Simulation as an aid to build a management expert system

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Abstract
Managers have to make management decisions many times a day. These concern matters such as price setting, development and marketing of new products, expanding or reducing the sales force, increasing or decreasing research activities, etc. This kind of decisions is mainly based on numerical data (turnover, market share and many financial ratios), but the manager's knowledge of and experience also plays an important role. In this paper an attempt is made to capture this kind of knowledge in the field of industrial marketing and to use it in an expert system. To assess the quality of such an expert system it has participated in a management game competing against a number of MBA students.

Keywords: decision support systems, expert systems, management game, simulation, marketing

1. Introduction

Characteristically the problems that managers face are often complex, managers have only limited information concerning alternative solutions and the outcome of their decisions involves some degree of uncertainty. On top of that, bad decisions can lead to enormous extra costs. In order to reach a sensible decision, a manager may use a variety of decision making tools. Computer based tools play an important role in this context. Early attempts at using the computer to solve management problems were aimed at 'eliminating' the manager. This led to programs based on mathematical optimization procedures that were not used by managers in the field. Since then more attention has been paid to the subjective judgment and feeling of managers themselves. Today managers make use of decision support systems, management information systems and also increasingly of knowledge-based or expert systems. Because of the nature of the knowledge that managers use to arrive at their decisions, expert systems would seem well suited to capture this knowledge:

- a large part of management knowledge is qualitative rather than quantitative in nature and consists of rules of thumb,
- many problems are complex enough to require expert knowledge,
- a large body of knowledge is available in textbooks or can be made explicit

Until now though, few expert systems have been developed for management and marketing problems. Of the existing systems, that are largely still in a prototype phase, most are set up as a diagnostic instrument. The decisions themselves are left to the manager.

The small number of existing expert systems in marketing covers various sub-branches. In

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[Wierenga, 1992] 27 of such expert systems are enumerated: sales promotion (7), following market developments and report generation (5), advertisements (4), media planning (3), new product development (3), automated data analysis (2), negotiating (1), determining strategies (1) and prediction (1). According to [Walden, 1992; Mentzer and Gandhi, 1993] the field of marketing and, more particular, that of industrial marketing is promising with respect to the development of expert systems.

For the field of strategic marketing management even less expert systems have been developed. Wierenga refers to only one system giving strategic advice. Walden has developed an expert system for strategic marketing and Van Bruggen [Bruggen, 1993] applies in his research project a marketing expert system developed by himself.

In this paper we will describe an expert system for industrial marketing, that is not only an instrument for analysis but can advise a manager as to what actions to take and offer him a second opinion. The expert system has been designed and tested using a management game, also called management simulation.

In the first section we will describe some aspects of industrial marketing, the concept of creating a *competitive advantage* and the *strategic marketing process*. In the second section we will formulate a basic strategy and show how it can be formalized to fit the needs of an expert system. Next we discuss the performance of the expert system and in the last section we will present our conclusions.

2. Industrial marketing

Industrial versus consumer marketing

Instead of consumers, the customers of an industrial organization are other companies. Because of the usually large number of potential customers the focus of attention in consumer marketing lies on bringing about a single transaction, followed up by repeat purchases. For several reasons the industrial market has always been much more relation oriented. In industrial markets the number of customers is smaller but the orders of each customer are much larger. For the production of the end product, customers depend critically on their suppliers. Constant product quality and reliability are therefore often more important then cheap bargains. The idea to manage the relations in industrial markets has been the beginning of industrial marketing. Although there are some differences, many principles from the consumer marketing also apply to industrial marketing.

Today's importance of research and development

Since the early seventies big changes occurred in industrial markets. The international competition increased, markets became more fragmented and more demanding. New technologies that emerged grew out of date with increasing speed. Consequently, companies focused more and more on new product development and product technologies. To survive in a competitive environment product and process development have become necessary conditions. In this sense, a good R&D program is a competitive advantage [Clark and Wheelwright, 1993].

