Intelligent Decision Support for the Pricing of Products and Services in Competitive Consumer Markets

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Abstract—In this paper we describe a new class of systems called intelligent tactical decision support systems which enable firms to make superior pricing decisions within a dynamic competitive environment. The paper outlines the unique aspects of such systems in relation to commercially available systems. These aspects are seen to be their ability to process and use knowledge on the one hand and information external to the organization on the other. The systems use nonlinear models, optimization, and learning algorithms to provide decision support capabilities for the generic price-setting problem. The general theme of the paper is to see the systems described within this paper as the support tools for a generic price setting process. The description of the systems start with a generic one for pricing decision support in any consumer market and is then specialized to various markets each of which could benefit from a specific variant of the generic pricing technology which has been adapted to that particular industry. The adaptations from the generic pricing system to the systems for petrol pricing, retail pricing, and telecommunications taxation, have been explained. These three examples show a variety of price-setting situations ranging from near commodity pricing, as in the case of petrol, to pricing of very sophisticated services, as in the case of mobile telephony. Field experiments with these systems show that they perform significantly better than unassisted human decision-makers. This is seen from controlled experiments where these systems have demonstrated significant profit uplift when applied to the experimentation sites as compared to the “control” sites where the systems have not been applied.

Index Terms—Decision support systems, decision technologies, intelligent systems, price-setting process.

I. INTRODUCTION

A. Pricing in Competitive Consumer Markets

In free markets, it is the price and product or service differentiation which supports market interactions. Virtually all firms attempt to provide a greater or lesser differentiation of their product or service offerings, in order to compete and, if possible, to command a price premium. For example, oil companies retailing as undifferentiated an offering as different grades of petrol or banks accepting retail deposits of similar maturity attempt to provide differentiation of the “image” of their offering through various branding strategies. For the individual firm, which has created differentiated products or services, to a greater or lesser degree, the issue of pricing these within their specific competitive market is of vital importance. This is true irrespective of whether or not the firm has a high degree of product differentiation, since even for firms with relatively differentiated product offering, it is still necessary to set the most appropriate prices and to revise these from time to time.

In this paper we describe a new class of information technology systems to support the process of price setting for an individual firm in a competitive environment. The support systems to be described can help both firms competing on the basis of low prices or on the basis of product differentiation. This will be seen from the results of field experimentation in three different industries: gasoline retailing (low product differentiation), grocery retailing (higher level of product and quality of service differentiation), and mobile telephony (high level of service differentiation). These systems are called intelligent tactical decision support systems (ITDSS) and we will relate these to the existing information technology systems.

B. Tactical Pricing

The pricing issue that is dealt with is one of tactical pricing where it is recognized that price is only one element of the marketing mix. The situation being considered is that of a firm which needs to price and re-price its products and services from time to time. The need for re-pricing arises typically in the light of changes in the prices of competitors in the firm’s market, in the cost of its inputs, or in its efforts at continual product or service differentiation through the periodic introduction of new products or services.

The periodicities of price changes being considered range from once or twice a day, as may be the case for a gasoline station, to several months as in the case of regular price reviews and new services introduction in mobile telephony or in financial services.

The kinds of firms being considered here are the ones which sell their products or services directly to consumers at prices that they choose. Thus firms who sell their goods via intermediaries and do not set the final price to the consumer are not considered here. The situation being considered is one where our “client” is one amongst a small number of competing vendors who sell similar products or services. Each vendor is able to set and display prices at which some consumers buy the products or services and others do not, i.e., there is no price negotiation. In this paper, “products” will be taken to mean both physical products like petrol as well as standardized services, e.g., telephony tariff plans.
C. Embedding Tactical Pricing Within Longer Term Strategy

The short term or tactical pricing problem being considered here is assumed to be embedded within and thus constrained by the firm’s longer-term strategy, which is recognized as being made up of three key aspects.

1) Price Positioning: This is concerned with giving signals to consumers about the relative quality of the firm’s products or services in relation to the competition and it typically involves ensuring that an appropriate relationship is enforced between the prices of the individual products or services of the firm and those of its competitors. Price differentials also need to be enforced between the different products or services of the firm again to emphasize the differentiation aspects.

2) Market Focus and Penetration: This is concerned with ensuring that within the different market segments that the firm’s products or services are sold, appropriate volume goals are met.

3) Continual Product or Service Differentiation: This requires that the firm introduces new products or services from time to time in order to continually differentiate itself from its competitors.

