The Method of Constructing a Development Trajectory as the Basis of an Intelligent Module for Strategic Planning of the EPM System

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Abstract

The application of computational intelligence methods for solving strategic problems based on the analysis of research in the field of strategic management and forecasting is considered. The description of the process of forming strategic goals for the company as procedure of the business process to form the company development program is presented. This business process is implemented as a separate module of the strategic planning subsystem of the Enterprise Performance Management system. A solving for the problem of choosing strategies to achieve strategic goals is proposed. The choice of strategies is based on the analysis of development trajectories. A method for constructing a development trajectory is proposed. The method uses the idea of a sequential analysis of options. Each point of development trajectory will correspond to market positions that the company must have at strategic intervals in order to achieve the strategic goal. Possible market conditions (company positions) at intervals of the planning period are determined based on predicted values of market parameters and solving the segmentation problem. The segmentation problem is formulated as a classification problem and is implemented by one of the Machine learning methods. Forecasting is based on neural networks. It is proposed to use a neural network with the Temporal Fusion Transformer architecture.

Keywords 1

Strategic goal, development strategy, forecasting, development trajectory, sequential analysis of options method, neural network, classification problem.

1. Introduction

Modern companies should change management mechanisms in a dynamic market environment to support their competitiveness. First of all, this concerns strategic management. The main problem is not only to form a strategic goal, but also to choose effective strategies for achieving it [1].

Currently, many works are focused on the development of new approaches to solving strategic management problems, including methods of artificial intelligence. For example, the concept of strategic alignment is most often used to solve the issue of the infeasibility for strategic objectives. Strategic alignment is the process and result of connecting the structure and resources of the company with its strategy and business environment. Issues remain and with strategic alignment, both a sound choice of strategic goals and the choice of appropriate strategies for their implementation [2].

To solve individual complex of strategic management tasks companies use special software systems for informational and analytical support to the strategic planning process. For example, the business efficiency management system (EPM - Enterprise Performance Management) is an enterprise management concept which is based on a set of information technologies that automate the base management processes: forecasting, planning, budgeting, monitoring and analysis [3, 4].

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In this article, the strategic planning subsystem as part of the EPM system will be considered. The main task of such a subsystem is to develop a strategic plan of the company's development. To develop such plans, it is necessary to analyze the market position of the company and predict the market change in the strategic period. On the basis of these forecasts, an effective strategy for achieving a strategic goal is selected.

Strategic forecasting is seen as a rebirth of long-range planning, albeit with new methods and theories. Companies should make the building of strategic forecasting capability a priority [5].

2. Background and Related Work

The problem of choosing a strategy for achieving goals, taking into account changes in the external conditions of the company's functioning, has been devoted to many scientific works.

In paper [6], an analysis of the contradictions is conducted between the company's strategies; a conclusion is made about the need to achieve a strategic consensus; the necessity of strategy orientation to the external environment is justified, the analysis of the processes is provided that contribute to the achievement of strategic consensus, its influence on the effectiveness of the decisions is analyzed. Thus, many researchers link the success of the implementation of the strategy with their alignment with the business environment. Decision-makers can analyze and comprehend goals based on the results of current processes.

To implement the process of strategic alignment many researchers pay attention to the analysis of the impact of existing business processes in the company to implementation of strategies. In the research [7] a model for assessing the adequacy of strategies for the company's business processes is presented.

Balanced Scorecard is often implemented to coordinate and monitor the fulfillment of the company's strategy in the management system [8]. Over the past decades, a number of works have appeared in the field of cascading goals [9]. It is shown that the cascading of goals allows not only to implement successfully the process of strategic alignment in many cases, but also to increase the efficiency of the company's functioning [10].

To determine market conditions in a strategic period, the company solves the problem of forecasting market indicators and classifies market conditions (market segmentation) in which the company will operate.

The market segmentation problem is currently viewed as a classification problem or a clustering problem using machine-learning methods to solve them.

The paper [11] deals with problems of marketing research data classification by means of artificial Neural Networks algorithms. Two basic methods are described, classification with the aid of Multi-layer Perceptron neural network with Back-propagation algorithm and classification with the aid of Self-organizing (Kohonen's) maps. Applicability of these algorithms is compared. Possibilities of more complex structural recognition methods and semi-supervised learning utilization are suggested.

Strategic forecasting results are important for product strategy development. In the paper [12] the continuous improvement business process of Product Development is presented for the sustainability of company, which is based on the Strategic Planning method.

Now forecasting systems are becoming part of intelligent decision-making systems. Neural networks and machine learning algorithms are increasingly used to predict performance indicators. The using of computational intelligence tools for forecasting tasks is explained by the need to structure, analyze and only then use the collected market information for forecasting. Combining the methods of mathematical statistics and machine learning methods allows solving complex economic problems in dynamics.

