Knowledge Support Systems for "Smarter" Pricing and Resource Allocation

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At the tactical or management control decision making level in companies the two key issues are product pricing and resource allocation. These two problems are well suited to analysis and decision aiding using knowledge support systems since models and operations research techniques can be used to structure a part of the problem, while managerial expertise and knowledge are required for the rest. An architecture for knowledge support for these two problems has been developed and concrete systems have been devised to implement these concepts.

The product pricing example given here is for gasoline pricing in the French market by a leading multinational company. The resource allocation example illustrates promotional budget allocation for a British bank.

Knowledge Support and Decision Making

Knowledge support systems is a generic term used to describe computerized aids for helping knowledge workers in the performance of cognitive tasks. In this paper we will consider knowledge support for decision making by companies operating within a competitive environment. We note that vast numbers of interrelated decisions are made by organizations. Fortunately, it is possible to group these in various ways, e.g., through a hierarchy of impact, time horizon of interest, data needs, degree of structure etc.

Anthony [1] describes four levels of decision making: strategic planning, management control, operational control, and operational performance. Strategic planning decisions are related to choosing the highest level policies and objectives and associated resource allocations. Management control decisions are decisions made for the purpose of assuring effectiveness in the acquisition and use of resources. Operational control decisions are decisions made for the purpose of assuring effectiveness in the performance of operations and operational performance decisions are the day-to-day decisions made while performing operations. Simon [2] has described decisions as structured or unstructured depending on whether the decision making process can be explicitly described prior to the time when it is necessary to make a decision.

Generally, as Sage [3] points out, operational performance decisions are more likely than strategic planning decisions to be prestructured. If we now think of the technological tool of expert systems which generally presuppose that a domain expert exists whose knowledge can be captured and put at the service of the novice user, and of decision support systems which are able to respond to "what-if" questions by using a model base, one could argue as Sage [3] does that: expert systems can usually be expected to be more appropriate for operational perfor-
mance and control decisions) than they are for strategic planning and management control decisions. Decision support systems will be more appropriate for strategic planning and management control than for operational control and operational performance decisions.

Note, however, that expertise is a relative term that depends upon familiarity with the task and the operational environment into which it is embedded. Since decision environments do change and since novices become experts through learning and feedback, clearly, there will exist many areas where the proper form of knowledge base support is a hybrid of a decision support system and an expert system.

We would thus expect to use hybrid knowledge based systems for the middle levels of managerial decision making. At these levels, the overall strategy of the company is already defined over a long time horizon (typically about five years) and it is the job of these levels of management to translate this strategy into the day to day operations. To go from strategy to a day to day level, one needs to have a tactical level in between that is very aware of the competitive environment within which the company operates and defines the terms of the short-term competition. The key decision issues here are thus how to price one’s products and how to allocate resources to meet strategic aims. Clearly, these two areas are intrinsically linked to each other. However, because of differences in time scales between these problems, they can sometimes be decoupled. We will describe a knowledge support system for pricing which assumes a decoupling from other resource allocation issues as well as a resource allocation for the allocation of a company’s promotional budget which does not necessarily assume decoupling from pricing issues. Both of these systems have the same architecture, i.e., they are hybrid knowledge based systems. We first describe this architecture, next implement it for pricing decision making, and then show an example for a gasoline pricing problem in the French market. An approach is described for promotional budget allocation and the application of the marketing budget for a British bank illustrates the use of knowledge support for resource allocation. It should be emphasized that both product pricing and resource allocation for tactical decision making are generic issues. For example, our product pricing approach has been used for pricing automobiles, gasoline, interest rates in banking, bus tickets, fast moving consumer goods, and car washes. The resource allocation approach has been used for promotional budget allocation in banks, newspaper groups, mail order companies and for space allocation in retailing and for sales force allocation.