It should be noted that the time horizon over which each of the above three strategic aspects of pricing operate are significantly longer than the periodicity of price changes. For example, it took over two years for the Esso oil company to enact a new price positioning campaign called “Price Watch” in the U.K. gasoline market 1 when Esso gas stations have been typically changing prices on a daily basis. Similarly, lowering the short-term volume targets (typically through having higher prices) often lead to higher short-term profits but the volume once lost is much harder to regain. As far as product or service differentiation is concerned, although a pricing opportunity arises whenever a new product or service is launched, it may nevertheless be necessary to make several price moves in between product launches.

In view of the significant differences in the time horizons for the three strategic elements listed above and the shorter term issues of tactical pricing, we will treat the strategic elements as static constraints over each pricing period. Within the static strategic constraints we will find the mix of prices for the portfolio of the firm’s products or services which takes full account of the impact of the competitor’s prices as well as the firm’s own costs and profits.

Thus, the basic approach in developing the ITDSS described in this paper is to model the short term price–volume relationships for the portfolio of the firm’s products or services within its specific competitive environment, recognizing that competitor price or promotional actions could have a significant short-term impact on the sales volumes of the firm’s products. Using the short-term price volume models and taking into account the firm’s fixed and variable costs, an optimization problem is formulated. Given the current prices of competitors, this optimization problem involves maximizing profits subject to the price–volume model constraints as well as the constraints represented by the longer term strategy of the firm.

In the rest of this paper, we begin in Section II by formulating the generic pricing process and the pricing decision making problem which is at the heart of this process. In Section III we describe the architecture of intelligent tactical decision support systems to solve the generic price-setting problem in consumer markets. In Section IV, the relationship of ITDSS to other information technologies is highlighted. In Section V, the generic ITDSS for pricing is specialized to the specific problem of pricing of different grades of motor fuels at a network of gasoline stations. In Section VI, a specialization is provided for the pricing of goods in supermarkets and in Section VII, for setting telecommunications tariffs in mobile telephony as an example of the pricing of high value added services. In Sections V and VI we also provide results of experimentation in the field with the corresponding systems. Some conclusions are provided in Section VIII.

II. Generic Pricing Decision Making Problem and Support Process

The price setting process is one of the key processes of the firm. The aim of this process is to provide the mechanism to translate the longer term strategy of the firm in terms of price positioning, market share goals, and product/service differentiation into the prices which are set or changed on a day-to-day basis within the competitive environment of the firm.

The key elements for short-term pricing decision making within the longer term strategic constraints of price positioning, volume goals, and product and service differentiation include

1) costs and how they vary with sales volume;
2) sales and how they vary with prices;
3) impact of competitor prices on the sales of the company’s products;
4) interactions between the prices of certain products within the company’s product portfolio and sales of other products within the same portfolio (cannibalization effects).

Information about costs comes from the accounting systems within the firm. However, typical accounting systems do not readily provide the expected costs for different sales levels. For this, a model is required which separates out the fixed and variable costs and then allows one to predict what the costs would be as the sales or other variables, which impact upon the costs, change.

Information and knowledge about the relationships between the sales and a company’s prices lies, in principle, with the sales managers and the marketers of the company. The competitor analysis section within the marketing department typically possesses information and knowledge about the likely impact of changes in competitor prices on the sales of the company’s products.

Although most of pricing practice is based on the idea that the pricing of each product of the firm be considered independently

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1In response to the increasing market share of supermarkets selling cut price gasoline, Esso re-positioned its gasoline prices in 1996 from being significantly higher than that of the supermarkets to being no higher than that of the supermarkets or of anybody else within a 5 mi radius of an Esso station. Now U.K. consumers have registered that the change in Esso’s price stance is perhaps permanent.
of the other products of the firm, there is significant profit potential if we can model the inter-relationships between the products. For example, certain products within the portfolio of the company might be in very price-sensitive markets while others might be in less price-sensitive markets. This might allow for trade-offs to be made between the products thus allowing for more profitable pricing. Again the sales and marketing departments should possess the information and knowledge required to assess these relationships albeit in a qualitative way.

As far as the strategic aspects are concerned, three generic issues stand out as mentioned above, i.e., price positioning, market focus and penetration, and product or service differentiation.

A. Idealized Generic Pricing Process

In large or even medium sized firms, prices are not set by one person but are rather a group decision to which many factors contribute. It should be seen as one of the important business processes of the firm, which typically is in dire need of re-engineering in order to improve its effectiveness.