Machine learning has a prominent role in solving clustering and classification problems as well as dimensionality reduction. Nevertheless, traditional statistical methods of forecasting continue to perform well in many practical applications. In the paper [13] the successes of machine learning in forecasting are considered critically.

In the paper [14] the method "Temporal Fusion Transformer" (TFT) is proposed. TFT an attention-based DNN (Deep neural networks) architecture for multi-horizon forecasting that achieves high performance while enabling new forms of interpretability. To obtain significant performance

improvements over state-of-the-art benchmarks, multiple novel ideas to align the architecture with the full range of potential inputs and temporal relationships common to multi-horizon forecasting.

Classification algorithms are used in many domains to extract information from data, predict the entry probability of events of interest, and, eventually, support decision-making [15].

3. The Method of Constructing a Development Trajectory Based on Forecasts of Market Conditions

3.1. Research of the process for forming the company's development program

The process of forming the company development program was suggested in the paper [16]. The business process of working out for development programs is presented in Figure 1, which is implemented within the framework of the company's performance management system.

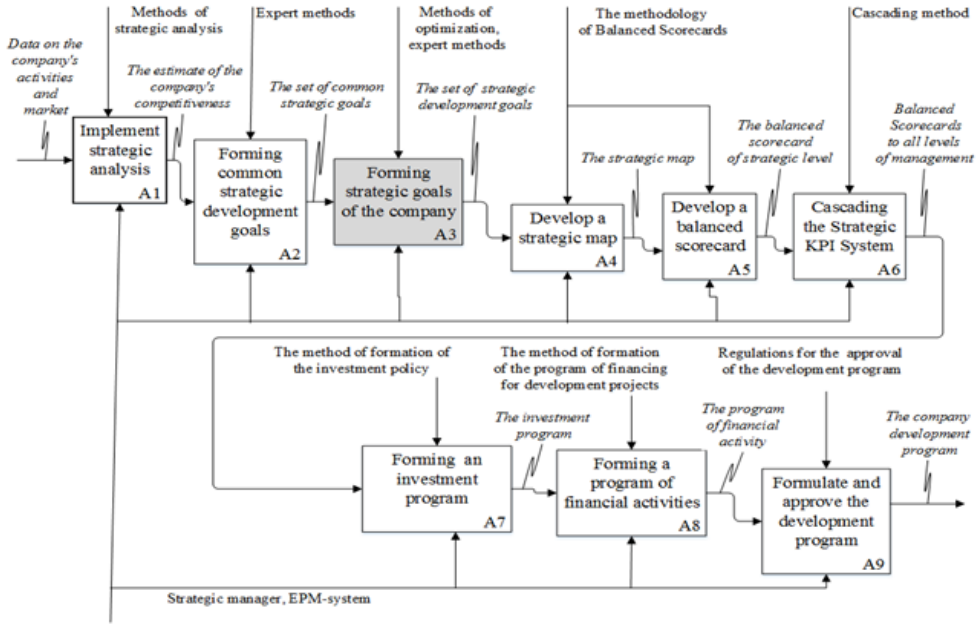


Figure 1: The business process of working out for development programs

Consider the components of this process.

A1. Conducting strategic analysis. As a result, priority directions of the company's development are determined.

A2. Forming of many common strategic development goals. The most promising goals are selected from the point of view of the success of the company's development from the all-permissible goals. Various expert methods are used for this including the hierarchy analysis method [17]. The indicator for the success of development is determined by the implementation of an iterative procedure that includes the direct and reverse processes of the hierarchy analysis method.

A3. Forming of strategic development goals for the company. To do this, it is necessary to analyze the overall objectives on the degree of their achievement under the existing and forecasted conditions of the company's operation. The procedure is described in detail below. Many goals are formed as a result which ensure the effectiveness of the company's operation in the strategic period.

A4. Constructing of a strategic map. The selected strategic goals are decomposed into goals for the future: finance, clients, business processes, personnel [9].

A5. Constructing the system of balanced indicators, which reflects the company's planned performance indicators at the strategic level [9, 10]

A6. Cascading the system of strategic KPI [8, 16]. The strategic KPIs are decomposed into KPI business processes and KPIs of the relevant structural divisions of the company. The planned annual

values of all KPIs are determined in the intervals of the strategic period. Cascading is carried out to the budget indicators. As a result, the KPI system will be formed at all levels of management.

A7. Development of a program of investment activities. The investment funds are defined to allocate on internal development projects and on external investment within the framework of investment activities of the company. The investment policy of the company is preliminarily determined. The following is formed within the framework of this policy:

- the portfolio of investment projects for the development of the company;
- the portfolio of investments (real and financial) for external investment activities.

