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EVALUATING A NEW MARKET: A FORECASTING SYSTEM FOR NONIMPACT COMPUTER PRINTERS

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ABSTRACT. In 1975, Xerox put on "hold" and nearly cancelled the development of a high speed xerographic-scanning laser computer printer because prior market research had failed to demonstrate that the company could profitably market such a product. A team composed of Management Scientists, market researchers, and product planners designed and implemented a market-research-based forecasting system for high-speed computer printers. The forecasting system models the behavior of each market research respondent with respect to choice of computer printers. It predicts his choices from among sets of alternatives and his usage levels of the selected products. The system then uses product marketing scenarios to construct a dynamic version of these predictions and produces detailed forecasts of product populations and usage over time.

Use of this system produced a credible analysis of the market; based on this analysis, Xerox decided to develop, announce, and manufacture the 9700 Electronic Printing System. The forecasting system was also used to design pricing and other marketing strategies for the new product. The 9700 is now an extremely successful product that is projected to produce billions of dollars of revenue for Xerox. The forecasting system has set a new company standard for evaluating new markets. It is influencing the design of other market-research-based forecasting systems and improving the overall quality of new product planning.

BACKGROUND

The history of the Xerox Corporation is one of the great success stories of American business [Dessauer, 1971]. During the late 1940's and the 1950's, the Haloid Company, a small photocopy film manufacturer, acquired and developed a new technology it named "xerography." In 1960, Haloid changed its name to the Xerox Corporation and introduced the first plain paper office copier. During the 1960's and into the early 1970's, it was a classic growth company. In 1969, it bought a mainframe computer company, Scientific Data Systems, and began to define its future in terms of the "architecture of information."

But 1975 was different! For the first time since 1951, Xerox's earnings declined. After five consecutive years of losses in its computer business, Xerox sold the business at a further loss. Earnings in Xerox's remaining operations declined in the face of new competitive pressures. The stock market had been falling, and Xerox

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stock, which had traded at 127 in July 1974, fell to a nine-year low in the mid 40's in December 1975. Many product development projects were cancelled, and the Chairman's message in the 1975 annual report stated, "We have tightened controls over asset utilization, with particular emphasis on capital expenditures [Xerox Corporation, 1976]."

At this time, a large project was under way in Xerox to develop a remarkable computer printer by adapting scanning laser technology to the powerful new two-page-per-second Xerox 9200 xerographic engine. The computer-controlled scanning laser offered exciting possibilities, such as extremely high quality print, multiple fonts on each page, electronic generation of forms, and automated merging of forms with variable data. The xerographic engine would produce 8½ by 11 inch cut sheet output and could ultimately print on both sides. This would save both paper and paper costs for its users, but would force them to abandon their traditional 11 by 14⅞ inch fanfold output. Since the product would be a nonimpact printer, it would be unable to print carbon copies, but it could produce collated multiple copies by automatic repeated printing. The Appendix of this paper describes the technology of this product more fully.

This was Xerox's largest development project outside of its main business. Although the project's technical risks were considered acceptable, this was a major investment in a high-cost product that was not a copier or duplicator. Furthermore, a prior market research study aimed at resolving market uncertainties had been unable to demonstrate that Xerox could profitably market this product.

At this point, the market outlook was further complicated by IBM's announcement of its own high-speed scanning laser computer printer. The IBM product would produce fanfold or cut sheet output and could accommodate 11 by 14⅞ inch paper. Now, the new Xerox product would have to compete in the computer center with a somewhat similar IBM product to which conversion would be easier. Xerox management nearly killed the product program. However, in a controversial decision, the project was allotted just enough funds to keep the key elements of the technical team together for another year. The project team was instructed to use that year to assemble a credible market forecast.