Hybrid Knowledge Based Systems Architecture

So far, we have highlighted the various kinds of decisions that senior managers make and pointed out that there is a spectrum of decision aids to help the manager which go from expert system to decision support systems as we go up the managerial decision making hierarchy. A number of hybrid knowledge based systems address specific problems in different industries. Some examples are: Price-Strat, a system for helping companies to price their products in competitive markets [4]; BS-opt, a system for banks and building societies to determine interest rate mixes in the face of competition [5]-[7]; Resource-opt, a system for space allocation in retailing and sales force allocation geographically and/or by industry segment [8]; TAPS, a system for marketing budget allocation and sizing [9]. A number of systems have also been developed for strategic decision making [10].

In each of the tactical systems, a three-phase process is used. In phase 1, the system extracts expertise from senior managers about the market and competitors through their responding to a series of “what-if scenarios.” These are combined with historical data and market research data to make up an initial market knowledge base. Historical information and market research are added to the knowledge base.

In phase 2, an inference mechanism interrogates the knowledge base to determine the profit maximizing decisions and their sensitivity. Sales and profit forecasts are also provided.

In phase 3, new data, which emerges after the application of the profit maximizing decisions, is used as a reality check. The system uses this to learn about the environment and to enrich its knowledge base. Thus, decision making is improved over time.

Example of a Hybrid Knowledge Based System for Pricing

Price is the only marketing mix element which generates revenue: all others involve expenditure of funds. The impact of price changes is usually immediate and direct. Appeals based on price are the easiest to communicate to prospective buyers. It is therefore very surprising that so little has been written about price setting for the firm.

At the aggregate level (an industry or the whole economy) pricing has traditionally been the forte of economists. The economist’s input into the price setting problem for a firm is, however, primarily at the strategic level. The actual prices are usually set by buyers (in retailing), marketing departments (in many other industries) or by Boards of companies (e.g., in the area of consumer durables like cars) which try to resolve conflicting aims of marketing departments and finance departments. Companies obviously do recognize the importance of “smart” pricing in a competitive environment given the amount of senior management time that they seem to be willing to devote to it.

Within the companies, final price setting is often seen to be more of an art than a science. In the rest of this section we describe the Price-Strat approach for pricing in competitive markets which has the potential of shifting the balance in price setting towards a more scientific basis. This is done by attempting to capture the intuition and expertise of key managers about the market and putting this within a coherent framework.

Any rational analysis for price setting for a company’s products needs to take into account the demand, cost structures, competitor prices and offers and the company’s own strategic objectives.

The broad strategic objectives usually boil down to a desire to achieve a certain market share and to maintain the image of company while optimizing profitability. In the face of competition, this involves positioning some of the company’s products in niches and/or competing on price directly for other products. Since companies usually produce various ranges of products which compete with different competitors in different segments of the market (or in entirely different markets) it becomes more meaningful for companies to take an overall strategic view of pricing. Thus, instead of considering the standard pricing approaches like cost plus pricing, break-even analysis and target-profit pricing, going rate pricing, sealed bid pricing, etc., which are relevant for very small companies with a single product or even product-line pricing which is meaningful for a single product line, it is important for companies to consider the pricing problem as portfolio optimization where all the products of a company are priced as part of an overall portfolio such that strategic objectives are met and profits are maximized.

Tactical Pricing

The main merits of tactical pricing are that the company can take advantage of varying demand and cost sensitivities as well as varying competitive pressures for different products in different markets. The overall long-term profitability point of view is taken for the whole company even though this may
be to the detriment of some of the business units. Obviously, the reward structures for the managers need to reflect this overall company profitability point of view.

A major reason why companies have not used portfolio pricing in the past for their whole portfolio of business units has been because of the difficulties in tackling the various problems which arise in such an exercise, e.g., analysis of competitors, demand structures, cost structures, company strategic objectives, etc., in each market. Further, there have been very significant difficulties associated with obtaining data. The Price-Strat system described below overcomes most of these difficulties.