A8. Development of a program for financial activities. The schemes of financing development projects and projects of external investment activity are developed. The sources of funding for the development program are selected.

A9. Forming of the development program as a system of company plans, plans of all structural divisions and strategic budgets. The reconciliation and approval of them is carried out in accordance to the regulations adopted at the company.

The result of this process is a strategic development program that includes:

- strategic goals and strategies for achieving them;
- the planned values of KPI's strategic performance indicators for the years of the strategic period;
- the planned values of the primary KPI indicators for the years of the strategic period;
- strategic budgets of the company and its divisions.

This process is an iterative process: each procedure has work to solve a number of issues related to the analysis, development and coordination of decisions. It is possible to return to the previous step after each procedure if it is impossible to obtain satisfactory results.

3.2. The process of forming strategic goals for the company

In the works of the authors, a method of forming strategic goals is proposed as the basis of the strategic planning module in the Enterprise Performance Management System [2].

The business process is presented in Figure 2, as the decomposition of procedure A.3 – "Forming of strategic development goals for the company".

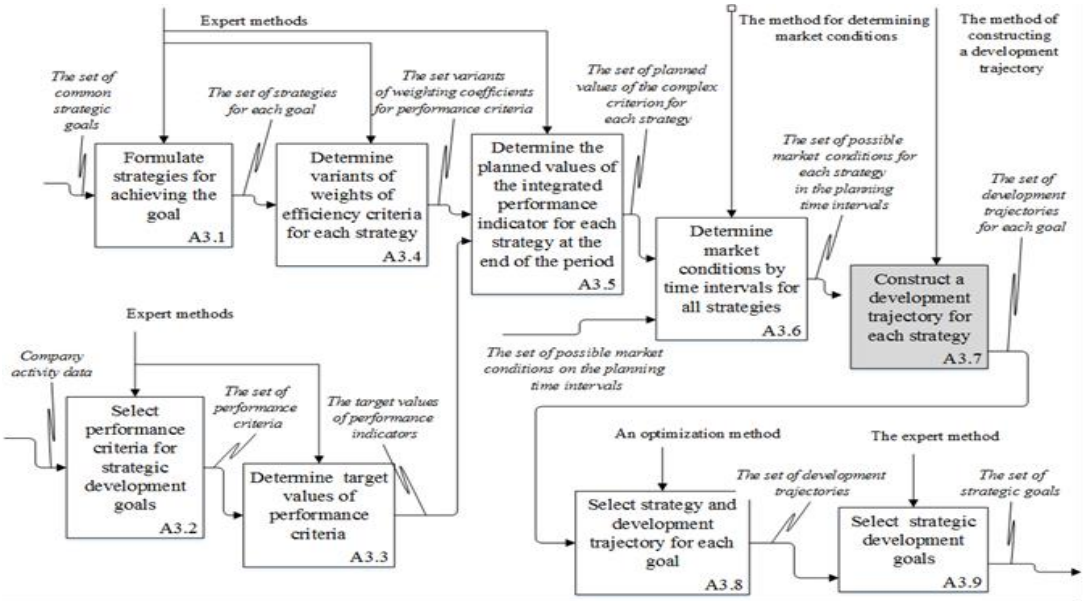


Figure 2: Business process of forming strategic goals for the company

Let's consider the idea of this process. The effectiveness of achieving each strategic goal is characterized by some complex criterion. This criterion is obtained as a result of aggregation of local efficiency criteria. It is possible to use different strategies to achieve the planned values of performance

indicators at the end of the planning period. A set of acceptable strategies for achieving certain goal is formed for each goal.

It is suggested to construct an acceptable company development path for each strategy in order to choose the strategy that is most effective for achieving the certain goal. These trajectories are a set of market conditions in which an enterprise can be located. The several trajectories are constructed for each strategy. This is due to the fact that each strategy can be implemented in different ways. Sets of possible market conditions are formed preliminary on the basis of forecasts. Each trajectory is a set of optimal transitions from one market state to another. As a result, each strategy will have its own set of trajectories.

The trajectory is chosen from the set for every strategy in such way that implementation of this trajectory will allow the enterprise to achieve planned performance indicators in the best way. All goals and corresponding development trajectories are analyzed. Those goals that best match the opportunities and predictable market conditions are chosen

3.3. Method of constructing a development trajectory for a given strategy to achieve a strategic goal

This method is used to implement procedure A3.7 (Figure 2). Assume that the strategic planning period contains T intervals.

Consider the space of variables Φ, which characterizes the market state of the company. Φ consists of subspaces in the intervals of the planning period: $\Phi = \{\Phi_t\}$, $t = \overline{0,T}$. Possible market states are generated in accordance to the intervals of the planning period which are determined by some variables.

