Methodology of probabilistic modelling of the current activity of industrial enterprises

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Abstract. The article discusses the approach to the methodology of modeling and forecasting the production activities of industrial enterprises. It uses mathematical probability theory. All the studies are made by the example of the furniture industry enterprises. This approach enables to carry out effective planning of production and commercial activities. It also contributes to an increase in the effectiveness of marketing activities and decision making. The presented results have been achieved through the use of mathematical models and tools based on the application of the approach to defining the probability of non-zero demand for the goods. The developed mathematical models make it possible to prepare the initial data and make effective management decisions based on them in the form of plans and programs of industrial activities in a quick manner. The enterprises producing goods or providing services in a large assortment are forced to conduct a comparative mathematical analysis of the business units of the industrial enterprise in order to make a decision on the distribution of investment resources. The priority field of enterprise activity (which brings the maximum profit) receives the maximum financial investments.

1. Introduction
The presented approach is carried out in a form of a certain sequence: analysis of initial data → determination of a purpose → formulation of tasks → justification of a scientific and methodical apparatus → solution → efficiency evaluation. Modeling and forecasting production activity of industrial enterprises (in the current economic conditions) is made in the frames of this approach.

This approach takes into account existing methods and means, which in practice are not supported by the necessary content that ensures efficient and rational management of the current production activity of furniture industry enterprises in the current economic conditions [1].

In essence, such elements of any enterprise management system are different: methods and means for analyzing initial data, determining the purpose of current activities and setting tasks for modeling and forecasting, justified application of scientific and methodological apparatus and resulting solution.

Thus, in order to implement the general methodology scheme for modeling and forecasting a state of enterprise in the furniture industry, there is a need not only to develop or improve methods and means for analyzing and forecasting the activities of an enterprise, but also to clearly identify and determine the conditions under which the enterprises ensure implementation of production and commercial activities.
2. Method

In our case, the determining factor is compliance of possible release of a required product volume by the enterprise with the corresponding needs on the market. And the features of forecasting the enterprise’s activities dictate the need to determine and take into account the stage of its development. Proceeding from this, we can use a group of methods based on the implementation of models based on BCG (BCG, Boston Consulting Group) matrix and ADL / LC Arthur D. Little [2, 3] to identify the necessary strategy for the development of furniture industry.

It is necessary to have data on sales of products of all industry for rational use of BCG matrix and conducting reliable analysis (Anisimov Yu.P.). In our case, it is necessary to have data on sales of furniture for individual orders (73%) and mass production (27%), since these goods are manufactured by furniture enterprises. In addition, a similar structure of products in the total volume of sales is typical for other enterprises in the industry. Their comparative analysis is shown in Figure 1.

An assortment matrix is a document that includes a complete list of all the goods items produced by enterprise, taking into account the requirements of the assortment policy and features of the chosen type of products.

Construction of an assortment matrix is an integral element of the assortment policy of a store, regardless of its management organizational structure [4].

The best option for determining the product groups is combination of "commodity group hierarchy" and matrix understanding [5]. In the hierarchy of product groups, the entire product range is consistently divided according to the homogeneity of the needs metered into hierarchical levels under any of the most convenient names (directions, types, types, groups, subgroups, etc.) up to the desired depth of penetration (up to each product) (Figure 2):

Assortment units formed at the lower level (Figure 2) make the left vertical column of a flat table, or matrix (Table 1). The upper line of the matrix consists of similarly obtained segments of the market in which consumers of certain product types are grouped according to the parameters necessary for the enterprise.
Range units, formed on the lower level (Figure 3), make the left vertical column of the plane table or matrix (Table 1).

**Table 1. Matrix for defining product groups**

|                | Segment 1 | Segment 2 | ………  | Segment N |
|----------------|-----------|-----------|--------|-----------|
| Type 1         | Group 1   | Group 2   | Group 3| Group 6   |
| Type 2         | Group 4   | Group 5   | Group 7|           |
| ………           |           |           |        |           |
| Type N         |           |           |        |           |

Crossing rows and columns of the matrix (that is, product type and customer segment) give a desired definition of a commodity group.

Now it is necessary to define the parameters, the values of which further characterize each commodity group in a separate way, and which are used subsequently to modify BCG matrix instead of typical parameters of this method - market share and market growth [7].

The similar structure imposes restriction on direct application of regression approach during forecasting. Therefore the problem of demand forecast for the goods was presented by the following stages:

1. Determination of probability of nonzero demand for goods $P(y \neq 0)$. Calculation comes down to the solution of a problem of classification for the established panel of data set;
2. Calculation of expected value for all the set of cases of nonzero demand [8]:

\[ \hat{\vartheta} = f (x \mid y \neq 0), \]

where \( \hat{\vartheta} \) – demand assessment (regression). Here is the solution of a problem of regression on selection with lack of values of zero demand values.

