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Agent simulation modeling of corporations' innovation performance

Abstract

This article represents the agent simulation model of corporations' innovation performance in confectionery production and sale.

Simulation is an obligatory step in making decisions for critical strategic management by companies actively utilizing modern information technologies in their activity.

Supporting tools of strategic planning based on computer simulation allow formalization of complex nonlinear interactions in business as well as effects assessment for various scenarios or future developments prediction.

The subject of study is scientific, methodological and practical issues of planning and assortment optimization by an enterprise due to the methods of simulation modeling.

The aim of the article is to develop a generalized computer model in innovation performance for an enterprise of confectionery branch in order to investigate possible scenarios of the system development with variations of certain parameters.

The methodology is based on the theory of agent-based simulation systems. In the course of study we used the provisions of system and economic analysis for environmental monitoring of the corporation involved in confectionery production and sale. The author implemented the methods of sociological study including interviews, questionnaires, and observation to define preferences of customers' priorities, and to provide market segmentation.

Due to computer simulation we specified the expected market share with set model parameters, the degrees of brands penetration into the market, the levels of repurchase and those of purchasing intensity.

Keywords: simulation, model, buying, commodity, planning, market.

JEL Classification: M11, O31, C53, C88.

Introduction

The modern state of corporate management requires the wider use of simulation modeling methods for making decisions in planning and assortment optimization. Knowledge in principles and opportunities of simulation modeling, the ability of models development, research and practical utilization becomes the important condition of the modern management. Computer modeling technology allows experiments building and conduct using simulation model of commercial and production system or a process of any complexity and duration. The least mistake or inadvertence made on strategic planning stages results in unreasonable costs or even loss of great capital investments. Making experiments with computer models allows appraising the vital capacity of the system under planning, and minimizing material expenditures required for any project execution. It is due to the methods of simulation modeling with real business processes of an enterprise that the level of reasonableness is increased for decisions made while the risk of their implementation is decreased.

To develop some versions of goods or to extend lines is the popular way to provide new goods and get revenue through realization of a trade mark capital. The issue of numerous kinds of one and the same article is used for some purposes, and namely: orientation to different segments, higher level of

potential sales due to extension of consumer basis, and price discrimination among consumers with some other advantages and requirements. Besides, the chance appears to provide the market with full line of goods under the same name that would make shopping easier thus contributing in formation of buyers' loyal attitude, and capital of a trade mark. Sale forecasting by means of simulation modeling allows the establishment of the level of sales stabilization and the required period.

Today simulation modeling is a powerful analytical tool that includes the whole arsenal of modern information technologies. Among them there are developed graphic envelopes for models designing purposes with interpretation of modeling outputs, multimedia means and video for animation support in real time scale, object-oriented programing, Internet, etc.

A special attention should be paid to the fact that the present simulation modeling is considered to be the obligatory stage of making important management decisions in companies that actively use modern information technologies in their work. To assist their managers such companies acquire systems for making strategic management decisions. They include tools for strategic planning support based upon computer simulation modeling that allows formalization of complex nonlinear interactions in business and assessment of effects for various scenarios or future developments prediction.

On the present stage of development of the national economy simulation modeling is getting more and more extended and used as the most valuable element of the process of decision-making at enterprises.

The issues of specification and simulation modeling utilization in economic systems are considered by works of numerous national and foreign scientists, in particular Hamdy A. Taha, Samuelson D., O’Sullivan D., Holland D., Gilbert N., Lychkina N., Trakhtengerz E., Siebers P., and Petrova A. Numerous scholars have presented many different mechanisms to reduce uncertainty in management decisions, but each mechanism has its own limitations in actual implementation. In this regard, we have proposed to use the agent-based simulation to investigate the corporations’ innovation performance. The problems being solved on the level of strategic planning are complicated, of multi-factor and weak structured character [3, 5, 8]. They have the high degree of both external and internal indeterminacy that determines the dominance of expert skill in formalizing problems. An enterprise is faced with the basic system formation tool in the procedure of decision-making that is dynamic systems of structural modeling, first of all the methods of system dynamics.

The aim of the article is to construct the generalized computer model of innovation performance with an enterprise of confectionery branch in order to investigate possible scenarios of the system development with variations of certain parameters.

1. Model

Data Mining technologies are widely spread depending on tasks, and namely statistical methods including regress and cluster analysis, methods of

risks assessment, and intellectual technologies including neuron nets, genetic algorithms, expert systems, and the methods of experts evaluation [2]. They are used on the stage of formation of the basic simulation model in enterprise strategic development that identifies the head inner structure and the modeled system functioning as well as analyzing the outdoor environment like market, competitors and governmental regulation.