Possible or permissible market conditions are formed on the basis of forecasts of market conditions and resource capabilities of the company.

Market segment can be chosen as a market condition that is characterized by the volume of sales, the average market price of products and other parameters.

For simplicity, consideration is given to the case when the company produces one kind of product.

Let's designate $\chi_t = \{\chi^l\}_t$, $l = \overline{1,L}$ as a vector of the variables defining a market condition of the company on *t*-th interval, $t = \overline{1,T}$, L is number of state variables. All possible states over the intervals of the planning period generate sets P_t, $\mathrm{P}_t \subset \Phi_t$, $t = \overline{1,T}$.

Values of state variables are defined for all market states from set P_t.

Let's define $\overline{\chi}_t^s = \{\overline{\chi}_t^{s1}, \overline{\chi}_t^{s2}, \ldots \overline{\chi}_t^{sL}\}$, $s = \overline{1,S}$ as vector of values for variables that describe s-th states, S is number of the market conditions for the company.

Then $\mathrm{P}_t = \{\overline{\chi}_t^1, \overline{\chi}_t^2, \ldots \overline{\chi}_t^S\}$. At the beginning of planning the initial market condition of the company is described by the vector of initial values for variables $\chi_0 = \{\overline{\chi}_0^1\} = \{\overline{\chi}_0^{11}, \overline{\chi}_0^{12}, \ldots, \overline{\chi}_0^{1L}\}$.

Assume that company at each interval can be in only one market condition.

Let the company make "transition" from state $\chi_{t-1} \in \mathrm{P}_{t-1}$ to state $\chi_t \in \mathrm{P}_t$, which is associated with certain benefits as well as costs. Let's designate $F_t(\chi_t, \chi_{t-1})$ as company's efficiency indicator at the t-th interval which is defined by market condition χ_t on current interval and χ_{t-1} on previous one. This indicator is calculated as follows.

Let the company's position in a certain market condition be determined by the performance indicator which can be denoted as $f_t(\chi_t)$ and the costs associated with the transition from state χ_{t-1} to state χ_t will be denoted as $h_t(\chi_t, \chi_{t-1})$.

The efficiency indicator will be calculated for each possible market condition as follows:

$$F_t(\chi_t, \chi_{t-1}) = f_t(\chi_t) + h_t(\chi_t, \chi_{t-1}).$$

Since $F_t(\chi_t, \chi_{t-1})$ characterizes the qualitative transition of a company from one market condition on (*t–1)*-th interval to another state on the *t*-th interval then the efficiency of all transitions in the planned period will be determined by the criterion:

$$F = \sum_{t=1}^{T} F_t(\chi_t, \chi_{t-1}).$$

The choice of a company's market condition implies qualitative changes in its functioning and, as a consequence, a change in the values of its performance indicators. Therefore, we can talk about the solution of the development task at the planning period. The issue can be formulated as follows. Define such market conditions of the company $\chi_t^* \in \mathrm{P}_t$, $t = \overline{1,T}$, so that the criterion of total efficiency of the company reaches its maximum value:

$$F(\chi^*) = \underset{\{\chi_t\}}{opt} \{ \sum_{t=1}^{T} F_t(\chi_t, \chi_{t-1}) \} \quad (1)$$

under constraints

$$\chi_t \in \mathrm{P}_t,\ \mathrm{P}_t \subset \Phi_t,\ t = \overline{1,T},\ \chi_0 = \{\overline{\chi}_0^1\} = \{\overline{\chi}_0^{11}, \overline{\chi}_0^{12}, ..., \overline{\chi}_0^{1L}\} \quad (2)$$

Thus, the issue is reduced to constructing a development trajectory on the basis of optimal transitions from one state to another along the intervals of the planned period. This issue can be solved by the sequential analysis of options method [18]. Graphical interpretation of the solution is shown in Figure 3.