3. Summarizing the estimated forecast value of demand as a mathematical expectation of demand for goods [9]:

\[ Y = E(y) = P(y \neq 0) \times \hat{\vartheta}, \]

Numerical experiments have shown that the specified approach is justified in terms of optimization of target metrics. At a final stage (after modeling by the means of machine learning methods) the combination of the results was made.

On the provided data it is visible that the combination of the results is carried out by a simple procedure of an arithmetic average for all \( m \) to methods for classification or determination of probability of nonzero demand and on all \( j \) to regression methods. On a formula (3) the final decision looks as follows [10]:

\[ y = E(y_{ji}) = P_{kj} (y \neq 0) \times \hat{\vartheta}_{kj} = \sum_{i=1}^{m} p_{ki} / m \times \sum_{j=1}^{j} d_{kj}, \]

where – assessment of probability of nonzero demand, the \( j \)-\( m \) calculated by the method, – assessment of regression value of demand calculated by \( P_{kj} \) by method.

Let us consider averaging for assessment of probability of non-zero demand:

\[ P_{kj} (y \neq 0) = \frac{\sum_{i=1}^{m} P_{ki}}{m} = \frac{\sum_{i=1}^{3} P_{ki}}{3}, \]

where \( m=3 \) - result of use of 3 models of probability assessment during which methods of logistic regression, accidental sales of products and a gradient busting are chosen. It is made in a view of the fact that value of correlation is worse between results of logistic regression and accidental sales with regularization, and the quality of regression with regularization.

Let's give characteristics of the models making the set of modeling. Logistic regression has the following specification [11]:

\[ P(x) = \frac{e^{Bx}}{1 + e^{Bx}}, \]

\[ BX = \beta_0 + (a_1 y_{r-1} + a_2 y_{r-2} + a_3 y_{r-3} + a_4 y_{r-4} + a_5 y_{r-5} + a_7 y_{r-7}) \times B_{1C} + B_{2X_2}. \]

Here, \( \beta_0 \) - shift, and, \( a_1, a_2, a_3, a_4, a_5, a_7 \) and \( y_{r-1}, y_{r-2}, y_{r-3}, y_{r-4}, y_{r-5}, y_{r-7} \) - coefficients and value of functions of demand respectively, \( B_{1C} \) - a set of coefficients and \( C \) - mock set of variables which reflects the belonging of the modeling and forecasting object to the commodity type; \( X_2 \) - a set of other predictors with a matrix of coefficients \( B_{2X_2} \). The full range of the predictors used in modeling consists of 136 variables.

The main drawbacks of the matrix:
- it loses its visibility in case of multi-product production; moreover, it requires separate consideration of product groups;
- difficulties may arise with finding the necessary information on competitors' products, for example, their cost, which is not included in the statistical reporting, as well as in annual reports and balance sheets of enterprises [12];
- it does not give an understanding of what will happen to “difficult children”: whether they will become losers or leaders, how long the “stars” will burn, and “cows” will produce high yields;
- the nature of the market, number of competitors and other market factors do not consider what can lead to the wrong strategic actions; The Matrix is fully focused on "grocery strategy" and financial flows of the company. For development of strategy of the company in other areas it is necessary to develop: technology, production, management, shots, investments, etc.
An example of constructing and analyzing BCG matrix is impossible without defining goods that can be considered in the projection of this system.

Areas of business that are not related to it. It can be [13]:
- Various services and production of related products.
- Assortment groups of an enterprise, sold in one market. For example, selling apartments, renting apartments, selling houses etc. That is, real estate market is considered.
- Goods classified into one group. For example, production of furniture.

Construction of a diagram of dependence of market share on the rate of its growth is half solution of the task of strategic marketing. The critical moment is correct interpretation of the position of goods on the market and the choice of further actions (strategies) for their development or liquidation. BCG matrix is an example of analysis [14, 15]:

Item No. 1 is located in the zone of low market growth rates and relative share. This commodity unit has already passed its life cycle and it does not bring profit to the company. In a real situation, it would be necessary to conduct a detailed analysis of such goods and determine the conditions for their release in the absence of profit from their sale. Theoretically, it is better to exclude this commodity group and release the resources for the development of prospective goods.

Item 2 is in a growing market, but it requires investment to increase competitiveness. It is a promising commodity.

Item 3 is at the peak of its life cycle. This type of assortment unit has high indicators of SDT and market growth rates. An increase in investments is required, so that the business unit of the firm producing this product brings stable income in future.

Item 4 is a profit generator. The money received by the company from the sale of this category of the assortment unit is recommended to be directed to the development of Items No. 2, 3.

3. Results and Discussion

An example of construction and analysis of BCG matrix facilitates identification of the following four strategies.

Increase in market share. Such development plan is acceptable for the goods located in the zone "Wild cats", with a view to their transition to the "Stars" quadrant.

Preservation of market share. It is recommended to apply this strategy to obtain a stable income from the "Dairy Cows".