The Price-Strat system provides a framework for helping companies to tackle the four key problems in strategic pricing, i.e., Demand estimation, cost estimation, competitive analysis and final price recommendation within a coherent framework. The three elements use a combination of historical information, market research information (where available) and the experiential wisdom of key managers which is extracted through their responding to a series of "what-if" scenarios. The Price-Strat system organizes this information in a coherent way in order to make up a "knowledge base."

The knowledge base is operated upon by sophisticated mathematical tools to recommend intermediate and final prices which maximize profitability and, at the same time, meet the strategic objectives of the company within a highly competitive environment. The Price-Strat system runs on a stand-alone desktop computer (IBM PC 386 or compatible machine) and allows managers to study various options and respond rapidly to changes in the market place.

Knowledge Base

In order to build up a picture of demand, cost structure, company strategic objectives and competitors for any specific company in each of its markets, the Price-Strat system first constructs a knowledge base. This is built up relatively rapidly (within a week) by managers defining their strategic aims, price positioning aims, their perceptions of competitors, etc. All this information is fed into the computer and used by the Price-Strat program to generate a series of "what-if" pricing scenarios where the price of the company's products vary as do those of different competitors. For each "what-if" scenario, a group of the company's managers fills in their best judgement of impact on sales and various types of variable costs for each pricing scenario independently. The costs sides of the scenarios are usually completed with the help of the company accountants who use the sales forecast for each pricing scenario to estimate the various variable costs.

The costs sides of the scenarios are usually completed with the help of the company accountants who use the sales forecast for each pricing scenario to estimate the various variable costs. Price-Strat refines this knowledge by building not only individual models but also the most optimistic views, pessimistic views, averages, and averages without optimists and pessimists which constitutes the consensus knowledge of the group. This knowledge is enriched by adding historical data and market research data.

The knowledge base is then interrogated by pressing a button and within 1-2 minutes, the computer calculates the optimal prices which meet strategic constraints and maximize profits.

The user can then modify any strategic constraint and recalculate (within 1-2 minutes) the opportunity cost of shifting a strategic boundary. Equally, if a competitor makes a price move or the company's buying prices change, the new information can be fed in interactively and the resulting optimal prices for the company's portfolio of products can be calculated rapidly.

Experience with the application of Price-Strat in different industries shows that despite the differing views of the world of the various managers (head office, regional, marketing bias, finance bias, etc.), the optimal pricing strategies are close to each other if not identical.

Reality Check and Knowledge Base Enrichment

The decision recommended by Price-Strat can be implemented and after a short horizon the real sales data can be fed in. This provides a reality check. More importantly, Price-Strat uses this new data to enrich the knowledge base and through it, keep track of the slowly changing factors.

The scenarios completed by managers can be scanned by them after a few periods to see if their views of the world have changed and this provides a way of initializing the knowledge base periodically. It also provides valuable continuing education for sharpening the intuition of managers about the markets.

Control Theoretic Concepts Used in Price-Strat

Any knowledge support system for pricing needs to recognize that the company's goal, be it revenue or profit maximization in the long term or the short term, is related to its portfolio of brands and products. Thus, the pricing problem from a control theoretic point of view is a multivariable control problem concerned with managing the prices of the full portfolio of the firm's products.

Typically one could argue that the sales $Q_i$ of brand $i$ for $i = 1$ to $n$ brands will be related to the following: price of brand $i$ ($P_i$); price of brand $j$ to take into account potential substitution effects between one's own products ($P_i$); price of competitor $A$'s brand ($P_{iA}$); price of competitor $B$'s brand ($P_{iB}$); price of competitor $A$'s brand ($V_i$); perceived quality of competitor $A$'s brand ($V_{iA}$); perceived quality of "our" brand ($V_{iO}$); our image in the marketplace ($I_i$); competitor $A$'s image in the marketplace ($I_{iA}$); competitor $B$'s image in the marketplace ($I_{iB}$); competitor $M$'s image in the marketplace ($I_{iM}$); income levels in the neighborhood ($S_i$, etc.). In equation form this would be:

$$Q = f(P_i, P_{iA}, P_{iB}, V_i, V_{iA}, V_{iB}, I_i, I_{iA}, I_{iB}, S_i, etc.)$$

where $f$ is an appropriate demand function.