Knowledge obtained is the input information for simulation model under formation allowing conduct of correct parameterization of the dynamic simulation model on the ground of real data and knowledge. These data can be stored in the data and knowledge base to simplify the further procedures of the simulation model identification.

In general case the simulation experiment conduct shall be divided into the following stages [6]:

1. Description of the actual scheme of the process under investigation.
2. Establishment and description of features, the succession of actions, limitations and resources to be used for all members of the process by means of state diagrams.
3. Introduction of probabilities distribution laws for key parameters of the model.
4. Values simulation for key parameters of the model.
5. Analysis of performance and decision-making.

We developed the agent-based simulation model of a corporation’s innovation performance in confectionery industry. The model allows determination of measures on forming demand and promoting sales as follows (Figure 1).

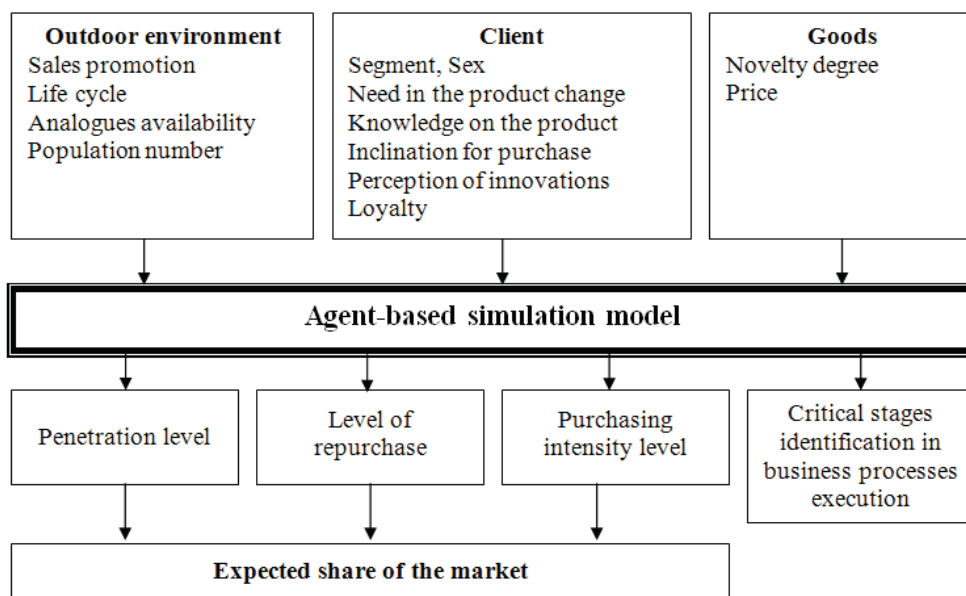


Fig. 1. Simulation model of an enterprise innovation performance in confectionery industry

The outdoor environment is characterized by $S = \{s_1, s_2, \dots\}$ states depending on such parameters as sales promotion, life cycle of products, availability of analogues, and population. In any moment the outdoor environment can be in one of these states. Transition to another state occurs with inner parameters change that happens due to agent actions $A = \{a_1, a_2, \dots\}$. The system behavior can be modeled with env: $S \times A \rightarrow \wp(S)$ function specifying the system current state as the result of the a action in the s state.

Each consumer in the system is characterized by the set of parameters $C = \{Segment, Sex, Inclination for risk, Knowledge of the product, Requirement of changes, Perception of innovations, Loyalty\}$, each

product – $T = \{Novelty\ degree, and Price\}$. The problem of finding the optimal agent’s behavior is equivalent to finding the expected share of the market – L .

The agent-based simulation model of the corporation’s innovation performance is expressed through the formula as follows:

$$(S \times A) \times C \times T \rightarrow L. \tag{1}$$

We propose to establish a product novelty degree based on ranks. For pastry five levels of products novelty shall be distinguished depending on such parameters as components, shape and packing (Table 1).