It was clear that something other than a traditional market research study would be required. In Xerox, market research was typically based upon "concept tests" in which potential customers are asked to choose between unbranded descriptions of alternative product "concepts" such as a traditional computer printer, the proposed Xerox product, the IBM product, etc. If the descriptions of the concepts for the test can be made similar to real products, then a projection based upon such choices can provide a credible estimate of market interest in the proposed product. However, if the products change from those presented, if the conditions for the simulated evaluation change, or if brand effects are important, then the credibility of this approach is seriously undermined. All three of these conditions were present. Because of long development times, computer printing product characteristics undergo significant change, new competitive products are frequently announced, and important market conditions such as paper costs can fluctuate widely. Furthermore, to be credible a forecast must account for IBM's brand image in the computer center. Yet, it was essential that the forecast be robust and defensible on the basis of believable assumptions and consistent logic. There was an alternate market research approach that seemed appropriate for addressing the issue of changing product characteristics and market conditions. This approach is based upon preference functions that attempt to describe how market research respondents evaluate and choose among alternative products. However, because of previous failures, this approach was not highly regarded by Xerox management. Some of the prior difficulties with this approach were caused by use of ''off-the-shelf'' models that did not respond to Xerox needs. In addition, the forecasts from these models had often been inconsistent with concept test projections.

DESIGNING THE FORECASTING SYSTEM

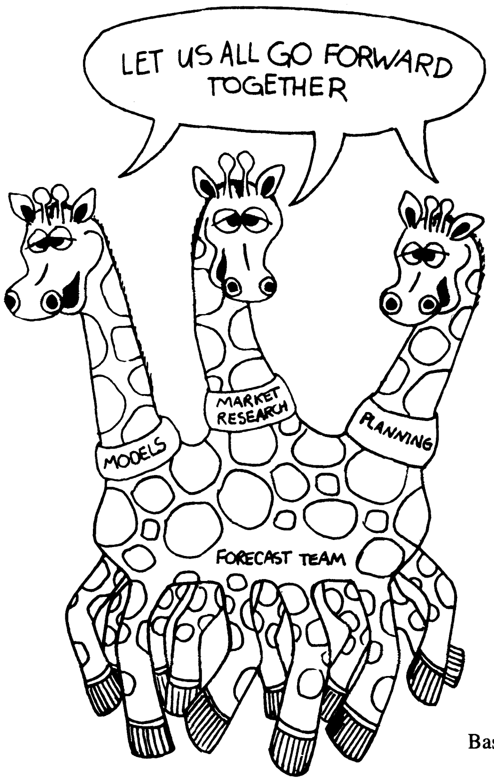
The situation required an innovative approach to quantifying and analyzing the market for the proposed product, the 9700 Electronic Printing System. Some of us had worked with members of the 9700 program staff on previous projects and so were given the opportunity to propose an approach for a system to forecast the computer printing market. A conceptual framework for a forecasting system, as well as some of the detailed mathematics, had been developed in previous Xerox projects and in individual basic research. The eventual agreement to proceed with the development of the forecasting system was a partnership of necessity: the 9700 program team needed a credible forecast for its product, and we needed a practical context for testing and extending our approach to market analysis.

It was decided at the outset of the project to form a working group consisting of the authors plus representatives from the 9700 program staff and the corporate market research staff. This working group, which was led by the 9700 program manager, had complete responsiblity for the design, construction, and implementation of the market forecasting system. In retrospect, the team approach to the construction of the system had major effects on the entire process. For example, the overall logic of the market forecasting system was hammered out through an extensive series of two-day meetings. These meetings, which were long, loud, and exhausting, involved extensive negotiations between the 9700 program staff, the market research representatives, and ourselves. (See Figure 1 for a view of the working group drawn during one of these two-day meetings.) We had to build a system that would answer the necessary questions about the marketplace, that would be logical and computationally tractable, and that would require market research data that could be gathered in a credible fashion with reasonable resources. These negotiations required nearly four months and consumed considerably more resources than would have been required if a single team of model builders had designed the forecasting system without requiring the approval of the other members of the team at each step of the way.

On the other hand, some very important benefits accrued from this process. First of all, the 9700 program staff understood the logic of the forecasting system and ''owned'' the system before the first line of computer code had been written or the first piece of market research data had been gathered. This, more than anything else, insured the credibility and eventual use of the forecasting system as part of the Xerox decision process.

Secondly, and just as importantly, the market research study design was fixed only after the logic of the forecasting system had been agreed upon by the team. This meant that the market research study was designed primarily to produce data for use by the forecasting system. It was clear how each datum from the market research study would enter the forecasting system and how it was to be interpreted. Thus, the

FIGURE 1. AN INSIDER'S VIEW OF THE FORECAST GROUP.



Based on original by Wiegel.

logic of the forecasting system served as the framework for the market research study, not the converse.