Creating a sustainable competitive advantage

According to Porter a company must, to be successful, create a sustainable competitive advantage [Porter, 1985]. In some way or the other a company has to distinguish itself from competitors by better meeting the demands of the customers than the competitors do. There are two strategies to achieve this. The first one is called cost leadership, whereby a company tries to minimize the costs of the production process. The second strategy is product differentiation, whereby a company aims to offer a product that better meets the customer's demands. The latter often results in offering various variations of the same product, each variation directed towards one or more groups of customers. Naturally, by this approach the advantages of scale of mass production are lost. Based on the competencies of the company and the type of market in which it operates, the manager selects one or a combination of both strategies.

The strategic marketing process

To structure the decision making, that must lead to a sustainable competitive advantage, the strategic marketing process has been developed [Kotler, 1991]. Schematically, the strategic marketing process can be considered as a number of consecutive actions: analysis of the market, market segmentation, selecting the target market, taking position relative to the competition (positioning) and determining the marketing mix (product, price, promotion and distribution).

3. A basic strategy

In a previous section we discussed some aspects of industrial marketing and the consecutive steps of the marketing management process. In this section we will demonstrate how a basic strategy is formalized into a number of production rules. A more detailed discussion of the expert system can be found in [Stout and Willemsen, 1996]. First we will briefly characterize the strategy, later on the various components will be discussed more extensively.

Innovation and market oriented product development

We discussed before that a company's success in a competitive environment depends on the degree in which it succeeds to create a sustainable competitive advantage. To achieve this we have chosen for a strategy of product differentiation. We think that the best way to build a strong relation with our customers is to offer products that better satisfy the needs of customers than competing products. This idea has been translated in a strategy containing three key elements:

– developing completely new products,
– developing better products and
– developing new technologies.

In order to take advantage of the various needs of the groups of customers when developing new products, we have segmented the market based on the type of industry that will apply the product. The idea behind this, is that a strong correlation exists between the type of industry and the needs of customers with respect to the physical characteristics of the product, whereas there is a less strong correlation between these needs and, for example, the company's size or its location.

Formalizing the management process

We have simplified the strategic marketing process described above and reduced it to the following seven steps:

1. product assortment analysis
2. target market selection

3. positioning of new products
4. research and development
5. product management
6. sales and technical force management
7. budget allocation

For programming purposes, we have divided all decisions into those that have financial implications and those that do not. The first six steps concern management decisions that put no burden on the marketing budget, the last step *budget allocation* covers all decisions that do. We have formalized the decisions in each area using so-called *production rules*. These are if...then...-statements that can be programmed in an expert system. After each step we give one or more examples of such production rules.

Product assortment analysis. Our strategy is to develop a superior product for each market segment. Each period we develop only one new product to focus the attention of the R&D department. In order to determine for which segment we should develop a product, we check which segments are already served by one of our existing products. We say that a segment is served when at least one physical characteristic of a product we market, matches the needs of this segment. The needs of each segment, translated in product characteristics can be procured by market research.

Example: **If** the value of at least one physical characteristic of one of our products comes close enough to the value preferred by a certain segment, **then** this segment is served based on this characteristic.

Target market selection. The choice of a target segment depends on the question whether or not we distinguish ourselves from our competitors by a special technology and on the attractiveness of a segment in terms of size and growth. If we have a special technology, we develop a product for the segment whose needs are most difficult to satisfy with inferior technologies. In case we do not have such a technological advantage we simply develop a product for the most attractive segment.

Example: **If** we do not have a technological advantage, **then** we target the most attractive segment.

Positioning of new products. We position a new product as the best (physical) product for the target segment we have selected. Within the limits of the technologies that are available to us, we set the value of the physical characteristics of a new product as near as possible to the preferred value of the target segment. To determine this *ideal value* of the target segment, a market research study is ordered.

Example: **If** a target segment has been selected to develop a new product and some ideal value of the target segment cannot be met by our technology, **then** we set the value of this characteristic of the new product as near as possible to the ideal value and we set the value of the remaining characteristics at the ideal value of the target segment.

Research and development. To enable us to develop excellent products, we spend great efforts on technological research. Development of completely new technologies has priority over development of new technologies for existing product groups, because we expect a higher return from totally new products. When a new product has been positioned, the values of non-important product characteristics and the production costs are set.

Example: **If** we already possess a technology to make a completely new product and we do not have a technology to improve our existing product assortment, **then** we invest in this last technology.

