AT&T's Telemarketing Site Selection System Offers Customer Support

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Over 180,000 telemarketing centers in the United States employ over 2,000,000 people. Because of the rapid growth in the telemarketing industry, site location has become a critical problem. The National Technical Center came to Business Operations Analysis to develop a decision support system to help AT&T customers determine "good" locations for their telemarketing centers. The core of the system is a mixed integer programming model which minimizes labor, communications, and real-estate costs, while determining the optimal number, location of centers, and geographic regions to be served. In 1988, 46 AT&T customers made decisions on site locations swiftly and confidently, while committing to $375 million in annual network services and $31 million in equipment sales.

AT&T is a major supplier to the telemarketing industry, which in 1986 produced over $118 billion in revenues and employed over two million people. It is predicted that by the year 2000 the industry will employ over eight million people [Glastris 1986]. The rapid growth of the telemarketing industry and the decline in the growth rate of the labor force [Johnston et al. 1988] has made the lock-in decision of site selection a critical problem for the telemarketing industry. In 1987, AT&T's National Technical Center (NTC) asked the Business Operations

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Analysis (BOA) group in AT&T to work with them to develop a decision support system to help AT&T customers determine locations for their telemarketing centers. The core of the system is a mixed-integer-programming model that minimizes labor, communications, and real estate costs while determining the optimal number of centers, their locations, and the geographic region to be served by each center. In 1988, AT&T used the site-selection process to help 46 customers make timely and informed decisions on site locations while controlling the operating costs associated with labor, communications, and real estate. At the same time, these customers have committed to $375 million in annual AT&T long distance network services and $31 million in telephone and computer equipment sales from AT&T.

Background and History — From Fraud to Telemarketing

The present day telemarketing industry had a shaky start. In 1920, penny stocks opened a new world of opportunity for fast-talking con artists who used the telephone to bilk penny stock investors. This created a criminal image, and consequently, the general public associated phone sales with con men. Because of this negative image, legitimate businesses shied away from using the telephone as a sales tool.

By the 1950's, legitimate businesses — mainly in the publishing industry — had rediscovered the effectiveness of telephone sales. Then in 1961, AT&T introduced WATS, a special billing arrangement for long-distance outbound calls. In 1967, AT&T introduced 800 service, which provided for toll-free inbound calls. The airlines, car rental companies, and hotel chains were quick to adopt 800 service for their reservations networks. These industries found that telephone sales carried great economies of scale, and the telephone became recognized as an innovative marketing tool. The drawing power of the 800 number caused telephone sales to soar.

In the 1970's, AT&T promoted "phone power" progams designed to teach businesses how to use the telephone as a sales tool. These programs helped customers to increase business, to reduce the cost of doing business, and to expand their market coverage. The knowledge AT&T gained from promoting "phone power" created the basis for what was to become telemarketing.

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AT&T officially introduced telemarketing in 1980. AT&T promoted it, trained customers in its use and techniques, and sponsored telemarketing professional organizations. AT&T defines telemarketing as a marketing discipline that uses telecommunications and information systems to execute a marketing program. AT&T telemarketing combines consultation, AT&T long-distance network services, and AT&T telephone and computer systems for a complete solution to the customers telemarketing needs. An AT&T

telemarketing solution is a carefully planned method that employs marketing and management techniques and is generally part of a company's overall marketing mix.

Telemarketing can be divided into four major categories:

— Order processing,
— Customer service,
— Sales support, and
— Account management.

Order Processing is a marketing approach that offers customers an immediate avenue to buy. Order-processing centers generally replace or supplement mail orders with orders placed through salespeople. A good example of order processing is catalog sales using 800 service.

A customer service center enables customers to voice their concerns and to gain ongoing support after purchasing a product. Companies that provide telemarketing customer service programs can generally expect to develop loyal customers, increase positive word-of-mouth contact, and improve their company's or product's image. Examples include requests for repairs, requests for flight schedule information, and inquiries about bills. These are primarily inbound 800 calls to the center; however, some problems may require service people to call customers back.

A telemarketing sales-support center works with and helps an outside sales force. Even though the outside sales force "owns" the clients, telemarketing can greatly improve its effectiveness and efficiency. Sales support centers track shipments, resolve billing problems, and take orders when the salesperson is not available. Customers usually call using the 800 service and normally require calls back.