Table 1. Levels of a product novelty

| Degree of an article novelty (rank) | Parameters of an article under innovation (grades) | | | |
|---|--|------------|--------------------------------|-------|
| | Packing | Components | Material features (plasticity) | Shape |
| Modification of external appearance with preservation of existing consumer properties | 0-1 | 0 | 0 | 0-1 |
| Partial modification of consumer properties due to improvement of basic technical characteristics but without fundamental modification of production techniques | 1 | 1-2 | 0 | 1 |
| New functions combinations, appearing of new additional functions together with introduction of important technical improvements | 2 | 2-3 | 1 | 2 |
| Fundamental modification of consumer properties leading to substantial changes in the way of satisfaction of the corresponding need | 3 | 3-4 | 2 | 3 |
| Appearance of the product having no analogues | 4 | 5-6 | 3 | 4 |

Using grades for evaluation of a product novelty degree represents the more demonstrative form provided the highest novelty rank of ($S_o = 17$ grades) equals to 100%. Here an article novelty degree (H) can be expressed through the formula [1]:

$$H = S / S_o \times 100\%, \tag{2}$$

where S is the number of grades characterizing an article novelty according to all parameters.

Thus, we can consider an article to be new when its novelty is in excess of 70% in accordance with the calculation method proposed. We treat articles characterized by the novelty between 20 to 70 per cent as products of a new kind, and classify articles of below 20% novelty degree as products of negligible novelty. However such fact has slight influence upon their quality.

Every new product has strongly pronounced stages of its existence. They form a product life cycle investigated in the theory of marketing [1]. According to the theory the demand for goods includes the following stages of development.

Introduction is the period of slow growth of sale amount when a product is just entering the market and winning customers. Then profit is low due to

high expenditures while marketing costs are high, and the factors of sales scale include quality, advertisement, price reduction with service improvement.

Growth is the period of the rapid recognition of a product by consumers followed by considerable income increase when advertising costs get stabilized while the great effect is provided by advertisement, quality, price reduction and service improvement.

Maturity is when the demand for a product achieves its peak, and the rate of consumption increase is getting slower with the increase of marketing costs while the greatest effect is provided by price reduction together with measures intensification for demand formation and sales promotion.

Saturation is when the demand for a product is on the high level while the slump in demand is already taking shape in spite of price reduction

Decline is the period of sales volumes reduction with revenues decrease.

The rate of the process of spreading or diffusion of innovation depends upon the type of the innovation. There are five characteristics influencing it:

- ◆ Relative preference over existing alternatives.
- ◆ Complexity as an integral part of a new idea or product.
- ◆ Conformity with existing preferences and habits of potential consumers.
- ◆ Communicativeness as the simplicity of representation of an innovation essence to potential consumers.
- ◆ Opportunity of the small-scale approbation of a new product prior to the full scale purchase reduces relevant costs.

We disclosed some factors promoting new goods success [1]:

- ◆ Correspondence of goods to market demands (85%).
- ◆ Correspondence of goods to internal functional superiorities of a company (62%).
- ◆ Technologic advantages of goods (52%).
- ◆ Support by top management (45%).
- ◆ Following the process of a new product development (33%).
- ◆ Favorable competition environment (31%).
- ◆ Arrangement of the development process (15%).

We divided purchasing of fixed demand goods into two categories: first (trial) and recurrent ones. Initially the number of buyers purchasing goods for the first time is growing and then is declining as soon as the majority of potential customers proved the goods. Repurchasing occurs when goods satisfy expectations of a certain group of customers. Later they become loyal buyers, and the curve of the sales aggregate volume assumes the form of a horizontal line. So, we consider the volume of repurchasing to be the best indication of market satisfaction.

For decomposition and forecasting of market share on fixed demand goods we can apply Parfitt-Collins Theorem dividing it into three components [1]:

1. The level of a trade mark penetration ($L1$) to the market is specified as general volume of trial purchasing, i.e. the percentage of consumers having made the trial purchase during the t period. This value grows at first, and later, following the reduction of non-involved potential buyers-beginners stabilizes quite rapidly.
2. The level of repurchase ($L2$) indicates which share of customers who made a purchase buys the product again. With some certain number of purchases achieving this coefficient gets stabilized.

3. The level of purchasing intensity ($L3$) demonstrates the manner of correlation between the purchasing volume of a brand under investigation and the average volume of purchases in the commodity category as a whole. Here we distinguish between active, moderate and inactive customers of a definite category goods depending upon purchases volume.