The time scale for pricing decision making at the tactical level is usually much shorter than the time it would take for the firm or the competitor to be able to change the perceptions of product quality, the image, and income levels, etc. In fact, in the short time horizon of the tactical pricing decisions, all the above could be treated as constants which change slowly as we go from one decision horizon to another. Thus, by using the concept of singular perturbations [11] for this multivariable problem, we are able to reduce (1) to

$$Q = f_i(P_i, P_{iA}, P_{iB}, P_j - P_{iO})$$

$$i = 1, 2, ..., N; j = 1, 2, ..., N; i \neq j$$

within any pricing decision horizon. The
The multivariable pricing problem for a firm with $N$ products and $M$ competitors operating during a fixed pricing interval $t$ is thus to maximize profits subject to the strategic constraints, i.e., for given competitor prices find $P_1, P_2, \ldots, P_N$ so as to maximize

$$Z = \sum_{i=1}^{N} [P_i - Q_i] - C$$

subject to the strategic constraints given by the inequalities (3)-(5).

For an appropriate choice of the function $f$ and $g$ in (1) and (6) and the strategic constraint values $A_{max}, A_{min}, B_1, \ldots, B_M, C_1, \ldots, C_M$ in equations (3)-(5) by top management, it is possible to solve the above pricing problem provided that one can parameterize the relationships (1) and (6) for a specific pricing problem.

Parameterization

To parameterize the sale and cost models (1) and (6) one could use a) historical data, b) market research data, and/or c) the expertise of key managers extracted through their responses to "what-if" price scenarios.

The Price-Strat approach which implements the above solution process uses a combination of a), b), and/or c) above. The "what-if" price scenarios mentioned in c) above are generated randomly by the computer in such a way that a limited number of these (typically 30-40) enable the decision space to be adequately covered.

The combining of the data sources a), b), and/or c) above is done using a set of weights provided by the user. Within c), above, weights can also be used to appropriately combine the views of the different managers depending on their perceived degree of expertise or by any other method.

Example: Gasoline Pricing in the French Market

The French gasoline market is a highly competitive market with a number of key players with different aims and ambitions. At the time of the experiment (December 1989), 60% of the market share was held by 10 major oil companies, while the remaining 40% was held by the supermarkets and hypermarkets which retained cut price petrol.

In virtually all countries where price competition exists for retail petroleum products, the actual prices are not set for the full portfolio of the company’s product; rather the competition is done on the premium lead grade product only with fixed differentials in price between this product and the other products in the company’s portfolio. This clearly suboptimal procedure is adopted in order to simplify and make more manageable the frequent pricing changes required in this market.

Most oil companies use "bang-bang" type pricing strategies. They go in cycles from low prices ("going for volume") to high prices ("going for profit") and back again as they attempt to meet from month to month their overall sales volume targets. This tends to perturb the market and leads to suboptimal profit performance. Price-Strat’s ability to deal with the full portfolio and its optimization capability of maximizing portfolio profit within volume constraints was seen to be a major point in its favor. It also provides a very structured framework for decision making in this vital area. However, the point of the controlled experiment was to see if it outperformed the experienced company representatives in profitability. It did this for each of the four sites [12].

Indeed, it improved the overall profit margin by about 5%, which if translated to all the company owned sites in France could mean an annual improvement in profitability of $22 million.

Price-Strat has subsequently been used in further gasoline pricing experiments in the United States for retail, dealer tank wagon, and terminal pricing. Improvements as compared to the expert performance of the representatives of the company’s 8% to 30% were observed. These major improvements can be attributed to the optimization and the structured decision framework provided by Price-Strat.