A telemarketing account management center is an inside sales force that manages a specified group of clients who do not have an outside sales force. Account management centers call their business customers with information on new products, take orders, and in some cases manage the customer's inventory. These centers also provide customer service for their customers, but they primarily make outbound calls.

In 1980, 1,650 companies were involved in some formal telemarketing program. By 1986, the telemarketing industry had grown to include over 140,000 companies employing over two million people with sales in excess of $118 billion annually. By the year 2000, it is estimated that over 700,000 companies will employ approximately eight million people in telemarketing and generate annual revenue of about one half trillion dollars.

The rapidly growing telemarketing industry has become a target for AT&T's competitors. In 1984, AT&T went through the largest and most publicized corporate divestiture in history. The overall effects of the legal and regulatory changes have been the loss of market share from a monopoly position in the early '70s to less than 50 percent in some AT&T long-distance services and in telephone and computer system sales.

Telemarketing centers spend more on long-distance services and telephone and computer systems than the average business. In 1986, the telemarketing industry was estimated to have spent $20 billion,

and it is expected to grow 10 to 15 percent per year through 1990. With this high concentration of potential revenue, the telemarketing industry is fast becoming a major battleground for market share among AT&T and its competitors.

AT&T is perceived to be the highest price vendor. Our strategy to offset this perceived cost differential is to stress the extra value we bring to our products and services: our willingness to provide telemarketing consulting services at no additional cost to our customers. The strategy that helped start the telemarketing industry in 1980 has established AT&T as the industry leader and has influenced customers to buy from AT&T.

By taking a visible and active role in telemarketing industry efforts, such as market research and technical development, AT&T strengthens its consulting expertise. AT&T also develops decision support models for its consultants to use in dealing with customers who are establishing or redesigning their telemarketing centers.

Aware that change is inevitable, AT&T intends to stay ahead of that change. Its market research program helps AT&T retain its leadership in the industry. In 1985, our research showed that customers were becoming more aware of the importance of the availability of labor in deciding where to locate their telemarketing centers. This was a change from the norm. Historically, communications costs had been the driving factor. When 800 service was introduced in 1967, AT&T did studies on where to locate these centers. For the most part, the cost of 800 service determined location since labor was cheap. This favored the midwest, where many of the major hotel, airline, and car rental companies subsequently located their telemarketing centers.

The studies also took into consideration many other factors: labor markets, regional accents, real estate values, education levels, student populations, and age of the labor force. Because of these factors and the cost of 800 service, Omaha, Kansas City, Minneapolis, and Oklahoma City were considered to be the prime locations. The long-range effects of these studies led to Omaha becoming — and billing itself as — the 800 capital of the world.

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Today things are different. Communications costs are down, labor costs are up and the labor market is shrinking. In the 1970s and 1980s, the labor market grew at a rate of 2.9 percent per year. Through the 1990s the labor market will only grow at a rate of one percent per year [Johnston et al. 1988]. A new approach would be needed in the future for planning telemarketing centers.

Project Background

Two organizations within AT&T were most involved in developing the site-selection system: the National Technical Center (NTC) and Business Operations Analysis (BOA). The NTC is responsible for field sales support in communications

network design for business customers. The NTC determines user needs, funds development to satisfy the needs, and supports the end user of the system developed. BOA provides management consulting and analytical services to various groups within AT&T. The NTC and BOA have collaborated on many successful projects.

In late 1985, AT&T dedicated resources to better understand and define site-selection requirements. Initally, the company's market research group interviewed over 50 major telemarketing customers and identified the three primary operational cost elements: communications, labor, and real estate. The general perception of these customers was that communications or real estate costs had driven their current location decisions. Further research, however, indicated that in many instances it was neither communications nor real estate expense, but rather political considerations within the company. The political decisions were often emotional choices, such as locating a telemarketing center in the same city as regional headquarters or in a city where upper management wanted to have a presence. Based on the market research, AT&T anticipated providing a sales aid in 1987 in the form of brochures or white papers that could help customers better understand the cost of making political decisions versus cost-based decisions and the emerging importance of labor availability.