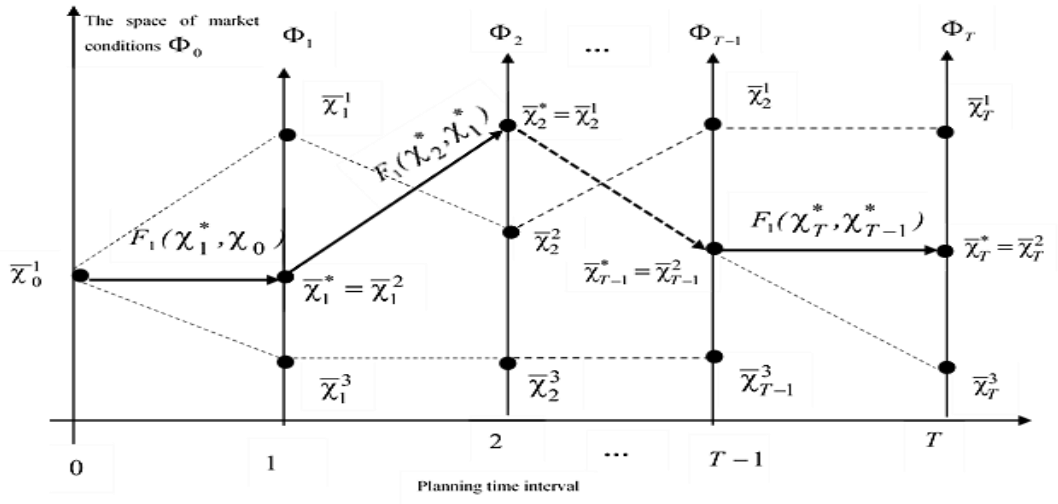


Figure 3: Possible "routes" of the company's transition from one market condition to another over the intervals of the planning period

In the subspace Φ_t, $t = \overline{0,T}$, the set of possible market conditions of the company is determined $\mathrm{P}_t \subset \Phi_t$. Points (ie. states) χ_{t-1} and χ_t, $t = \overline{0,T}$ are connected by line segments. All line segments which join the points of the sets P_0, P_1, …, P_T, form a set of polygonal lines.

Then it is necessary to define such polygonal line among all admissible polygonal lines which join $\mathrm{P}_0 = \{\overline{\chi}_0^1\}$ and $\mathrm{P}_T = \{\overline{\chi}_T^1, \overline{\chi}_T^2, .. \overline{\chi}_T^S\}$, that has minimal length. As the length of the line segment (χ_{t-1}, χ_t) the value of the efficiency function is considered $F_t(\chi_t, \chi_{t-1})$ and the length of the polygonal line is the total efficiency *F* of finding the company in market conditions over the planning period.

Then the optimal polygonal line will represent the transitions from one market condition χ_{t-1}^* to another χ_t^* and its length will be equal to:

$$F(\chi^*) = \underset{\chi}{opt}\ F(\chi) = F_1(\chi_1^*, \chi_0) + F_2(\chi_2^*, \chi_1^*) + ... + F_T(\chi_{T-1}^*, \chi_T^*).$$

Consider the algorithm for solving issue (1)–(2). We will use the idea of one of the sequential analysis of options algorithms (the "Kiev broom" algorithm that is applied to additive criteria [18]).

The idea of this algorithm is as follows.

The set of admissible solutions of issue (1)–(2) is reduced by excluding at each interval from this set those solutions about which we can say in advance that they will not enter to the optimal trajectory.

Let's define by Ω an admissible set of solutions for issue (1)–(2). This is the set of all possible options for transitions from the initial state of the company $\overline{\chi}_0^1$ to market conditions $\chi_T \in \mathrm{P}_T$.

Let's $H(\chi_t)$ be the value of the total efficiency of the optimal transitions from state $\overline{\chi}_0^1$ to state $\chi_t \in \mathrm{P}_t$. This value is defined as follows.

In the interval t=1 the transition to the state $\chi_1 \in \mathrm{P}_1$ takes place only from one initial state $\overline{\chi}_0^1$. Therefore, the total efficiency for each state χ_1 is defined as follows:

$$H(\chi_1) = F_1(\chi_1, \chi_0).$$

The set of admissible solutions Ω does not change.

In the interval t=2 the total efficiency of the optimal transitions from state $\overline{\chi}_0^1$ to state $\chi_2 \in \mathrm{P}_2$ will be determined as follows:

$$H(\chi_2) = \underset{\chi_1 \in P_1}{opt}\{H(\chi_1) + F_2(\chi_2, \chi_1)\} \quad (3)$$

Thus, to each state $\chi_2 \in \mathrm{P}_2$ will be put in line with the optimal value of the total efficiency $H(\chi_2)$. Those variants of admissible solutions that are not a solution of issue (3) are excluded from the set Ω Let's these variants form a set which can be designated by ω_1. Then all admissible solutions of the issue on the second interval form a set which can be denoted as Ω_2:

$$\Omega_2 = \Omega \setminus \omega_1.$$

Then the value of the total efficiency $H(\chi_t)$ is defined by induction on any t-th interval as follows:

$$H(\chi_t) = \underset{\chi_{t-1} \in P_{t-1}}{opt}\{H(\chi_{t-1}) + F_t(\chi_t, \chi_{t-1})\} \quad (4)$$

The set of all admissible solutions that contains variants of transitions that are not a solution of issue (4) will be denoted by ω_{t-1}.