Example of Resource Allocation: TAPS

Next we consider the second key issues for tactical decision making: resource allocation. A key role for top management is to arbitrate between the short term and the long term. This issue is most clearly seen in the context of the allocation of a company’s marketing or promotional budget where, in principal, it could be set to zero leading to increased short-term profits, but possibly to a major long-term disaster. The problem faced by big companies with significant marketing budgets is how to size and allocate these budget in order to promote the full range of the company’s brands or products using different advertising media (press, TV, radio, direct mail, etc.). This is a multi-criterion decision making problem where short-term earnings goals may be inconsistent with long-term earnings goals or image enhancement goals. Although nearly a trillion dollars are spent every year on marketing activities worldwide, the TAPS approach described below is one of the first serious attempts at tackling this problem in
a theoretically elegant but nevertheless practical way.

**The TAPS Approach**

Targeted Allocation of Promotional Spending (TAPS) assists managers in their decision making by enabling them to look at the total budget allocation process — from refinement of the tentative budget, to full campaign planning, backed by a thorough knowledge support system.

The TAPS follows a three-stage process. In stage 1 the judgements of a group of managers in response to a series of "what-if" expenditure scenarios generated by TAPS are captured. Each scenario seeks individual views of the impact on sales and/or image of different expenditure levels. The scenarios are based on a long-term strategic framework determined by the fixing of minimum/maximum spend for each media type. The responses are then drawn together to establish a consensus view and then combined with any available historical and market research information, to make up the initial knowledge base.

In stage 2, the expert knowledge base is used with the mathematical optimization routines within TAPS to build up individual campaign models, and indeed a model of the total budget allocation across all campaigns. These can be used to yield optimal spend decisions to maximize sales, or image, and to explore the trade off between the two.

Stage 3 is one of the exploration which can provide answers to questions such as: How can sales be increased from the same budget? How, if the budget is increased or decreased, will it be allocated across different products and media types, to maximum effect? How are trade offs made between sales and image?

**Practice**

Although TAPS involves complex mathematical optimizations, it can be used by non-computer experts. The process starts by modelling the allocation of expenditure for a particular market segment, in terms of short- or long-term earnings, and image. The first result is a set of recommendations as to the inclusion or exclusion of particular media types for a given campaign, i.e., should TV or press be included, and the allocation of spend across media types.

The individual product models can be used to build up the model of total promotional budget. TAPS can then be used to examine expenditure decisions at any level — total budget allocation by product or product allocation by media type.

Finally we note that the output produced by TAPS show the relationship between total expenditure and sales and/or image and the breakdown by media type. This type of information can be used to assess for example the media expenditure mix across all products that will maintain short-term earnings and image at an acceptable level, while maximizing long-term earnings.

Experience with a number of companies has shown that TAPS typically indicates around 10% improvement when compared to potential long-term earnings from the initial tentative budget, without sacrificing short-term earnings and/or image. Which is the marketer's ideal solution? TAPS has been used by three major banks, a newspaper group and a company in the financial services sector.

**Example: Promotional budget allocation for a bank**

For this Bank, TAPS was used to plan four campaigns in 1988, the full budget in 1989 and in 1990. In 1990, the bank promoted 13 brands/products and spent 39 million. The TAPS analysis enabled improvements to be made in each of the criteria: short-term earnings (+8% or £27.5M), long-term earnings (8.1% or £61.9M), and image (+5.1%).

**Conclusions**

Two key problems, pricing and resource allocation, exist at the tactical decision making level in virtually all companies. We have seen that a common architecture could be used to develop knowledge support systems to help with these decisions. The architecture has been used in the Price-Strat and TAPS systems and these have been shown to work within a practical setting. It should be emphasized that Price-Strat and TAPS are merely first attempts at providing such knowledge support and leave much room for improvement through further research.

References


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