In January 1987, AT&T's sales team learned that a major national retailer was reorganizing its catalog operation. The sales team contacted AT&T's National Technical Center for assistance in determining the network design, number of centers, and their locations. We realized that our initial intent to provide a brochure was inadequate to meet the needs of this sophisticated customer. The National Technical Center decided to establish a special study team to support the sales team's request. It enlisted the help of Business Operations Analysis because that group had experience in locating various types of AT&T facilities. In February 1987, the AT&T study team (NTC, BOA, and the sales organization) and the customer met. The customer explained its requirements and the AT&T study team

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described its plans for the customer's new telemarketing catalog sales operation. This meeting was essential in creating rapport and trust between the AT&T team and the customer. Including the customer in a team approach right from the beginning is essential. Time commitments were made, and the AT&T team began thinking in terms of a special study for one customer.

After the initial customer meeting, we added members of BOA's economic and statistics districts to the team. The economists provided expertise in regional economics, while the statisticians provided expertise in demographics.

During the next month, the AT&T team determined the economic, demographic, and AT&T internal data needed for site

selection. The team also agreed upon a site-selection process that consisted of three steps: (1) choose candidate sites, (2) determine the optimal and next-best solutions, and (3) evaluate the alternative solutions using both quantitative and qualitative factors.

AT&T next met with the customer to obtain the input data and constraints it needed to run an optimization model to generate solutions. AT&T and the customer agreed that site recommendations at the Standard Metropolitan Statistical Area (SMSA) level would be sufficient. After several meetings, the two agreed upon a group of candidate sites to be used in the optimization model.

Because an effective model was urgently needed for this project, AT&T elected to build a prototype system and to make ongoing refinements as it identified operational needs. Because of customer-imposed deadlines, the BOA group worked literally around the clock to develop a model, data bases, and reports that met the customer's requirements. BOA staff formulated and programmed a mixed integer program using IBM's MPSX/370 and MIP/370 [Mathematical Programming System Extended/370, Mixed Integer Programming/370, 1981]. They wrote a matrix generator using SAS [SAS USERS'S Guide 1985] and a coded report writer in FORTRAN. The system was far from user-friendly at this point. The prototype ran on an Amdahl mainframe under VM/CMS.

The AT&T team was now ready to run the customer's problem. Initial run times were excessive; however, by using heuristics, and MPSX/370 options and by increasing CPU and work space, the run time improved substantially. The team was able to generate the optimal solution and five next best solutions for the customer.

While AT&T was developing the model, the customer continued to evaluate sites. Their managers decided that they would open their first location in Texas because of their large market there. The customer decided that only Dallas or Houston would meet its requirements because of the favorable real estate prices and unemployed oil industry workers. After preprocessing the 13 Texas SMSA in the AT&T data base, we were left with five locations as candidate sites. The model showed the optimum location in Texas to be San Antonio. This caused a great deal of concern for both AT&T and the customer because the model's choice was not what the customer perceived to be the best choice. But the customer agreed to at least look into the model's recommendation. Although the customer had favored its original choices, it agreed in the final analysis that San Antonio was a better solution and scheduled its first catalog center for implementation in San Antonio, Texas. After San Antonio, we decided on nine additional locations using the site selection system. They complete the customer's nationwide catalog sales network. The additional nine locations were chosen by running the model several times to incorporate customer feedback.

Because the site-selection system had satisfied their customer and promoted AT&T sales, the NTC decided to evaluate the site-selection system as a standard sales-support tool. The NTC funded BOA