Then the admissible solutions of the issue on the t-th interval form a set Ω_t:

$$\Omega_t = \Omega \setminus \omega_1 \setminus \omega_2 \setminus \ldots \setminus \omega_{t-1}, \; t = 3, \ldots, T.$$

The values $H(\chi_T)$ and the set of admissible solutions Ω_T will be determined on the interval T. Then issue (5) is solved and as a result the trajectory of the company's optimal transitions is determined from the initial state $\overline{\chi}_0^1$ to the state $\overline{\chi}_T^* \in \mathrm{P}_T$ over the intervals of the planned period.

$$H^* = H(\overline{\chi}_T^*) = \underset{\chi_T \in P_T}{opt}\{H(\chi_T)\} \quad (5)$$

Thus, this trajectory will correspond to the optimal market conditions for company over the intervals of the planning period $\overline{\chi}_t^* \in \mathrm{P}_t$, $t = \overline{1,T}$.

This process is implemented for all admissible strategies of the strategic objectives under consideration. Set of acceptable development trajectories will be constructed as a result of each goal.

Further, the decision-maker (DM) chooses the trajectory for the goal with maximum efficiency which will correspond to the options for achieving it. DM chooses the goals that are most preferable and maximally realizable for the company based on the comparison of efficiency, the necessary investments for the implementation of the trajectory and the analysis of the company's capabilities.

Further, the stages of the development program (Figure 1) will be implemented on the basis of these goals and their respective development trajectories.

3.4. The procedure for forecasting possible market conditions

The formation of a set for market conditions of the market based on the solution of the classification and forecasting problem is proposed to be carried out.

The decomposition of the procedure for predicting possible market conditions as part of the business process for determining market conditions on intervals of a strategic period is shown in Figure 4.

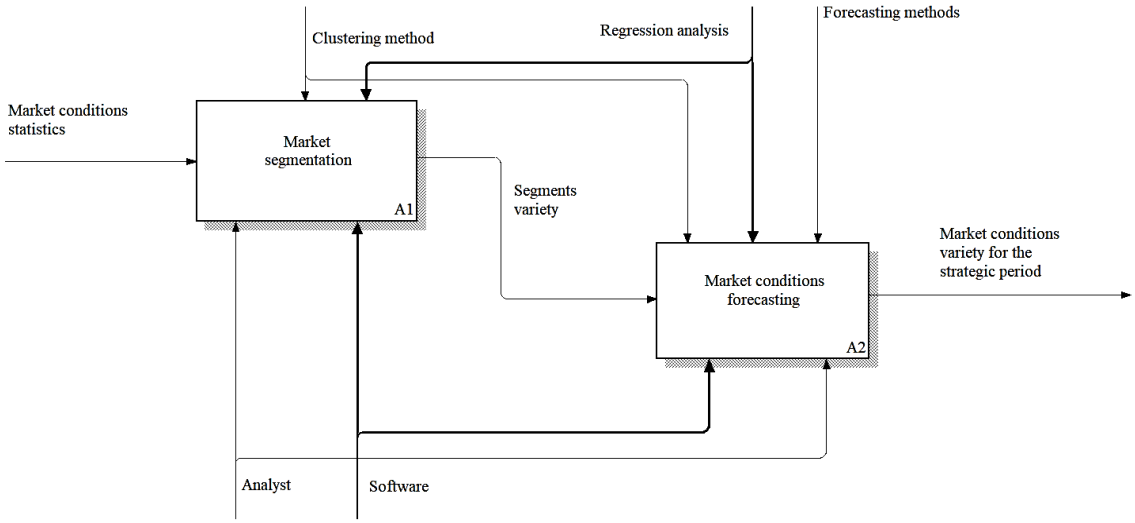


Figure 4: Decomposition of the procedure for forecasting possible market conditions

The method of forecasting market states in the strategic period was implemented using a neural network with the Temporal Fusion Transformer architecture [14]. TFT is used canonical components to efficiently build feature representations for each input type for high forecasting performance. The training of the neural network was carried out on the basis of statistical data. Forecasting is based on neural networks. It was proposed to use a neural network with the Temporal Fusion Transformer architecture. TFT an attention-based DNN (Deep neural networks) architecture for multi-horizon forecasting that enabling new forms of interpretability.

To obtain significant performance improvements it is introduced:

- static covariate encoders which encode context vectors for use in other parts of the network;
- gating mechanisms throughout and sample-dependent variable selection to minimize the contributions of irrelevant inputs;
- a sequence-to-sequence layer to locally process known and observed inputs;
- a temporal self-attention decoder to learn any long-term dependencies present within the dataset.