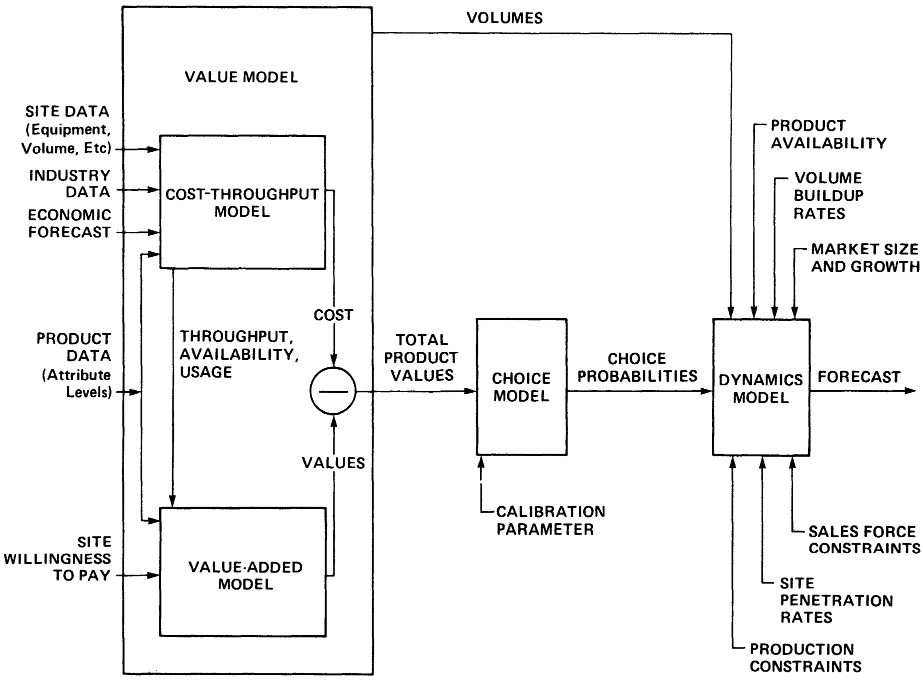
Two other aspects of the market research part of the process are worth mentioning. First, the market research interview included two standard concept tests that asked respondents to choose among several well-specified computer printers. The data from these concept tests were used to calibrate the forecasting system so that it would produce results consistent with the concept tests for product scenarios corresponding to the ones used in the concept tests. This greatly enhanced the acceptability of the forecasting system, since management now had the assurance that it produced results consistent with traditional market research. In addition, the concept tests were a hedge against the possibility that our new design concepts for a forecasting system might prove impractical to implement.

Secondly, one of the principal components of the forecasting system was a model of the impact that different computer printing systems would have upon the economics of printing at a computer center. This model, called the "cost-throughput" model, was also used as a communication vehicle in the market research itself, and allowed for the collection of unusually complete, accurate, and credible data from well informed respondents.

THE STRUCTURE OF THE FORECASTING SYSTEM

The market research respondents were obtained by selecting a stratified sample of data center managers from the target market. The Digital Printing System (DPS) forecasting system uses this market research data as well as subjective assessments to simulate the expected preferences, product acquisitions, and product usage pattern for this representative sample of the market. This simulated behavior is then projected to form an estimate of total market response to a specific scenario of computer printing products. The forecasting system consists of three main components: a value model, a choice model and a market dynamics model. Figure 2 is a block diagram of the system. It shows the different components and, in general terms, the input and output information of each.

FIGURE 2. THE DIGITAL PRINTING SYSTEM FORECASTING SYSTEM.



The Value Model and the Market Research Study

The value model can be characterized as a "dollar metric" [Pessemier, 1976] additive utility model. It assigns, for every sample site, a dollar value to each of the competing products. The model is composed of two main parts: 1) a cost-throughput model that calculates direct costs, throughputs, and usage levels associated with each product; and 2) a value-added model that assigns a dollar value to intangible product attributes such as brand name, reliability, copy quality, etc. The market research provided the data for these models. This included the site's work load profile, existing computer printers, mode of operation, desirability of special features, portions of the workload eligible for nonimpact printing, and willingness-to-pay for various levels of selected intangible attributes. Constructing this model required special attention to the three way trade-offs among the completeness of the model, the length of the interview process, and the quality of the information obtained.