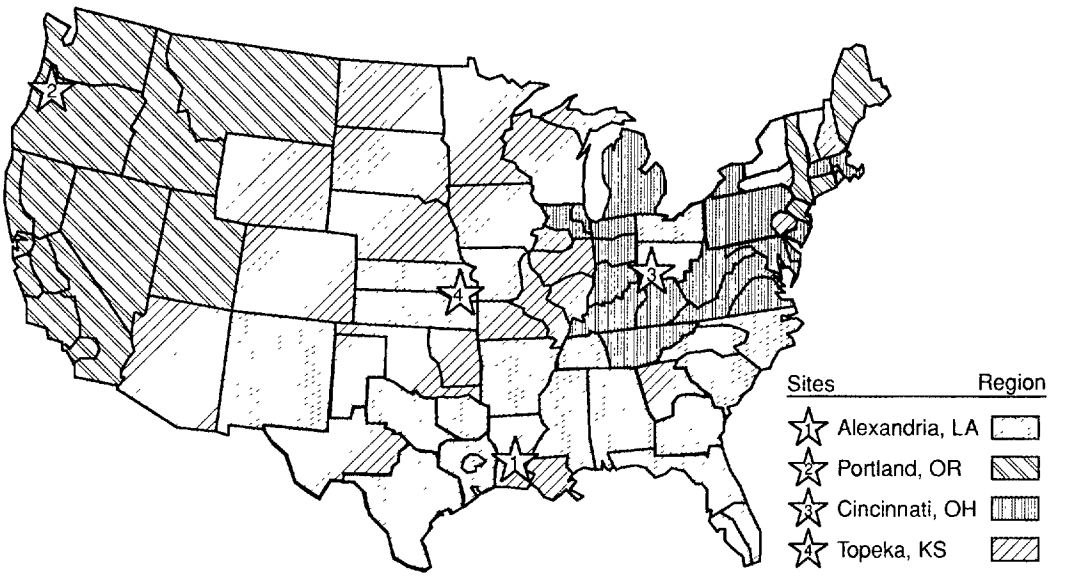

Figure 1: In this graphical representation of an optimal solution, the stars mark the location of the sites selected for the telemarketing centers.

to produce a user-friendly version for evaluation. BOA developed the user-friendly system to run on a mainframe under VM/CMS. It wrote the front-end and system data bases in FOCUS [FOCUS User Manual 1988] and coded the matrix generator in FORTRAN. The mixed integer program was coded using MPSX/370 and MIP/370. Finally, the report writer was coded in FORTRAN. BOA developed an interface to the PC-based Atlas Graphics system. An example of the Atlas Graphics output is shown in Figure 1. The map shows the location of the sites selected for telemarketing centers and the areas they serve.

As Figure 1 shows, the optimal solution is not contiguous, and several centers are not located in the regions they serve. These solution characteristics are typical in the problems we have encountered. The telemarketing center may not be located in the region it serves because intrastate communications rates may be higher than interstate rates. The region a center serves may be noncontiguous because of center size constraints and differences in communications and labor costs.

NTC and BOA continue to evaluate and refine the model jointly. In November 1987, they began field trials that included a variety of customers with diverse requirements. These customers needed different sized centers, had different regional or national deployment needs, and had wide variance in traffic volumes. The trial showed that the mainframe version was still difficult to use and very time consuming. BOA added several enhancements to make the model easier to use and a heuristic to improve run time. It completed beta testing of the system in February 1988 and released the system to the NTC.

The AT&T National Technical Center (NTC) received constant feedback from

customers and their associated sales teams. The NTC evaluated the field input and arranged for BOA to further improve the site-selection system. It added further demographic categories and economic forecasts and developed a proprietary telemarketing density index. We used a geographic mapping program to visually display the model's recommendations.

The NTC's overall evaluation of the field trial indicated that the site-selection system was a powerful consulting tool because it helped position AT&T's sales team at the customer's planning table and had a positive effect on AT&T's revenues. NTC decided to continue developing the site-selection system and planned to deploy a PC version to the sales force in the second quarter of 1989. In developing the PC version, we used Clipper [Clipper User Manual 1987], a dBASE-like compiler, for the user interfaces and data bases. We used LINDO [Schrage 1981] software to do the actual optimization [Sharda 1988].

The results can be measured from two perspectives: AT&T's and the customer's.

PC SITE is a PC-based version of the site-selection system that currently runs on a VM/CMS mainframe. We began testing the PC system in February 1989. The PC system has the same capabilities as the mainframe system, along with some new features.

These new features include increased demographic data on possible site locations, financial analysis, enhanced graphics, and a module that enables the customer to incorporate qualitative factors (such as local government cooperation and support services available in an area) into the site-selection process.

PC SITE runs on the AT&T 6386 machine, currently AT&T's most powerful PC. PC SITE is more user friendly, more flexible, and in terms of processing costs, less expensive than the mainframe version.

The Site Model and Site Selection Process

The SITE model is a mixed-integer program (appendix). Its overall goal is to provide structure and objective input to the customer's telemarketing planning process. The model does so by answering the following four questions:

(1) How many telemarketing centers should be opened?
(2) Where should centers be located?
(3) What geographic region will be served by each center?
(4) How many attendant positions are required at each location?