Decrease in market share. We will apply the plan to weak "Dairy cows", "Dogs" and unpromising "Wild cats". Elimination is a strategy for the "Dogs" and unpromising "Wild Cats".

The formula of the linear trend of the sales function is a traditional equation of linear polynomial:

\[ V = V_k \times T + C \]  \hspace{1cm} (6)

where \( V \) - sales volume, \( T \) – calculation period (month), \( V_k \) - estimated change (increment or decline) of sales in comparison with the previous accounting period, \( C \) - the constant of the equation, which can be interpreted as a theoretical sales volume in the first month. In the general case, the line coefficients \( V_k \) and \( C \) are calculated by the method of least quadratic deviation (Bezrukova T.L. et al., 2013).

A similar procedure for calculating the trend should be done for all the product groups provided that data on the monthly sales of each group must be highlighted from the total volume of monthly sales. In this case, trend equations for each \( i \)-th group will have a similar form:

\[ V_i = V_{ki} \times T + C_i \]  \hspace{1cm} (7)

Since \( V = \sum V_i \), then in accordance with the property of additivity of linear functions, unit increment of total sales volume consists of unit sales increments of all commodity groups included in the assortment.

After the analysis and evaluation of BCG matrix for other furniture industry enterprises, the data shown in Table 2 have been obtained. It is obvious that other industrial enterprises can use this method, and its application enables not only to evaluate the efficiency of conducting financial and economic activities, but also identify positive and negative development trends for each product group on time. The existing differences in the trend (X) and sales (Y) reflect the real difference in the conditions for
the implementation of financial and economic activities of branch enterprises that have developed in different regions. It is not difficult to see which overall trend remains.

Unlike matrix model of BCG using the ADL/LC matrix requires the data on current competitive position of the enterprise in the regional market in relation to other enterprises in the industry and indicators of product profitability and growth rate of sales that produce furniture products. To fully use the enterprise development matrix, it is necessary to identify variables that assess life cycle stage of entire industry segment of the analyzed enterprise and their relative position in the competitive market. It is necessary for the full use of the matrix of enterprise development. The position of an enterprise is determined on the basis of values of two indicators: stage of the life cycle of the entire industrial segment and a relative position of the enterprise in the competitive market.

| Enterprise | Trend of commodity group V1, (%) | Merchandising of commodity group V1, (%) | Trend of commodity group V2, (%) | Merchandising of commodity group V2, (%) |
|------------|---------------------------------|----------------------------------------|---------------------------------|----------------------------------------|
| PAO Glazov Furniture Factory | 79 | 84 | 42 | 29 |
| JSC GKMF | 81 | 58 | 39 | 37 |
| AO MK Shataka | 74 | 59 | 44 | 34 |
| OOO PC Angstrem | 70 | 62 | 33 | 46 |
| Graftsaya Kukhnya LLC | 72 | 59 | 36 | 41 |
| Somovo furniture | 76 | 43 | 51 | 37 |
| JSC HC Furniture of Chernozemeye | 69 | 37 | 42 | 41 |
| Furniture factory Stolplit | 75 | 41 | 37 | 47 |

An accurate and objective assessment of competitiveness can not be based on an arbitrary set of indicators. When selecting the indicators that are used in this methodology, specifics of the enterprises of the selected industry segment is taken into account. Availability of information on the indicators of financial and business enterprises on the basis of their public financial and accounting statements has been considered. This circumstance makes it possible to make mass assessment, controlling changes in the state of development of the enterprise by all participants of the economic process.

Competitiveness of an enterprise (its relative position on the market) is reflected in the matrix of optimal development along the abscissa axis. On the basis of this matrix, five key provisions defining competitiveness are graphically displayed by five segments, for each of which boundaries are set (table 2). The upper and lower boundaries of the abscissa axis (the axis of relative position of the enterprise in competitive market) are 100 and 0, respectively (using the development potential from 0% to 100%). On the segment, from the best value of 100 to the worst value of 0, the boundary values of all five positions of competitiveness are defined.

4. Conclusion
Thus, an enterprise with a general competitiveness rating from 0 to 20 is characterized by a weak relative position in the market, from 20 to 40 - by a strong position, from 40 to 60 - by a notable position, from 60 to 80 - by a strong position, from 80 to 100 - by a leading position.

Taking into account the above assumptions and limitations, it can be assumed that methods based on the implementation of the adapted Arthur D. Little ADL / LC model and cluster analysis and prediction based on the modified BCG matrix (BCG, Boston Consulting Group) can be used for strategy definition of optimum development of a furniture industry enterprise.
In addition to defining purpose and strategy of enterprise development, it is necessary to establish methods and techniques for forecasting the current activity of a furniture industry enterprise in the current economic conditions. It should contain: a system of indicators for analyzing current activities, a forecast background and a system of predictive background equations which determines the content of the current activity model of furniture industry enterprise.

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