The main reason, for this need for re-engineering of the pricing process is that present day pricing processes were designed to solve the pricing decision making problem of the single decision-maker, for whom, the pricing problem is too complex. The decision-maker thus ignores most of the above factors and takes the pricing decision within the framework of satisfying rationality [3] by focusing only on costs or on the competition [4], [5]. The advent of computers to support pricing decision-making has merely reconfirmed the satisficing framework by providing spreadsheets for calculating cost-based or competition-based prices.

The pricing process is one of the key business processes in the firm since it is linked to the revenues of the firm; most other processes deal with the cost side of the firm. Its outputs are highly visible to the consumer and give significant “image” messages about the firm and signal the goals of the company to the competitors. Pricing, if done well, has the potential to significantly add value to the firm. Equally, if not done well, it can put into question the very survival of the firm.

The process starts on the left in Fig. 1 with the “sales” box where the interaction of the prices of the company’s own product amongst themselves and with those of the competitors needs to be used to predict sales within each market segment where the company’s different products are focused. The strategic goals of product or service differentiation also form a part of this subprocess since this aspect is usually managed, in service industries via the introduction of new “products.” In industries with “harder” products, information and knowledge about the profiles of one’s consumers and competitors are key elements in predicting sales, and this information and knowledge needs to be extracted from the sales and marketing teams of the firms in a structured way. With the sales prediction, costs can be predicted using information and knowledge available within the firm’s accounting function.

The sales and costs are input into the third key box in Fig. 1 which allows the profit calculation to be performed and fed back to modify prices. In putting the longer term goals of top management as represented by price-positioning and volume targets along with the profits into the pricing decision box ensures that a firm’s own prices are such that these goals can be met. For example, other things being equal, higher volume targets usually equate to lower company prices.

The above generic price-setting process uses all the main sources of information and knowledge available to the firm in order to help it to make superior pricing decisions. It shows the source of information and knowledge which is required for the key steps of

1) sales forecasting;
2) resulting costs;
3) resulting profits;
4) price setting decision.

Real life price-setting processes in the vast majority of companies differ from this model in that typically no sales forecasting is done and the top management goals of price positioning, market share, and product or service differentiation are dealt with in an ad hoc way. The pricing decision typically involves first calculating the costs for a desired level of sales of each individual product, adding a target margin, checking that in doing so one’s prices are not too far from those of competitors, and adjusting them accordingly. The above generic model is vastly superior to such a price setting process for the following reasons.

1) It fully takes into account “what the market will bear” as opposed to what it costs the company to make. From the consumer’s perspective, what it costs the company is irrelevant.
2) It includes all costs including inventory holding costs and sales and marketing costs.
3) It constrains the prices in order to achieve the goals of top management.

While implementing a price-setting process based on the above considerations, a firm should provide better pricing, the amount of information and knowledge which is required to be manipulated and used in the steps of sales forecasting, and cost forecasting; profit calculation and pricing decision-making is so enormous in all but the most trivial cases that it would be
necessary to provide a computerized support system to support such a process.

Next we will examine the intelligent tactical decision support systems developed to support such an idealized generic pricing decision-making process.

III. DECISION SUPPORT FOR THE GENERIC IDEALIZED PRICING PROCESS: PRICESTRAT SYSTEM [6]

PriceStrat was developed as a generic tool to support the idealized pricing process outlined in Section II. PriceStrat is a piece of software that is sufficiently flexible to enable the user to tackle a variety of pricing issues in a coherent way. However, PriceStrat can only be used by an expert. To enable it to be used by the nonexpert user in a specific industry, variants of PriceStrat have been developed which are tuned to the specific aspects of the price setting problem for that industry. These industry specific variants include the Retail Price Optimizer for price optimization in mass retailing, the PriceNet system for setting prices of gasoline for a network of stations, the TelPrice system for setting tariffs in mobile telephony, and the BankPrice system for the setting of interest rates in retail banking.

With the generic PriceStrat system, 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 PriceStrat software enables one to first construct a knowledge repository. This is built up relatively rapidly by top managers defining their strategic aims, price positioning aims, and the marketing/sales managers’ perceptions of competitors, etc. All this information is fed into the computer and used by the PriceStrat program to generate a series of “what-if” pricing scenarios where the prices of the company’s products vary as do those of different competitors. For each “what-if” scenario, a group of the company’s sales/marketing managers is asked to give their assessments of the impact on the company’s sales and costs. In this way, PriceStrat is able to capture a significant element of the intuition and expert knowledge of experienced managers. The intuitive knowledge is combined with any other information available, e.g., past data and/or market research data and this completes the knowledge repository from which the initial parametric values in the price–volume predictive models can be calculated.