The modeling approach is similar to that for the traditional problem of facility location planning. We begin by meeting with the customer to obtain a clear understanding of the projected size and functions of the proposed facilities. We then determine candidate sites. The most critical step in selecting a site is determining whether or not the labor supply is adequate. Without labor, a customer cannot staff a telemarketing center. We base our assessment of the labor resource on a variety of demographic factors available from the Department of Labor along with some proprietary AT&T data that we have built into our site-selection system (for

example, relative wage, relative job pressure, population, and telemarketing densities, which forecast the ease or difficulty of attracting telemarketing employees). We then generate a list for the customer's approval and input it into the mixed-integer model. Our next step is to finalize the remainder of the input data. Information is required on communication parameters (call volume forecast, average length of call, and so forth), personnel parameters (target wage and benefits, shift differentials, agent utilization, and so forth), and site parameters (real estate costs, floor space requirements, and so forth).

In addition, we can establish constraints to identify or eliminate sites based on time zone, state, SMSA, or customer-defined regions. These constraints and the lower bounds for center size are where the model's formulation differs from the well-known straightforward capacitated facility-location model. The mixed-integer program now has all the input data necessary to evaluate the three primary telemarketing operational cost factors: communications, labor, and real estate. The model provides an optimal solution that minimizes these costs and satisifies all constraints. A major feature of the AT&T's model is alternative solutions. We provide alternative solutions to evaluate cost differences between sites and to empower the customer to make implementation decisions based on other factors should it choose to do so. An economic and demographical data base available in the site-selection system provides information on transportation, housing, income, and long-term labor market stability. We added an analytical hierarchy process (AHP) [Saaty 1988] module to PC SITE to enable customers to include other qualitative (or subjective) factors in their decision processes.

Selecting telemarketing locations is not a simple matter, but the process described above can be an invaluable aid. A customer should not decide on a site until it visits all locations under final consideration. What we have provided is a logical and orderly framework for analyzing the merits of possible locations.

Results

The results of the site selection process can be measured from two perspectives: AT&T's and the customer's. From AT&T's viewpoint, the measure of success is relatively simple: enhanced customer relationships and revenue generation. In 1988, the site selection process — in a highly competitive marketplace — helped to influence or close network revenue decisions by 46 customers affecting $375 million.

The use of the site selection process places AT&T at the customer's planning table. Once there, AT&T is able to influence the decisions being made, and as a result, AT&T has made telephone and computer system sales in more than 40 percent of the situations. AT&T's market share in these categories is generally less than 30 percent. These equipment sales were valued at $31 million in 1988.

AT&T has enjoyed a number of side benefits because of the site-selection process:

— An enhancement of the customer's perception of AT&T for future business,

— Shorter implementation cycles to start AT&T's revenue stream,
— The enhancement of AT&T's reputation as a telemarketing consultant and supplier, and
— A new value-added service to offer customers.

The site-selection process has been successful in a wide range of situations:

— The telemarketing centers implemented by single customers have ranged from one to 20.
— The size of the centers has varied from 30 to 500 agent positions.
— The site-selection process has addressed a full spectrum of telemarketing applications (order processing, customer service, sales support, and account management).
— It has benefited a broad scope of industries: the retail catalogue industry, the hospitality industry, freight and package-forwarding companies, the banking industry, the transportation industry, health care, the financial industry, telemarketing service bureaus, manufacturing companies, fast food and food producers, the consumer products industry, the federal government, and publishing companies.

From the customer's perspective, success can be measured by the timely implementation of telemarketing centers and subsequent revenue generated by those centers. The ability to make objective decisions based on a common set of factors has accelerated the customer's decision process, saving many hours of research and consulting costs, which have been reported by nine customers of the 46 studied to range from $50,000 to $240,000, depending on the size of the customer and depth of analysis. Of the 46 customers in our original study, 12 reported they had saved on average $1 million per year by using locations identified by the site-selection model instead of locations they had previously identified for consideration.

Finally, the success of the site-selection process has convinced upper management to plan for expansion. AT&T estimates supporting 375-400 studies per year (nearly a 10-fold increase over the initial level) by 1990. These studies will be an integral part of AT&T's value-added marketing strategy and will be provided through AT&T's regional consulting groups.

Actual Case

We will describe an actual case to show how the total site-selection process is utilized in the sales process, step by step.

A national manufacturer and distributor was being reorganized after a corporate takeover. Management's job was to reduce sales expenses and increase sales volume in the most effective way possible. The company had 42 branch offices with telemarketing sales support groups ranging from six to 40 people. The sales support group's mission was to back up the field sales force on their largest accounts by handling orders and problems when the salespeople were unavailable.