The principal input to the value model is a product scenario of competing nonimpact printers. Each printer is described in terms of its attribute levels and pricing plans, which may change over time. The cost-throughput model emulates, for each product, the economic analysis that a data center manager would perform at the time of an acquisition decision. Specifically, it calculates for each system of printers the volume that would be placed on each printer and how many printers would be required. The resulting total costs and throughputs are evaluated on a yearly basis based on the site's data, industry data, and economic projections of paper costs. In calculating costs, the cost-throughput model configures the optimal mix of impact and nonimpact printers. Furthermore, when multiple price plans are available, the model chooses the one that minimizes the site's costs.

The value-added model captures important factors in computer printing that are not accounted for in direct financial costs. These include throughput, print quality, brand name, paper type restrictions, reliability, and reluctance to change. As part of the market research interview, each respondent was asked to specify the premium he would pay, or the discount he would require, for various levels of each of these attributes. Threshold levels for each attribute were also determined. Based on this information, the value-added model adds up the dollar values corresponding to the attribute levels of the nonimpact printer under consideration, pro-rated according to the volume placed on it. The difference between this value and the cost from the cost-throughput model represents a net dollar value for each alternative nonimpact printer.

To facilitate respondent cooperation and obtain more accurate data, a static version of the cost-throughput model was employed as a market research aid. The market research interviewer described three specific types of nonimpact printer concepts to the respondent in considerable detail. As a part of these descriptions, the respondent was shown a cost-throughput analysis of his shop in its current state and then with each of the nonimpact printers under consideration. The data for the initial cost-throughput analyses were based on an initial telephone interview with the respondent, supplemented by default where necessary with ''industry average'' data. At the first interview, the respondent was shown the cost-throughput analyses and the assumptions used in calculating them. He then indicated the changes that would more accurately represent his current operation and his proposed use of the nonimpact printers. In a subsequent interview, he was given a revised analysis that incorporated his changes. The cost-throughput analyses motivated respondents to provide accurate data on their operations, and respondents viewed these analyses as worthwhile compensation for their cooperation.

The willingness-to-pay questions were keyed to the attribute levels and the costs of the present operation as determined by the cost-throughput analysis. Focusing on a cost analysis of his own operation led the data center manager to provide more accurate responses to these willingness-to-pay questions. In the second interview, the respondent was also asked to assess his likelihood of acquiring any of the alternative nonimpact printers. This information, which constituted one of the two traditional concept tests, was subsequently used for calibrating the system, as described below.

The Choice Model and Calibration

The choice model converts the values assigned to each alternative product into a set of choice probabilities. These describe the likelihood that an establishment, represented by a particular sample site, will prefer each of the products. Aggregating these distributions over all sample sites produces what we refer to as the market potential for each product. (An approach similar to this has been used by Hauser and Urban [1977] for predicting health care plan selection.) Because of measurement errors and individual differences, there will be a distribution of actual product values in the establishments represented by a sampled site. The choice model used in the forecasting system describes these distributions by assuming that the measured values from the value model contain additive random noise having a Gumble [1958] extreme value distribution. The choice probability of a product can then be viewed as the probability that the product's "true utility" will be the highest, and the dispersion of the noise distribution appears as a parameter in the model (see McFadden [1974]). The resulting choice model is the well-known multinomial logit model often used in mathematical psychology and economics to describe individual choice behavior. It has the attractive property that two products with almost equal measured values have almost equal choice probabilities.

We used a single dispersion parameter for all respondents. The calibration process adjusted this parameter so that the market potentials predicted by the value-choice models were closely matched to the corresponding potentials from both concept tests. In this matching process, we also corrected for systematic errors in the value-added model due to omissions revealed by respondent comments. The ability of the calibrated value-choice model to reproduce potentials close to those predicted by the traditional concept test approach was a key factor in establishing the model's credibility within Xerox.

The Market Dynamics Model

The choice probabilities produced by the value-choice model reflect a site's preferences with all the products available. The market dynamics model captures the transient market behavior caused by the dynamic nature of the product scenario. This model also accounts for the data centers' reluctance to change, growth in the total number of data centers, and migration of sites across the boundary lines of the sampling strata.