Product management. For each product we set the value of the following variables:

– product name,
– production,
– list price,
– maximum price discount,
– sales force commission,
– allocation of technical support.

The production depends on the number of units sold in the last period, the growth rate of the target segment for which it was developed and the of inventory level. The list price, as we do not use price as an instrument to position our products, is only adjusted for inflation. To avoid pricing our products out of the market we have instituted a price ceiling.

Examples: **If** there are still items of a product left in inventory, **then** the production is set at a level equal to the units sold in the last period increased by the expected growth rate of the target segment minus the number of units in inventory.

If a product is new and there are no similar products, **then** the production will be set at a very high level.

Sales and technical force management. This step concerns the way the sales force and technical force are organized (by geographical region, account size or industry) and the attention they give to the different market segments. As long as we have few products targeted at a specific segment we organize our sales and technical force by region to keep travel costs low, if we do have enough specific products, we organize them by industry. Markets are segmented on a macro and a micro level. Macro segmentation means segmenting the market according to region, account size or industry, micro segmentation is done at the level of the *decision making unit*. When a company decides which products to buy, different managers in an organization have some say in the decision making process. To increase our sales we focus our attention on the managers with the largest voice.

Example: **If** we have few products targeted at a specific segment, **then** we organize our sales and technical force by geographical region.

Budget allocation. This last step covers all decisions that have financial implications:

– sales promotion and advertising
– size of the sales and technical force
– training expenditures for both sales and technical force
– corporate communication
– investment in new technologies
– product development budgets
– marketing research expenditures

First a proposal is made, that states the amount of money to be spend on each decision area.

Examples: **If** a product is new, and there are no similar products, **then** a large amount of money will be spend on promotion and advertising.

If total sales have increased, **then** additional salespeople are hired proportionally.

Secondly this proposal is compared to the marketing budget actually available. If there is a surplus it is spent on the most important areas and if there is a shortage, the money is taken from those where we can best afford it. This allocation of the difference between the proposal and the actual budget is done according to a list of priorities based on our strategy. For example development of new technologies and products are most important and promotion and advertising expenditures are seen as less important (but not unimportant!).

Examples: **If** there is a surplus and the amount is smaller then the total amount of money needed to develop a new technology, **then** we invest the surplus in technology research.

If there is a shortage and the amount is less then we spend on increasing our sales and our technical force, **then** we hire less new employees.

4. Evaluation by simulation

Based on the previously formalized marketing strategy an expert system has been developed. To test the expert system on its management potentials we had it compete against human opponents in the industrial management game Industrat [Larréché and Weinstein, 1988].

A management game is a learning tool that offers a simulated economic environment in which participants run a business and have to compete against each other. Although the game is only a simplified version of reality, it obeys economic laws as much as possible and is complicated and unpredictable enough to demand the same high level of decision making as would be required in a real situation.

Compared to a real life test the use of a management game to test an expert system has several advantages. Apart from practical considerations that favor the use of a simulation (such as lower research costs), a management game offers a closed environment with a limited number of variables that makes it easier to determine the effectiveness of the expert system.

A brief description of Industrat

In Industrat five companies compete against each other. All of them produce and market a raw material called Korex. In the starting position each company markets four different Korex brands. In subsequent periods this number can be changed by introducing new products or by phasing out obsolete products.

Each Korex product has four physical characteristics: resistance, suspension, frequency and density. Of these characteristics only the first two are relevant to the customers. Each characteristic can have a range of numerical values. Products differ (physically) from each other in so far as they have different values for each of the characteristics.

Different groups of customers (market segments) have different preferences concerning the value of the resistance and the suspension of a product. A company can increase its sales to a certain group of customers by producing a Korex with characteristics close to the group's preferred value. To determine the preferences of different segments, market research has to be carried out. The range of values attainable however is limited by the technologies that are available to each company. Due to technological restrictions it may not be possible for a company to exactly meet the needs of a market segment. To expand the range of values a company must develop new technologies. Apart from the physical characteristics the price also plays a role in determining the preference of customers for a certain product.