Top management decided to expand and consolidate their telemarketing operations to cut sales expenses and to expand the company's availability to their customers. This decision was a result of proposals made by the AT&T sales team, who then offered to help the customer select locations for its consolidated

telemarketing operations. Top management had set an aggressive deployment schedule and welcomed AT&T's help. However, the AT&T sales team also needed help. Competitors were working hard to win the company's business, and AT&T was still a long way from closing the sale.

AT&T's salespeople presented the site-selection process to five corporate and sales vice-presidents. They agreed that AT&T had a method by which they could quickly and confidently decide on locations for telelmarketing centers. They wanted to move ahead on their project with AT&T immediately since they did not have their own method of evaluating locations. Because AT&T could provide this support as a value-added service, the company awarded AT&T the 800 service worth approximately $7.5 million annually. We established deadlines for data collection, final forecasts, and the submission of design parameters.

Within a week, AT&T sent the customer a first cut on locations that met the customer's criteria for relative wages, relative job pressures, and employed population. The customer eliminated some locations and added other locations that it had already considered as potential sites and wanted to have priced out for comparisons.

When all the data was in, we ran the model for one-, three-, and five-year forecasts. Then the model priced out the locations previously considered by the customer. Next, the site-selection system produced demographic data and economic forecasts for all the locations identified by the model and those selected by the customer. Two weeks after the original presentation, we presented the location recommendations and comparisons to the customer's vice-presidents. The customer had two regions (east and west), and we presented five configurations of two centers each for consideration for each region. AT&T recommended that the customer choose two or three configurations within a week for final consideration and then visit the cities before making its final decision.

The customer asked for a new configuration for each region. It picked the one location from its previous list that priced out the best for each region. The customer's original candidate list was made up of locations in which it already had large operations. The customer's top management felt that if the cost penalty could be justified, they could save some existing jobs and expertise.

Four weeks after the original presentation, they made the final location decisions. The customer chose configurations that combined locations recommended by AT&T and its original candidates. Top management was able to justify the cost penalties of $239,000 for the East and $503,000 for the West. The customer also acknowledged that it was still saving $1,040,000 annually or 12 percent over the configurations of its own candidate locations.

Once the locations were chosen, AT&T provided county-level demographic maps of the cities and the locations of AT&T's switching offices. This information helped the customer to localize its search for buildings.

While the customer was negotiating leases for building space, AT&T ran PC-CAPS, a simulation model developed in

1987 by BOA, to determine the implementation requirements for providing phone lines and the number of agents the customer would need. We used this information to compute costs the customer could expect for AT&T long-distance services and for employees.

Once it had agreed to the final designs, the customer decided not to accept bids on the telephone switching equipment. It awarded the contracts to AT&T because it believed that any savings it might realize with a different vendor would be more than mitigated by the savings it was going to enjoy because of the site-selection process.

The sales team's original assessment of this case was that AT&T's chances for winning the network business were poor because of the customer's cost-cutting. The sales team felt the network business would go to the lowest cost provider no matter how small the cost difference. Switching equipment, data processing, and data transmission sales were also considered very unlikely since the customer had long-term relationships with other vendors.

The end result was a complete turnaround of the customer. AT&T made sales in all areas: long distance service, telephone equipment, and computer systems. AT&T accomplished this because the site-selection process gave AT&T a role in the customer's planning and allowed AT&T to demonstrate its added value and offset any perceived cost differentials.

Acknowledgments

Since the development of the site-selection system has benefited from many contributors, we extend thanks to the following team members listed here by their affiliation at the time of their contributions:

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The success of the Telemarketing Site-Selection System is not due solely to the efforts of the above team members. Customer interaction and feedback during the development of the system was important to its success. So last but not least, we thank our customers.

APPENDIX: SITE Model Details

To be determined are the number,

locations, and sizes of the telemarketing centers required to handle customer call demand and the geographic region to be served by each center. The locations of a finite number of potential sites are assumed to be known (potential sites are selected in the preprocessing module of the system).

Formulation

The following index sets are defined:

i – Denotes location of calling public (for $i = 1$ to N). The country may be divided by area code (for example, $i = 3$ may represent area code 201) or state. "N" is the number of originating area codes or states.

j – Denotes potential telemarketing center location (for $j = 1$ to M). Potential sites are metropolitan statistical areas and area code regions. "M" is the number of candidate sites.

The following parameters are defined:

$C(i,j)$ = Cost per unit traffic from i to j. This includes the communications cost adjusted for interstate sales and excise tax plus labor cost at center j.