The expected share of market is calculated as the product of the following three values:

$$L = L1 \times L2 \times L3. \quad (3)$$

A plan of new goods introduction to market can be only effective if it takes into account the process of innovations acceptance by a target group of customers. The process of innovations acceptance is examined in works by Robertson, Lavidge and Steiner [1, 5, 7]. In general, the process can be represented in the form of some stages gradually passed by a buyer, and namely:

1. *Making acquaintance* when a potential customer C_i : $i \in 1, n$ (where n is the total number of agents) gets informed on the product existence. On this stage an important role belongs to advertising and spoken communication.
2. *Comprehension* based on awareness of understanding of what the product is and what functions it performs.
3. *Attitude* including attitude to a product, and inclination of an individual to evaluate any object of his or her environment positively or negatively. A customer's thoughts may be influenced by advertisements on a product concept as well as sellers or influential persons:

$$S_i \times C_j \rightarrow C_j.$$
4. *Sympathy* when a consumer expresses his or her favorable attitude being confident in the product advantages and correctness of the purchasing done.
5. *A trial purchase* when a customer utilizes a product in restricted volume motivated by publicity, or the opportunity to use a free sample.
6. *Acceptance* when a customer accepts the product and continues to buy or use it ($S_i \times C_j \rightarrow S_i$). The process of acceptance gets completed, and the further level of satisfaction depends on the quality of the product itself.

The process of decision making about a purchase can be represented in algorithmic form (Figure 2).

\forall client [if a number of purchases = 0 [if an inclination to risk \leq random 100 and knowledge \leq random 100 and the need of changes \leq random 100, then the number of purchases is to be increased by 1]
 if a number of purchases = 0 and the need of innovations \leq random 100, then the number of purchases is to be increased by a frequency else the number of purchases equals to -1.
 if a number of purchases $<$ 0 and the need of innovations \leq random 100 then the number of purchases is to be increased by a frequency]

Fig. 2. Algorithm of the process of making decision about a purchase

Besides, modeling shall take into account customers' segmentation depending on the time of an innovation introduction. There are five types supposing that the number of persons in each group is governed by the normal distribution law.

1. *Innovator* is the very first buyer of an innovation who is independent, hot-tempered, venturesome, and ready to test new ideas.
2. *Early follower* is a leader and influential individual in his or her spheres who easily accepts ideas but behaves carefully.
3. *Early majority* includes people who approve new ideas quicker than average consumers but require information and become leaders infrequently.
4. *Late majority* includes skeptics who approve an innovation after majority of consumers has already got acquainted with it.
5. *Backward* are partisans of traditions who look suspiciously at modifications.

So, developing the plan of a product introduction to the market we should choose such marketing instruments that correspond to each stage of the new product acceptance in the best manner [3]. Besides, it is important to observe how the target public changes from one stage of the process to another.

2. Results of market research

There exists a proposal to introduce ChocoWine to confectionery market of Ukraine as an innovation. It

is a chocolate bar with raspberry taste. This is the first and unique product containing resveratrol, a well-known anti-oxidant effectively fighting against human organisms' aging contained in the peel of black grapes.

One bar of ChocoWine includes more resveratrol than 50 glasses of red wine. The bar itself has chocolate and raspberry flavor, just 190 calories, and much cellulose. Pomegranate, peach, mango and blueberry are among other flavors proposed to buyers. The product also contains gluten and milk additives however it is free of trans-fats, hydrogenated oil or corn syrup with high percentage of fructose as well as artificial flavors, sweetening agents, preservatives, and cholesterol.

Resveratrol is widely used as a natural or artificially synthesized additive, and sold in the form of pills or medicinal liquids. But it is the first introduction of resveratrol in the market of food products. To produce the useful ingredient for chocolate bars manufacturers use two kinds of sources: the best grades of French red grapes and artificially synthesized additives that is 99 per cent compatible with the natural product.

ChocoWine chocolate bar is a good example of healthy nutrition. Its potential consumers can receive all advantages of resveratrol and other valuable nourishing substances enjoying the taste of wonderful chocolate (Table 2).

Table 2. Segment distribution of potential consumers of ChocoWine chocolate bars

| Parameter | Segment 1 (partisans of healthy nutrition) | | Segment 2 (seekers of rejuvenizing effect) | | Segment 3 (chance buyers) | |
|---------------|--|-----------------|--|----------------------|---------------------------|----------------|
| | Males | Females | Males | Females | Males | Females |
| Age | 30-40 | 25-35 | 41-55 | 36-60 | 17-29 | 17-25 |
| Education | Highest | Highest | High and the highest | High and the highest | High | High |
| Family status | Single | Single | Married | Married | Single | Single |
| Income | Middle and high | Middle and high | High | High | Low and middle | Low and middle |
| Motives | Rational | Rational | Rational | Rational | Emotional | Emotional |

In Segment 1 representing partisans of health way of nutrition the assisting factors of purchasing stimulation are to become the product's unique features. They are improvement of general well-being and capacity for work with men, and contribution to beauty and health with women. For buyers who would like to get rejuvenizing effect of the product the unique opportunities providing the fresh look of skin together with improved general appearance and well-being either with men or women are to become the additional stimulus for purchase of the chocolate. The third Segment includes chance buyers who purchase chocolate rather as a present than due to its unique features.