The price-volume model is treated as a constraint by sophisticated optimization algorithms which calculate the optimal prices which meet strategic constraints and maximize profits.

The user can then modify any strategic constraint and rapidly recalculate the opportunity cost of shifting a strategic boundary. Equally, if a competitor makes a price move or the company’s input costs 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.

A. Learning

The decisions recommended by PriceStrat can be implemented and, at the end of the optimization horizon, the real sales data can be fed in. This provides a reality check. More importantly, PriceStrat uses this new data to enrich the knowledge repository and, through it, modify the parametric values

in the price–volume predictive models, thus adapting them to changes in the market place.

B. Functional Architecture of the PriceStrat System

Fig. 2 shows the functional structure of the PriceStrat knowledge-based decision support system for superior pricing. The system has three main components.

1) Adaptive predictive model: This is a nonlinear dynamical model which relates the prices of the client’s products and those of competitors to expected sales in the next period. The inputs of this model are the following.
   a) Prices of each of the client’s products. For example, in the case of an individual gas station, these would be the prices of 4* petrol, unleaded premium, unleaded super, and diesel fuel in pence/liter. These prices are needed for the current and several previous weeks to account for dynamic effects.
   b) Prices of each relevant competitor’s products. For example, in the case of a gas station, one needs to feed in the prices of each neighboring station of 4*, unleaded premium, unleaded super, and diesel fuel each in liters. Again, current prices and those of several weeks in the past are required to account for dynamic effects.

The outputs of this model are the sales of each of the client’s product for the next period. In the case of the gas station, these are the expected sales during the coming week of 4*, unleaded premium, unleaded super, and diesel fuel each in liters.

The parametric values in this model incorporate not only the direct price–volume effects but also the effects over the next period of nonprice aspects of the marketing mix, i.e., promotions. The model is adaptive in the sense that these parametric values can be changed from one period to the next as a function of detected differences between the predicted and actual sales. This is done via the learning module described in the following paragraphs.

2) Optimizer: An optimization algorithm takes the equations of the adaptive predictive model as well as the costs and the price positioning and market share goals as constraints
subject to which a profit function is maximized. This leads to a set of prices for the next period and corresponding sales forecast. The actual optimization algorithm which is used for different variants of this system is different in order to take advantage of any structural peculiarities of the domain for which price-setting is being done. For example, for gasoline, although each station has only four products to be priced, the client needs to price on a daily basis at all the stations for a network of say 1000 stations. While each station is not directly coupled to another one, the optimizer must take into account the global sales volume constraint thus providing for interactions between the stations. In the case of mass retail, since a shop may have 50 000 or more products to be optimized, a hierarchical structuring of the optimization makes it amenable to analysis and calculation.

The optimizer in all cases takes into account:

a) all constraints including 1) the price–volume model’s constraints and 2) the top management set volume and price-positioning constraints;
b) all costs including 1) inventory holding costs, 2) marketing and sales costs, and 3) other fixed or variable costs.

The outputs of the optimizer are 1) a forecast of sales in the next period, product by product and 2) the optimal prices.

3) Learning Module: This module is driven by the differences between sales achieved at the end of the period and those forecast at the beginning of the period. Its output modifies the adaptive predictive model such that it minimizes the deviation between real sales and predicted sales for the next period.

The learning module is essentially a “parameterizer.” It allows the user to first initialize all the parametric values in the price–volume model and then to modify them from one period to the next.

The functional architecture outlined in Fig. 2 provides the basis of an ITDSS, which is of value for a wide spectrum of consumer industries ranging from those where price competition is of significant importance, e.g., in commodity markets like petroleum, or where it is less important, e.g., for fashion goods. In both cases (and for the spectrum in between), it is important to be able to set and modify prices for each portfolio of goods (or services) and fully take into account the following:

- all costs (fixed and variable);
- opportunities arising from possible portfolio interactions as consumers trade up or down within the client’s product range as the price differences between products are allowed to vary;
- sales, depending one’s own price mix and on competitor price mix;
- sales volume targets by product and for the whole portfolio of products, i.e., price positioning;
- ability to introduce new “products” within the portfolio to provide continual product or service differentiation.