$F(j)$ = Fixed costs at center j (the major component is the real estate cost of locating at center j).

$T(i)$ = Total usage hours originating at i.

$U(j)$ = Upper limit on size of center j.

$L(j)$ = Lower limit on size of center j.

$MAXSITE$ = Upper bound on the number of sites to select.

$MINSITE$ = Lower bound on the number of sites to select.

The following decision variables are defined:

$X(i,j)$ = Fractional traffic originating at i and handled by j.

$Y(j)$ = 1 if we locate a center at j, 0 otherwise.

SITE Model

The model can be stated mathematically as follows:

Objective function:

Minimize $\sum_{j}^{M} F(j)*Y(j) + \sum_{i}^{N} \sum_{j}^{M} C(i,j)*T(i)*X(i,j).$

Subject to

(1) Size constraints per site location:

$\sum_{i}^{N} X(i,j)*T(i) <= U(j)*Y(j)$, for $j = 1$ to M

$\sum_{i}^{N} X(i,j)*T(i) >= L(j)*Y(j)$, for $j = 1$ to M.

(2) Traffic constraint per area code or state:

$\sum_{j}^{M} X(i,j) = 1$, for $i = 1$ TO N.

(3) Total number of sites upper and lower bound constraints:

$\sum_{j}^{M} Y(j) <= MAXSITE$, $MAXSITE <= M$,

$\sum_{j}^{M} Y(j) >= MINSITE$, $MINSITE > 0$.

(4) Number of sites per region upper and lower bound constraints.

(5) Number of sites per time zone upper and lower bound constraints.

(6) Number of sites per state upper and lower bound constraints.

(7) Fixed site constraints:
$Y(j) = 1$, if site j is fixed.

(8) Integer and continuous variables:

If advanced 800 features allow traffic splitting then

$0 <= X(i,j) <= 1$, for $i = 1$ TO N and $j = 1$ TO M

$Y(j) = 0$ or 1, for $j = 1, M$;

otherwise,

$X(i,j) = 0$ or 1, for $i = 1$ TO N and $j = 1$ TO M

$Y(j) = 0$ or 1, for $j = 1, M$.

Other feasibility constraints, for example:

(a) Traffic routing constraints force a certain percentage of traffic to terminate in a given region;

(b) Several alternative size ranges for a center (for example, small, medium, large); and

(c) Force homing of traffic to a site.

The objective function gives the cost when $\Sigma\ Y(j)$ centers are to be located at those sites corresponding to positive-valued $Y(j)$. Total cost, which includes communication costs, salaries, and real estate costs is minimized. The first constraint set puts upper and lower bounds on the size of the centers. The upper and lower limits are set by the customer with consideration given to the need for diversification in deployment and economies of scale in center size. In addition, the first constraint set makes sure assignments are made only to open centers. If center j is selected, then the variable $Y(j)$ is equal to 1 and 0 otherwise. This ensures the proper fixed costs are incurred. The second constraint set specifies that all originating traffic from NPA i must be handled by some combination of centers. Constraint (3) gives an upper and lower bound on the number of sites selected. Constraints (4) to (7) are optional. Nonnegativity and integer restrictions on decision variables $X(i,j)$ and $Y(j)$ are given by (8).

Solution Technique

The model formulation is an enhancement to the traditional capacitated facility location problem. Additional side constraints and a lower bound on the center size have been added to make the model realistic for the telemarketing environment. In order to optimize the model, we used the MIP/370 feature of IBM's mathematical programming system — MPSX/370.

This software package uses a mixed integer programming algorithm, an optimization technique that handles problems in which some of the variables are allowed to take on only integer values. For example, the decision variable $Y(j)$ is 1 if we locate a center at j, 0 otherwise.

An advantage of the MPSX-MIP software package is that multiple feasible integer solutions are produced in the search for the optimal integer solution. MPSX extended control language was used to code a procedure to generate alternate or "next best" solutions. These "next best" solutions are extremely important to customers, since factors other than cost play an important part in their decision making.

Because of excessive run-times for the case when $X(i,j) = 1$ or 0, a Lagrangian relaxation heuristic, recently developed by AT&T Bell Labs [Klincewicz and Luss 1986] is used to generate solutions. A PC version has been developed for the AT&T PC6386 using LINDO and the Lagrangian relaxation heuristic described above to solve the mixed integer programming problem.

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