Each company has the opportunity to develop a second product class called Lomex. This is also a raw material and is marketed in the same way as Korex products. The sales of Lomex and Korex do not influence each other, they are no substitutes nor complementary goods. The physical characteristics of Lomex are: convexity, conductivity, purity and maximum energy. Similar to the Korex product, only the first two are relevant to customers.

Industrat is played over a series of a maximum of 10 sessions. In each session, the participants have to make decisions in five areas:

Product management: for each product choices have to be made concerning production volume, price, maximum discounts, etc.,

Sales and technical force management: hiring and firing of sale and technicians,

Corporate marketing: to promote the name of the firm as a whole (instead of its individual products) a certain amount of the budget has to be spend on corporate communications,

Research and development: what new technologies and products must be developed.

Market research: which information is useful, and which can we do without.

In order to make the right decisions the players of Industrat have the following sources of information at their disposal:

Company report: this is handed out to each team at the end of each period and contains for example the quantity of products sold, the profit, the available resources in the next period and the product characteristics of the competing products,

Market research studies: these are provided on request and contain more detailed information on the performance of products, markets and the competition,

Decision support system: this tool is used to present the available information in a more convenient way (for example, based on a regression analysis the preferred physical qualities of each end user segment are calculated).

Because some decisions cost money all participants get an initial marketing budget. During the game the budget will depend on the performance of the companies. All five companies start from different initial positions but all have an equal chance at winning. At the end of the last session the winner can be determined by comparing for example the total profit each company has made or the market share of each company.

The game is led by the *administrator*, usually the professor who gives the course. His function is to process the results each time the participants have made their decisions. He may decide to offer loans and decides whether or not to allow licensing between companies. He can also fine companies that cheat.

Putting the expert system to the test

To evaluate the performance of the expert system it has fully participated in the industrial management game Industrat. Instead of trying to mimic a manager in a real world situation, the objective of this experiment has been to successfully replace one human player by an expert system. For the experiment to be considered a success the expert system must achieve an average or above average final ranking.

Industrat can only be played with five teams. For organizational reasons two games were played in parallel. In each game three human teams took part and an expert system as fourth player. Consequently, to each game one more team had to be added: the administrator playing a short term strategy.

The first five teams played in a game called *Industry A*, the others in *Industry B*. The games are played independently in industry A and B and the activities in one game do not influence those in the other game. In industry A company 3 was played by the expert system, in industry B company 4 (A3 and B4, respectively). In both industry A and B the dummy company played by the administrator was company 5 (A5 and B5). This has been done to make a comparison between both games more convenient.

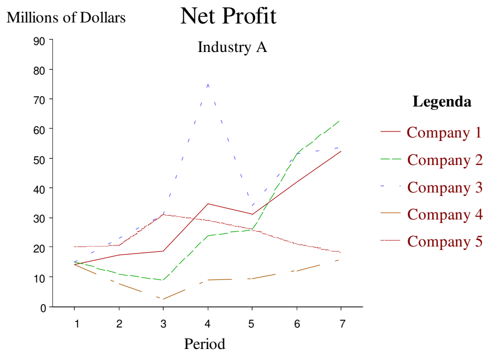
The human participants were MBA students of the Rotterdam School of Management with practical experience in business management.

The communication between the players and the management game was done off-line and the other (human) players were unaware of having an expert system among them.

The transfer of data from the management game to the expert system was done by hand.

5. Results and conclusions

Both companies played by the expert system have performed properly and their decisions are understandable. Both have achieved the objective to at least perform at an average level. It is difficult to say more about their final position. Industrat offers a number of assessment criteria and the performance of each company depends on which criterion is observed: market share, turnover, net profit, cumulative net profit, etc.



In the figure above, the results of the five companies in Industry A are displayed with respect to the net profit. After period 4 the expert system succeeded to take the first position. At the end of the game (period 7) it has achieved a second position. The large increase in profit of company A3 in period 3 must be attributed to the first introduction of a Lomex product. In the next period the competitors also introduce Lomex products and therefore the profit drops again. In Industry B the success of the expert system was less striking but it ended in a close finish on a third position. When an other criterion is considered, such as cumulative profit, it finished first (A3) and third (B4).

Although it was carried out in an artificial economic world this experiment has demonstrated that it is possible to apply an expert system to advise a manager in making management decisions.

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