At one end of the spectrum (commodity pricing), the price sensitivities of the products are typically much higher than at the other end (relatively differentiated product offering). However, in both cases, there are bound to be differences between the price sensitivities of the products within the portfolio. The optimizer takes advantage of these to yield more profit for firms anywhere within this spectrum.

It should be emphasized that the PriceStrat support system is equally valuable for a firm producing products with high initial fixed costs and low marginal costs, e.g., software, or the inverse (petrol) since all costs are fully taken into account within the optimizer including the amortization costs, inventory holding costs, marketing costs, etc.

C. Architecture of the PriceStrat System

PriceStrat is a knowledge-based decision support system which comprises the following main components as shown in Fig. 3:

- dialogue generation and management system which provides the user interfaces;
- model-based management system which incorporates the nonlinear elasticity models relating prices to sales, the optimization module, and the learning module;
- knowledge-based management system for extracting the expertise of users through their responses to “what if” scenarios generated by the software as well as various management rules;
- database management system which allows the maintenance of the integrity of the various databases.

1) Mapping the Functional Architecture of Fig. 2 Onto the KBDSS Architecture: The architecture in Fig. 2 (see functional architecture of the PriceStrat system) describes the various functions which need to be performed in order for the system to calculate the best prices and improve these over time.

The architecture in Fig. 3 is an implementation architecture where the adaptive predictive model and the optimizer are a part of the model-based management system. The data needed to represent the products, their current and past prices, and the various constraints are in the databases. The integrity of the databases is managed by a database management system. The initialization of the parameters in the price–volume model requires knowledge and this, along with any management rules, is in knowledge bases with a knowledge base manager ensuring their integrity.
Knowledge in this context means primarily the business expertise of managers which enables them to be able to predict what the sales would be under different price scenarios if they or their competitors were to change the prices of some of their products. It is represented in the form of a computer check. A second form of knowledge is in the form of business rules typically found in expert systems. Such knowledge are numerical values of expected sales resulting from different scenarios. Knowledge in this form can be easily encoded into the computer and its integrity is represented as “IF–THEN” rules and it can also be easily encoded and its integrity checked.

D. PriceStrat for Supporting the Idealized Generic Pricing Process

Fig. 4 is a reformulation of Fig. 1 and it shows how PriceStrat could lie at the heart of a new generic pricing process where, instead of merely doing cost plus pricing, one is able to implement the process of Fig. 1. This figure depicts PriceStrat as providing intermediation between top management (as custodians of the company’s strategy), the marketing department (providing knowledge and information about the market), and the finance/accounting function providing costing information and knowledge as well as performance monitoring.

PriceStrat is the first example of a new class of information technology systems: ITDSS. In the next section, we relate this new class of systems to those which are commercially available.

IV. POSITIONING OF ITDSS IN RELATION TO COMMERCIALLY AVAILABLE INFORMATION TECHNOLOGY SYSTEMS

The intelligent tactical decision support systems described above represent a wholly new class of systems as compared to commercially available systems. To understand their new features, let us examine them in relation to the commercially available systems, which are closest to them, i.e., decision support systems, neural networks, and expert systems.

• **Expert Systems**: Like the intelligent tactical decision support systems described in this paper, expert systems also use knowledge although the primary knowledge representation in expert systems is in the form of “IF–THEN” rules whereas in ITDSS, it is a combination of rules and numerical responses to price scenarios. Also, the inference engine does not permit the system to do optimization. They work well where the end result is an on–off decision. For pricing on the other hand, the end result is not an on–off decision but rather a decision on what the new prices should be in a precise numerical form.

• **Decision Support Systems**: Such systems are typically mentioned in conjunction with data warehousing technology and refer to the notion of running sophisticated queries on the information within the data warehouse. Such decision support systems have at best the database management part of the ITDSS plus a search engine. They do not use any form of knowledge explicitly within the system; the knowledge is in the head of the user. They do not permit optimization through a direct use of the system.

• **Neural Networks-Based Forecasting Tools**: These enable one to throw a lot of data at the tools in order to train the neural net, followed by further data in order to forecast what would happen. They cannot be used for performing price optimization since the “models” which relate the inputs and outputs are not explicitly representable.