The product scenario inputs to the market forecasting system include characterizations of market factors such as product introduction dates, launch strategies (e.g., timing of city openings), sales force sizes, and production constraints. Over time, a customer is likely to switch from one product to another as more preferred products become available. However, because of the inconveniences and costs associated with such changes, a customer will tend to switch only if he perceives some definite advantage in the new product over his current one. In the market research interview, the respondents were asked to specify the savings necessary to induce them to switch to a product that is equivalent in every other respect. These data are used to calculate choice probabilities that depend upon the product at the site. Thus, the choice probability vector is expanded into a preference matrix whose rows represent choice probabilities conditional on having a particular product. (A similar notion of inertia has been employed recently by Jeuland [1979] in the context of stochastic brand-switching models.) This preference matrix is recomputed each year for each sample site by setting the choice probabilities of unavailable products to zero and renormalizing the rows.

The core of the dynamics model is a nonstationary Markovian population process whose states are characterized by current and preferred product. This characterization depends upon the distinction between preference and acquisition. With durable industrial products, a customer may prefer a new product for some time while still retaining his old one because of constrained availability, limited sales efforts, and lengthy change processes. Furthermore, his preferences may even change again before they are realized. As illustrated in Figure 3, the market dynamics model tracks two types of state transitions. Preference transitions account for preference changes due to new product offerings, price decreases, performance improvements, etc. They are calculated from incremental changes in the preference matrix. The other transitions are acquisitions of preferred products; these are governed by assessments of penetration rates, sales force size, and production capacity limitations.

Using this logic, the market dynamics model tracks by current product and product preference the distribution of the market segment represented by each sample site. If the competitive scenario calls for different availability dates in different geographic regions, then these distributions are tracked separately for each region. Further adjustments of the distributions account for market growth and migration of sites across strata boundaries.

Transferring volume from impact to nonimpact printers is a gradual process at each site. Hence, the usage level and number of new units acquired by a site will not jump instantaneously to the levels predicted by the cost-throughput model. This transient effect is also incorporated into the market dynamics model; it tracks volume and unit buildup at captured sites, using subjective assessments of volume buildup rates for different types of printing.

The machine populations, usage levels, and product trades generated by the dynamics model as a function of time are stored in a disaggregated form. This allows the model's users to obtain machine populations, usage level, and activity forecasts by strata and sample site as well as for the total market. This feature has been very useful in helping users understand the forecasts produced by the system and to trace unintuitive results back to the assumptions and market research data that caused them. This "transparency" has been instrumental in building users' confidence in the model. It is facilitated by the deterministic nature of all the calculations and would have been nearly impossible in a Monte Carlo simulation.

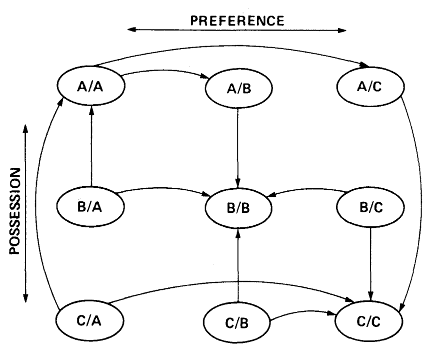
USE OF THE FORECASTING SYSTEM

The DPS forecasting system has been in use since the middle of 1976. The forecasting system was used initially to support the program team's request both for product development funds and for permission to announce the 9700 Electronic Printing System. This required many runs with the system to explore a base case competitive scenario and many variations of it. The sensitivities of the resulting forecasts to a wide variety of planning assumptions were also examined. Initially these runs produced surprises. Tracing the sources of these surprises occasionally identified artificial effects of the modeling assumptions that required adjustments to the system, but usually they produced an improved understanding of the market.

After several weeks of these familiarization runs, the frequency of surprises diminished greatly, and the program team and the division management presented their forecast and market analysis to the corporate management and its staff. The staff scrutinized the market research, the forecasting system, and the market analysis. They enthusiastically accepted the market research and the forecasting system, but not the market analysis or the product program. Instead, they proposed a very aggressive competitive product scenario that contained a low cost, high-speed computer printer using a new printing technology. Within a few days we were able to represent the relevant market characteristics and likely usage patterns for the hypothetical new printer in terms comparable with those of the xerographic nonimpact printers we had studied. We then created a series of forecasts based upon successively lower pricing for the hypothetical printer. As the price went down, the new printer's market share increased. However, to the surprise of both the corporate staff and the program team, the forecast for the 9700 did not decrease significantly until after the hypothetical printer had greatly reduced the forecast for other nonimpact printers. A detailed examination of the forecast confirmed that this result was not an artifical modeling effect, but a realistic market phenomenon. Various characteristics of the hypothetical printer caused it to appeal much more to IBM 3800 customers than to potential Xerox 9700 customers. At this point, corporate staff recommended and obtained approval of the 9700 program. The forecasting system had transformed the debate about the future of the 9700 from an unresolvable, emotional argument about forecasts to a constructive discussion of competitive scenarios and other forecasting assumptions.

