchase to supplement their current component testing equipment. The PDS required the expenditure of over two million dollars for product development and testing. The reliability of the entire system, rather than just individual system components, is tested at the factory. This is unique in the industry and greatly facilitates installation.

The PDS was launched in 1983. The initial sales were slow; competitive firms spent considerable time and effort attacking PDS and raising doubts about it. Sales in '83 and '84 were mostly trial adoptions to innovative and early adopter organizations. In 1985, ABB's education of the utility market started to pay off, and sales of PDS have risen on a strong, steady basis. In 1987, the PDS product accounted for almost 20 percent of the firm's sales. It is the only such product on the market, and in the last four years, rather than make the necessary investments (estimated at between $15 to $30 million), two major competitors have closed their plants that manufactured transformers (the major components of substations) that competed in the PDS size range.

Implementation of Management Science

Why did management science work at ABB Electric? There are a number of reasons: the firm gathered the data specifically for each model rather than trying to simply model the available data; the marketing information approach developed by Dennis Gensch is innovative and powerful; the implementation by Steve Moore, Nick Aversa, and other ABB employees is creative and diligent; but clearly the major reason this firm has implemented the management science approach throughout its entire organization is because of the president and CEO, Daniel Elwing. Mr. Elwing sought out outside consultants to start a management approach based heavily upon data analysis. He spent money to gather the data and to buy hardware and software to enable the firm to use and develop sophisticated analytic techniques. He was directly involved in the development and implementation of key models and fully understands their assumptions, strengths, and weaknesses. He established an organizational climate that required departments to support their plans or proposals with data and analysis before they would be considered. The company offers employees considerable financial support to upgrade their management science technical skills. Dan has repeatedly stated that "management science is not a project or set of techniques; it is a process, a way of thinking and managing." This management style has created the environment at ABB Electric in which a management science approach has flourished.

Summary and Conclusions

Successful management science applications are traditionally associated with large well-known firms with sufficient staff to provide technical expertise. ABB Electric is an example of a small firm whose management turned to management science techniques during a crisis period, obtained outside technical expertise through consultants where needed, integrated management science approaches into the decision processes throughout the firm, and now, having survived their crisis period, are using these same approaches to become the market leader against major well-established competitors.

The electrical equipment industry is

1972	ITE (sold to Gould – BBC)
1974	Wagner Electric
1975	Allis Chalmers
1976	Central Maloney
1978	Standard Electric
1979	Sierra Transformer
1984	Westinghouse – closed Sharon, Pennsylvania, plant
1986	G.E. – closed Pittsfield, Massachusetts, plant

Table 4: Since ABB Electric originated in 1970, six US transformer manufacturers have left the industry completely, and two major competitors have closed major facilities that produced transformers that competed directly with ABB Electric.

extremely competitive. Industry sales have never regained the pre-1974 levels, nor are they expected to return to those levels soon. Since ABB Electric originated in 1970, six US transformer manufacturers have left the industry completely and two major competitors have recently closed major facilities that produced transformers that competed directly with ABB Electric (Table 4). During this time no new firms have entered the industry.

Table 5 shows the growth of ABB Electric measured in market share as measured in total dollars. Because most of ABB Electric's units are in the larger, more sophisticated size range for medium power transformers (particularly since the emergence of PDS), ABB Electric's market share measured in dollar volume is considerably above the market share reported in units.

The management at ABB Electric feels they have developed a depth of detailed information on the real needs, wants, and perceptions of potential customers not possessed by any of ABB's competitors. This information was developed and is constantly updated using a series of multiattribute choice models. The marketing strategies flow directly from this information. The operations and production systems needed to support the various marketing strategies rely heavily on management science models to integrate and manage the various functions.

The information on customer perceptions and preferences guides ABB's sales force in determining call patterns and message content. It is used to determine and design the promotional pieces carried by salesmen. A direct-mail campaign allows the firm to target its customers and focus the company's resources on the product features of most concern to

Year	ABB's Market Share	
1971	2%	
1972	4%	
1973	6%	
1974	6%	
1975	8%	Five-year warranty
1976	15%	Application of basic choice modeling
1977	17%	
1978	17%	
1979	18%	
1980	16%	
1981	18%	"Switchable" customer approach
1982	24%	
1983	25%	
1984	24%	
1985	28%	PDS Growth Starts
1986	30%	
1987	34%	
1988	40%	

Table 5: ABB Electric's market share measured in dollars shows the effect of some of its innovations.

various customer segments. Using the modeling approaches described here, we have developed a new-product modeling approach that not only guides us to products that will be strongly preferred over existing offerings but will also have basic structural long-run cost advantages over those of our competitors. The PDS is the first major product developed under this concept. As of today, it dominates the preference functions of multiple market segments, and there is no direct competitive alternative to it.

Accurate market forecasts provide a framework within which the operations and manufacturing divisions can use sophisticated and interactive models that interrelate marketing, design, and manufacturing schedules. The tight boundary conditions allow for considerable flexibility in the design and manufacturing processes. This permits ABB to achieve the dual conflicting goals of being the quality leader and the low-cost producer simultaneously. The flexibility also allows the sales force to sell customers products specifically designed to their particular needs rather than standardized models. Without sophisticated management science models of optimal design and flexible manufacturing, this would not be possible.

"Management science is not a project or set of techniques; it is a process, a way of thinking and managing."

The use of integrated manufacturing modeling underlies the following practical results. First, ABB Electric has never had a through-fault failure, and it is the only manufacturer that can make this claim. Second, because of its quality, ABB Electric can provide a five-year, standard warranty while competitors provide at most a one-year warranty. Even with five times the warranty exposure, ABB's overall quality costs are the lowest in the industry. ABB is the world leader in TPT for medium power transformers. ABB has the highest employee productivity in the industry measured in sales per employee, value added per employee, and product MVA per employer. Inventory turns are twice the industry average. In short, ABB Electric utilizes management science models with a breadth and depth few other firms can approach. Because of this, ABB is achieving results few firms can match.

Finally, the future looks very promising as PDS and other new products continue to grow and major competitors are making decisions to leave the industry rather than make the substantial investments required to remain competitive. The continuing growth in market share is resulting in reduced cost per unit as ABB achieves strong economies of scale in marketing and promotional activities as well as some economies in production.

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