• **New Class of ITDSS’s**: The mix between external and internal information is such that a much higher amount of external information is required to tackle the problem being solved by the intelligent tactical decision support systems as compared to any of the above mentioned systems. This is because for pricing decisions even the largest firms have at most 20%–30% market share and thus only possesses information in their databases about these 20%–30% of consumers. To obtain external information about the remaining 70%–80% of consumers some of whom the client is trying to attract involves interpretation of relatively poor quality information and requires a significant amount of business expertise/knowledge.

Except in the case of expert systems where the expertise is incorporated in the software, none of the above mentioned systems have an explicit representation and use of knowledge, i.e., the knowledge comes from the user of the system. The ITDSS’s, on the other hand, have the knowledge of the organization explicitly within the software (in the form of a combination of “IF–THEN” rules and price scenario responses). It is in this sense that the ITDSS’s are “intelligent.”

Further, the optimization capacity of the ITDSS allows the user to make the “best” decisions with the system cutting through millions of options in calculating the decision.

The learning capacity of the system allows it to improve its ability to make superior decisions which are taken repetitively as is the case for most pricing decisions.

The above discussion shows that seen from an IT systems perspective we have the following.

• ITDS systems are unique; there is no equivalent or near equivalent product in the market today.

• The PriceStrat system described in Section III is an excellent example of this new class of systems.

2IT industry research firms like Forrester Research, Gartner Group, etc. try to quantify the size of this market and follow the different firms in it. This definition is very different from that used by academic scholars like Sage [1]. Sage’s definition would fit better with the new class of ITDSS’s, described in the following paragraphs, once one has added a knowledge component to Sage’s definition.
Next, we show a variant of the PriceStrat system for the important area of petrol pricing.

V. KNOWLEDGE SUPPORT FOR PETROL PRICING [7]

A key aspect of petrol retailing is that companies usually have networks of stations each operating in unique competitive environments with prices needing to change frequently. Price wars are rampant in petroleum retailing in many countries.

A. Present Day Fuel Pricing

The most common approach taken by fuel retailers is to keep prices in line with competitor prices. Although this does protect sales volumes, it does not enable the management to achieve profit aims. More specifically profit performance is harmed by price wars and the subsequent reaction of increasing prices (to recover profit margins) results in the loss of sales volume.

To manage prices and to establish control over profit performance, fuel retailers aim to

- make available adequate up-to-date information;
- use this information in a pricing process, that also uses all the skills and intuitive market knowledge available in the company, to promptly make effective price moves by grade and by outlet;
- identify the tactics that will best achieve the strategic aims for the retail network in the competitive market place.

The pricing process not only needs to set effective prices, but also needs to

- involve staff with local market knowledge;
- reassure the retail network management that the pricing image is being maintained and that the sales volume and profit performance goals will be achieved;
- provide feedback to reassess the tactics of price, promotion, acquisition/disposal, etc. that will best achieve the retail network’s strategic aims.

The PriceStrat system has been specialized for this problem and this version is called PriceNet.

B. Pricing Process Using PriceNet

PriceNet is an intelligent price decision support system specifically designed for fuel retailers. PriceNet provides the following key benefits:

1) capturing and enabling the explicit use of local market knowledge for each station on the price/sales volume models that are then constantly updated by actual performance;
2) enabling the network management to set achievable sales volume and profit targets within an explicitly defined price positioning strategy;
3) providing prices for each grade and each outlet that will achieve the sales volume targets more profitably;
4) focusing management attention on those outlets that need (or would benefit from) a price move;
5) enabling alternative pricing options to be examined; quantifying the benefits and risks of implementing each option;
6) providing sales and profit forecasts and price positioning information that enables the network management to review tactics.

The actual management of the pricing process using PriceNet involves the transmittal, on a daily basis, of the prices of competing stations in the neighborhood of each of the company’s stations, by telephone to the company’s mainframe computer which also has in it that day’s costs of the products as traded on the Rotterdam spot market. All this information is downloaded into PriceNet via a flat-file. PriceNet is then run by a single analyst and his manager who between them are able to control and set prices at several hundred stations.

1) PriceNet Price/Sales Volume Model at a Single Site: While a large number of factors influence the sales of fuel, it is only price moves that cause rapid changes in sales volumes. PriceNet models the price/sales volume relationship in great detail.

The PriceNet model is built by estimating, for each of next week’s products, the nonlinear elasticities for

- influence of its own price on sales;
- influence of each competitor’s price on sales;
- influence of each of the other product’s price on sales.