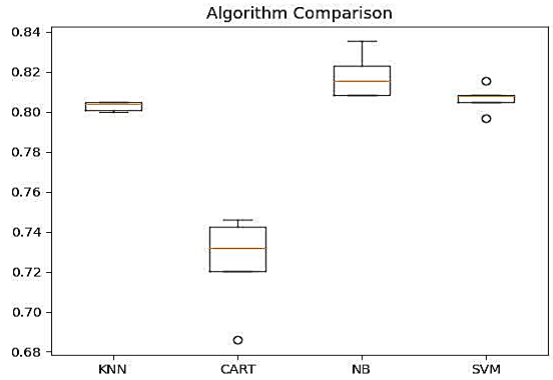
TFT enables three valuable interpretabilities use cases helping users identify globally-important variables for the prediction problem, persistent temporal patterns, and significant events.

To solve the problem of market segmentation, classification methods were considered: k-Nearest Neighbor (k-NN), Decision Tree CART, Naive Bayes (NB), Support Vector Machine (SVM) [19]. Each of the classification methods showed different efficacy and accuracy based on the kind of datasets. There are various evaluation metrics for comparing the classification methods that each of them could be useful depending on the kind of the problem.

As an example, the classification of the IT services market in Ukraine was carried out according to the data for 2019. As an example, the classification of the IT services market in Ukraine was carried out according to the data for 2019. On figure 5, it is shown comparison of classification methods results: k-Nearest Neighbor (k-NN), Decision Tree CART, Naive Bayes (NB), Support Vector Machine (SVM), which were applied to task of Ukrainian IT-service market segmentation. Results of classification precision were shown for k-NN – 0.803; for CART – 0.725, for NB – 0.818, for SVM – 0.807. Errors as standard deviation Are represented for each method: k-NN – 0.002; for CART – 0.0217, for NB – 0.01, for SVM – 0.006. According to received data, the conclusion was made that the best

method from precision perspective is NB. At the present time, research on the choice of classification methods for different types of Ukrainian commodity markets is being carried out by the authors of the article.

The market segmentation process includes the following procedures. Experts analyze statistical data and prepare them for further processing. Correlation and regression analysis is carried out to identify the dependence of the segmentation criteria. The market is segmented by the selected classification method based on the selected criteria.

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KNN: 0.802762 (0.001976)
CART: 0.725279 (0.021678)
NB: 0.818114 (0.010132)
SVM: 0.806608 (0.005986)
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Figure 5: An assessment of classification methods

The decomposition of the market segmentation procedure is shown on Figure 6.

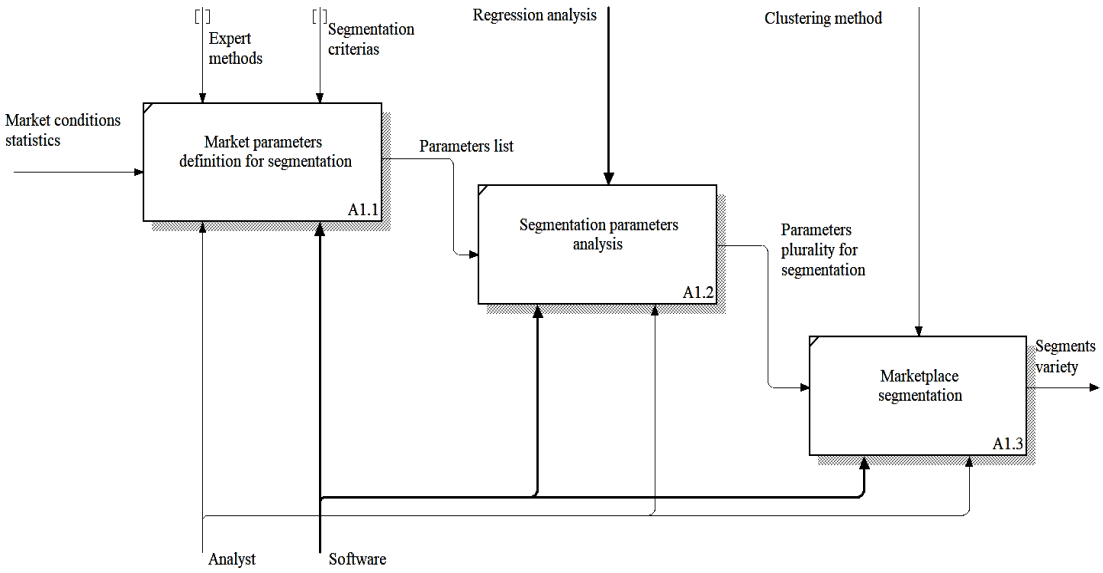

Figure 6: The decomposition of the market segmentation procedure

After market segmentation according to the current data, the market is forecast by intervals of the strategic period as follows. Forecasts of parameters that characterize the criteria for market segmentation are determined. For forecasting, it is proposed to use a neural network with TFT architecture. The analysis of the predicted values of the market parameters is carried out, the dependent data is determined and the criteria for market segmentation are determined. Further, the markets are segmented by intervals of the strategic period using the selected classification method. Decomposition of the procedure for forecasting market segments at intervals of a strategic period is shown in Figure 7.