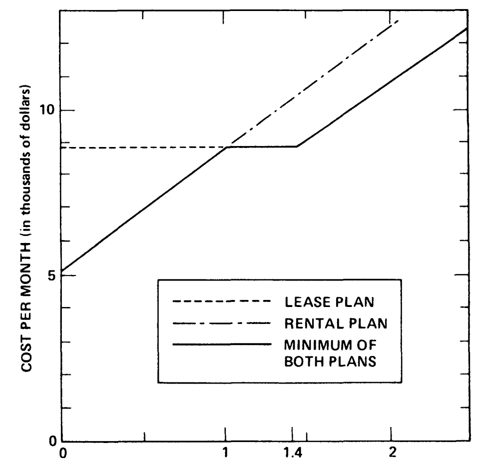
After this, the market effects of a large number of tactical alternatives were examined with the forecasting system. Some of these examinations merely confirmed or refined management's expectations. This occurred, for example, in the analysis of the timing of the 9700 announcement and of the effects of Xerox's geographically constrained product introduction. However, examination of pricing alternatives suggested an unusual and unexpected combination of price plans that had the effect of eliminating the incremental usage charge between 1 million and 1.4 million impressions per month. Figure 4 shows these plans. After evaluation, these were recommended by division management and accepted by corporate staff. They are still in use.

FIGURE 3. EXAMPLE OF A DYNAMICS MODEL STATE TRANSITION DIAGRAM FOR A PARTICULAR SITE IN A PARTICULAR YEAR.



Preference Changes are Horizontal Transitions; preference Realizations are Vertical Transitions.

FIGURE 4. PRICE PLANS FOR AN ATTACHED 9700.



After the product was announced, the model was used to evaluate the market impact of proposed product enhancements such as the capability for two-sided printing. These evaluations were used to allocate resources and assign priorities for developing the enhancements. The model has also been used to evaluate the market for proposed new Xerox computer printing products. Although the forecasting system forecasts only the US market, the cost-throughput model has been used to evaluate the economics of the 9700 in selected foreign data centers. (At present, the 9700 is available commercially in Canada and Japan.)

Planning assumptions, including competitive scenarios, are updated and the model is rerun from time to time as part of the Printing System Division's long range planning process. To date, the model, when supplied with realistic planning assumptions, has produced forecasts that have tracked actual market developments with a precision that lies well within the range that could be expected from the size of the original market research sample. The Printing Systems Division is currently supporting a project for updating and expanding the market research and adding new capabilities to the forecasting system.

The DPS forecasting system has also had a significant effect on forecasting methodology within Xerox. The completeness and flexibility of this forecasting system has become the standard within the company and has set the conceptual stage for the development of quantitative market forecasting in new business areas within Xerox. About two years ago, a calibrated value-choice-dynamics forecasting system for document creation systems was created by a program team that included one of the authors. This system has now been in regular use for a year and a half helping to define Xerox's business plans in this strategic area. At least one further application of the methodology is under way.

Different aspects of the DPS forecasting system have different degrees of transportability. The team approach to the model building process and the idea of a calibrated value-choice-dynamics forecasting system have proved the most transportable. The basic logic of the choice model and the dynamics model have also proved transferrable; but the value model, including the cost-throughput model, must be largely customized for each new application. Thus, both specific mathematical concepts and the design-construction-implementation process have proved to be generalizable to other contexts. More importantly, the expectations and requirements for a ''good forecast'' have been significantly increased as a result of the success of this system.