The number of potential customers is calculated considering the fact that chocolate forms habituation with 30% of women and 15% of men. In accordance with data by State Committee for Statistics by January 1, 2011 there were 21,032,600 men and 24,565,600 women in our country, thus 3,154,890 men and 7,369,680 women for whom the innovation shall be oriented in the confectionery industry.

Introducing a new product to Ukrainian confectionery market we also take into account the response to the innovation of future consumers (Table 3). The price for the product can be ranged within reasonable values (Table 4).

Table 3. Response to the innovation of consumers

| Characteristic | Partisans | Neutral | Negative |
|--|-----------|---------|----------|
| The need of a product modification through the understanding that no product represented in confectionery market satisfies a consumer's requirements | 30 | 31-70 | 70 |
| Knowledge about a products through active advertisement in mass media and promotion | 80 | 81-95 | 96 |
| Inclination to risk and desire to prove a new product | 40 | 41-80 | 81 |
| Innovations welcoming | 45 | 46-75 | 76 |

Table 4. Price range for ChocoWine chocolate bars by segments

| Price range for the product, UAH | Sex | Segment 1 | Segment 2 | Segment 3 |
|----------------------------------|--------|--------------------|-------------------|-------------------|
| 15-19 | Male | 1.25 times a month | 0.5 times a month | 1.5 times a month |
| | Female | 2.5 times a month | 1 time a month | 3 times a month |
| 20-22 | Male | 1.5 times a month | 1 time a month | 1 time a month |
| | Female | 3 times a month | 2 times a month | 2 times a month |
| 23-25 | Male | 0.75 times a month | 2 times a month | 0.5 times a month |
| | Female | 1.5 times a month | 4 times a month | 1 time a month |

3. Simulation results

As the outcome of experiments we established that for UAH20 price after 48 months 48% of 1,000 persons did not test the product at all while 25% became loyal clients, and 27% did not welcome the innovation and rejected the product (Figure 3).

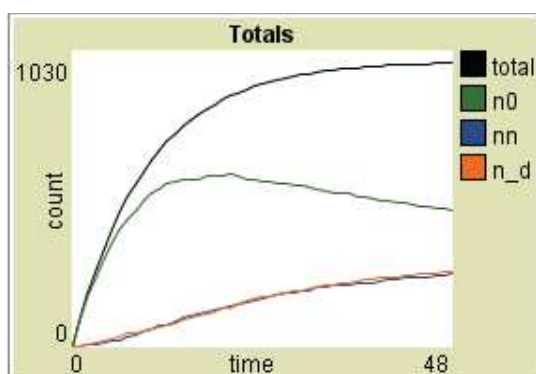


Fig. 3. Proportions of clients by segments

Under such conditions the expected share of market comprised 22.89% considering $L1 = 52%$ penetration level, $L2 = 25%$ level of repurchase, and $L3 = 1.76$ purchasing intensity level (Figure 4).

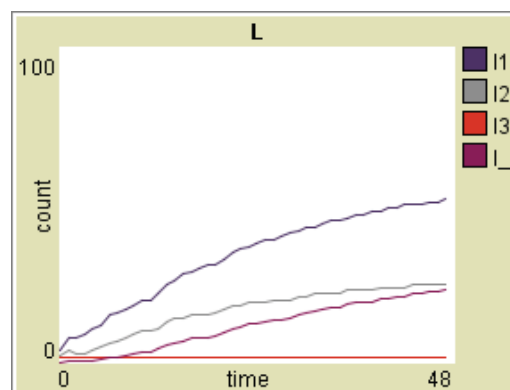


Fig. 4. Constituent parts of the expected market share determination using Parfitt-Collins Theorem

Conclusions

Thus, in the course of computer experiment based upon specified input data we got the resulting index of the market share (22.89%). It can be recognized as the product of penetration level to the market, and that of repurchase with purchasing intensity. Investigators have the opportunity to alter parameters of the new product, its price and duration of introduction to the market, and to make more substantiated managing decision on this ground.

Further research is to deal with additional parameters of internal and external environment introduced to the developed simulation model. This would allow improvement of simulation modeling quality and accuracy in the sphere of strategic planning of enterprises' activity under investigation.

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