Thus, predicted market conditions as possible company positions on intervals of the planning period are determined based on predicted values of market parameters and solving the segmentation problem.

The segmentation problem is formulated as a classification problem and is implemented by one of the Machine learning methods.

4. Conclusion and Future Work

The difficulties of decision-making at strategic level are related to the gathering and processing of a large amount of diverse information as well as the solving of complex tasks.

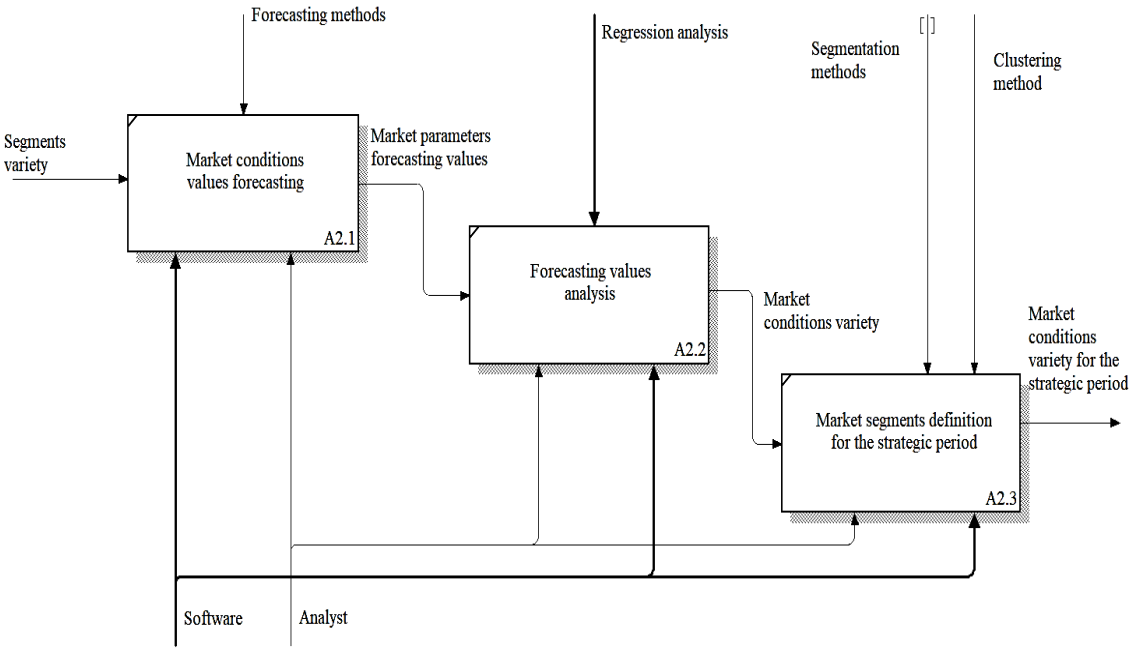

Figure 7: Decomposition of the procedure for forecasting market segments at intervals of a strategic period

To solve complex of strategic management tasks, companies use the business efficiency management system - Enterprise Performance Management. In this article, the strategic planning subsystem is considered as part of the EPM system.

The description of the developed business process for forming strategic goals of the company is considered.

The method is proposed for selecting a strategy for realizing the company's goals which is based on the idea of a sequential analysis of options. The company's development trajectories are constructed for each strategy for a given goal as a result of this method. This method allows the company to analyze its capabilities and capabilities of the market and use this information to choose those strategies, the implementation of which will grant not only achieve strategic goals but also effectiveness for a long-term period.

Each point of development trajectory will correspond to market positions that the company must have at strategic intervals in order to achieve the strategic goal. Possible market conditions (company positions) at intervals of the planning period are determined on the basis of predicted values of market parameters and solving the segmentation problem. The segmentation problem is formulated as a classification problem and is implemented by one of the Machine learning methods. Forecasting is based on neural networks. It is proposed to use a neural network with the Temporal Fusion Transformer architecture.

The future study will focus on:

1. Analysis and selection of computational intelligence methods for predicting market conditions depending on existing market data and of factors of influence on the market;
2. Using of fuzzy neural networks to solve the problem of determining the market conditions on the strategic period;
3. Improving the method of market classification based on the use of machine learning methods;
4. Development of a subsystem of EPM system for choosing development strategy of a company using methods of computational intelligence and classical decision-making theory;
5. Analysis and selection of Data mining methods for the formation of initial data for solving problems of classification and forecasting of market conditions.

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