CONCLUSION

When we set out to build a forecasting system for the nonimpact computer printing market, we had two objectives: We wanted to help Xerox make the right decision about a proposed new product for this market, and we wanted to improve the methodology for analyzing markets and evaluating new products in Xerox. We believe we have succeeded in both objectives. Because of our work, Xerox decided to launch the 9700. This strategically important product is an economic success as well as a technological marvel. Over its life, it will result in billions of dollars of highly profitable sales. While we cannot give precise profit projections, during each of the past ten years Xerox products have earned an average pretax return on sales of between 18% and 29% [Xerox Corporation, 1979]. The 9700 will also save billions of pounds of paper. Furthermore, the value of the approach we developed is widely recognized in Xerox and is now being pursued in other parts of the company.

Robert V. Adams, President of Xerox's Printing System Division, has stated:

> The 9700 Electronic Printing System is a major profitable product for the Xerox Corporation in what is now accepted as an important market for Xerox. The 9700 and supplies for it are projected to be a multibillion dollar revenue program for Xerox. In addition, Xerox is actively considering further product offerings in this market.
>
> The DPS forecasting system gave us the ability to understand the needs of the computer printing market. It also gave us the ability to convince ourselves that the 9700 would enable Xerox to compete profitably with mainframe computer suppliers in the computer printing market. The DPS forecasting system was pivotal in our decision to pursue aggressively this new market.
>
> We have used the DPS forecasting system since 1976 to help plan our business. We use it to track the market for nonimpact computer printers and to evaluate proposed 9700 enhancements (such as automatic two-sided printing) and new computer printing products — both competitive offerings and proposed additions to our own product line. In addition, we used the model to evaluate alternative 9700 launch strategies and to select the pricing for the 9700. Since its completion in 1976, the forecasting system has tracked the market extremely well.

Donald W. Pendery, Xerox Vice-President, Planning has stated:

> It is a key function of Xerox management to choose the products it will sell and the terms upon which it will offer them. Improvements in this process ultimately reflect themselves in the success of the corporation. The quality of the innovative DPS forecasting system enabled it to play a pivotal role in Xerox's decision to develop and manufacture the 9700 computer printer. The decision to go ahead with the 9700 is one of the key strategic decisions made by Xerox in the last decade. This forecasting system set a standard within Xerox for evaluating new markets. The system is influencing the design of other market-research-based forecasting systems within Xerox. In particular, the design of our forecasting system for office information system products was directly influenced.

ACKNOWLEDGEMENTS

The project described in this paper was a team effort. We wish to acknowledge the important contributions of other members of the 9700 forecast group: Henry Johnson, its leader; Richard Frank; Robert Ratonyi; Robert Sharpe; Ronald Thomas; and John Wiegel. The work of our market research contractor's able team of interviewers was vital. We are also indebted to Lester Edelberg, George Hess, and Dennis Samson. Finally, we wish to thank the Xerox Corporation for its support of this work and the research that led up to it, and for allowing us to describe it publicly. XEROX, 9200, and 9700 are trademarks of the Xerox Corporation.

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APPENDIX: THE TECHNOLOGY OF THE XEROX 9700

The Xerox 9700 merges three major technologies — digital computers, with their capacity for high-speed handling of information; lasers, with their high-resolution imaging capabilities; and xerography, with its ability to produce quality printed output at high speeds — into a system of extraordinary capabilities.

Computers

Digital input from either an IBM System/370 or System/360 computer on-line or a 9-track magnetic tape drive unit off-line is read under program control and buffered on the Xerox 9700 disk unit. This input data is brought into a digital processor memory together with previously stored digital information that will create a form image. The character dispatcher accepts the form and the input data, merges the two images, and sends them to the electronic image generator. Character fonts and forms are stored in the image generator memory as dot patterns; the image generator produces each character and form as electronic patterns which control a scanning laser beam.

Lasers

The actual character image is formed by the laser beam which scans across an electrically charged, light-sensitive belt. Because light causes this belt to lose its charge, a character is formed by momentarily interrupting the laser light as the beam scans across the belt, similar to the way a pattern is formed by the electron beam on a television screen. And because the narrow laser beam has extremely high resolution — 300 by 300 dots to the inch — the 9700 produces output of outstanding quality directly from digital information.

Xerography

The latent image of a printed page, in the form of a charged image on the belt, is moved past the dry ink developer, with the charged areas on the belt attracting the oppositely charged black particles of dry ink. This page image in the form of charged toner particles is transferred and fused to a sheet of paper which is delivered to either of the two output bins or the sample tray. The entire process produces pages at a continuous rate of two per second.