PriceNet makes an initial estimate of these relationships using local knowledge of the market supplied by the sales management, combined with historical data of the actual sales, prices, and competitor prices over the recent past (if it includes at least ten significant price changes).

At the end of each week the PriceNet models are updated with actual sales performance. This learning process adjusts the elasticities and accounts for any changes in the influence of nonprice factors on sales volumes.

Fig. 5 shows how the modeling, optimization, and learning interact at the level of a single station in order to provide profit maximizing prices for the station such that the price positioning and volume goals of the station are satisfied.

Experience shows that thanks to the learning loop, the difference between predicted and realized sales grade by grade is usually less than 5%. A bigger difference triggers an alarm signal. Texaco (U.K.) Ltd., a user of this system, has publicly stated that their difference between real sales and predicted sales is now within 1% per week.
2) **Network Optimization**: The problem of pricing for the oil company client is not so much the setting of prices of the four grades of petrol at a single station, but rather the setting of prices of the four grades at each of the company’s network of stations. The pricing problem viewed from a company’s head office involves

1) a volume target for the whole network for the next week;
2) price positioning constraints\(^3\) in terms of
   - min/max price limits for each grade,
   - min/max price relationships with each specific competitor for each grade,
   - min/max price differentials between grades;
3) maximum allowable price changes;
4) how the volume targets for each station should be set for the network such that the overall volume target in 1) is met and the constraints in 2) and 3) are satisfied.

PriceNet’s network optimizer addresses this problem as depicted in Fig. 6. Essentially, the sales and profit targets for the network are fed into the network model which is made up of the individual site models. An optimizer then solves this problem and passes the desegregated volume targets to each station.

### C. Using PriceNet

PriceNet is a Windows 95 application written in Computer Associates’ Visual Objects 2.

\(^3\)Some of the above constraints would apply uniformly across the whole network while others would be specific to individual sites.

On entering the system, the explorer is used (Fig. 7) to look at information at the level of the oil company broken down into each group of stations which typically are supplied from a single depot.

On the right window (Fig. 7), it is possible to look at diverse information relating to any specific site, e.g., its competitor site prices, elasticities, forecasted versus achieved volumes, price differentials, volume targets, and site details, etc.

To use the system, we start with the network optimizer level shown in Fig. 8.

The network optimizer shows the profits and volumes currently achieved as well as the optimum profits and volumes for the coming week. It also shows five profit–volume options for the whole network which are feasible within the constraints structure. The user selects one of these options and the system calculates the optimum prices for each grade at each station within the group and outputs a decision dashboard. Fig. 9 shows the dashboard with the information on the different sites where opportunities for extra volume or profit exist.

If the user wishes to examine a particular site in detail, then clicking on that site on the dashboard in Fig. 9 allows us to reach Fig. 10.

Fig. 10 shows the current and optimum prices and sales at this site. Current means previous week’s profits and volumes while optimum means next week’s profit and sales which take into account seasonality calendar events, etc. It is possible to override the optimal prices, and the system produces new forecasts corresponding to the prices that have been input.

For the site in Fig. 11 (Chirch St), we can see the difference between forecast and achieved sales over the past few weeks. The price differential constraints are shown in Fig. 12.

Next we describe some field trials in the use of this system.
D. Initial Field Experiments With an Earlier Version of PriceNet

- For a client in the U.K., where 90 day experiments were done on six sites in different parts of the country, average net margin increased by 33% while volume remained constant within the clients strategic price positioning aims.
- At DTW areas and Jobber terminals, improvements in profitability over the period considered was 30% and 4%, respectively.

These experiments are described in detail in [8]. They demonstrated the significant potential of the system to improve oil company profits through superior pricing.

It should be noted that the above mentioned early experiments in the use of the system in fact only involved the use of the site by site optimization and not the network optimization. Following these experiments, large-scale experiments on petrol pricing were done for an oil major in the U.K. for a much larger number of sites over one year and the system was improved with the addition of the second level network optimizer.

As a result, Texaco (U.K.) Ltd., Repsol U.K., and another multinational oil company have obtained licenses for this technology, and other oil companies are currently testing it in Europe, Asia, and the Americas. A recent experiment in the U.K. in the use of PriceNet for an oil company is described in Section V-E.

E. Recent Field Experiment Using PriceNet

For the last 18 months or so, a petrol price war has been raging in the U.K. which has decimated the margins of oil companies. While the Monopolies and Mergers Commission, in its 1989 report on the U.K. petroleum industry, estimated the net margins of oil majors to be 0.7 p/l [9], Forecourt News [10] currently estimates these margins to be less than 0.3 p/l.

The experiment involved the use of PriceNet for modeling and setting prices at 15 petrol stations over a period of 17 weeks. During the same period, another group of 15 stations were matched to the trial group to act as the control group. Over the previous six-month period, the differences in performance between the two groups were averaged and these were found to be 0.0004 p/l, i.e., there was a very small difference in profit performance between the two groups which was in favor of the trial group.

Next, PriceNet was used to set prices for the subsequent 17 weeks and removed from the trial group at the end of week 17. It was observed that the average volume difference between the trial group and the control group remained unchanged while the profit performance of the trial group improved substantially. Fig. 13 shows the evolution of the profit difference in pence per liter prior to, during, and after the trial. The average improvement was 0.65 p/l, i.e., more than 200% and this with no volume loss.

VI. RETAIL PRICE OPTIMIZER: PRICESTRAT VARIANT FOR MASS RETAILING

In mass retailing, the number of products can be in the tens of thousands as compared to the four products at a gas station, but, with PriceNet, we are managing the prices for a network of stations.

The retail price optimizer is used for setting the prices for a category of products comprising typically up to 1000 products with six or seven subcategories within it. The dimensionality issues within the modeling, optimization, and learning have been resolved in the design of the retail price optimizer using ideas from hierarchical systems theory [11].

We next provide some results of experimentation in the field with this system.

A. Results in Petroleum Convenience Stores

The objective was to reach an optimal pricing of 2500 products each in five convenience stores of petroleum retailers. Profits and volumes were compared prior to and during the
period of experimentation of three months between the five “controls” convenience stores and the five “pilots” convenience stores. The results showed an average profit improvement of £1200 per week per store. This represents £30 million profit uplift per annum for 500 stores. The company is now a licensed user of the system.

B. Profit Improvement in SupermarketRetailing

Similar to pilots in convenience stores, five “pilot” stores and five “control” stores were selected with the main criteria being each control store should match a pilot store in terms of social and economic environment and sales and profits. In each store, three product groups (spirits, chocolates, butter and margarine) were analyzed on a 12-week period.

The results have shown a 6% increase on sales units and a 3.2% increase in cash turnover which means a profit increase of 25.5%.

VII. TELPRICE: PRICESTRAT VARIANT FOR SETTING MOBILE TELEPHONY TARIFFS

As a final example of intelligent pricing decision support, we describe the TelPrice system which is currently being field tested with two mobile telephony operators in Europe.

In mobile telephony, a “product” is a bundle of services and includes a number of price variables. These include

- line rental;
- connection charge;
- handset;
- peak rate tariffs;
- off peak rate tariffs;
- GSM peak rate;
- GSM off peak rate, etc.

The operator introduces new “bundles” from time to time in order to differentiate its offer in relation to that of competitors. When a new “bundle” is introduced, the marketing of “old” bundles ceases. However, the subscribers in the old bundles remain although they can’t accept new subscribers. This led us to characterize the client’s product set as comprising two classes of products. “Active” products into which new customers can enter and from which customers can leave as well as “inactive” products where new customers can’t enter but they can leave.

The adaptive predictive model needed to be decomposed into three interacting components as shown in Fig. 14. These components deal with the phenomenon of churn (where the customer goes to another operator), migration (where the customer moves to another tariff plan of the operator), and acquisition (where a new customer signs on with the operator).

A. Results

We estimated the size of the benefit of using TelPrice for an operator in the French market. The results were

- net profit increase: £16 million per annum or 8.86%;
- number of additional new subscribers over 4 months: +20.84%;
- average net revenue/subscriber: +5.9%.

This operator now uses TelPrice for pricing its mobile telephony tariffs on a day-to-day basis. Alcatel is currently marketing the TelPrice system to mobile telephony operators worldwide.

VIII. CONCLUSION

In this paper we have examined the key business process of pricing in consumer industries and suggested, that as organized at present in virtually any company, it is well worth it to reorganize the process. This paper has focused especially on the provision of IT support, and software support in particular to enable a firm to improve not only the efficiency but also the effectiveness of the process. We have seen how the PriceStrat family of tools is well suited for providing this support given examples of this from a number of consumer industries including petrol retailing. We have also provided an outline of the basic scientific principles underlying these new tools and related them to existing commercial IT systems. We have seen that in all cases, the scope for improving profitability is very large indeed.

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