The technology of short-term planning for resolving the problems with high level of uncertainty on an enterprise

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Abstract. The problem of short-term planning in the face of uncertainty is considered. The major tasks of planning on an enterprise are highlighted. The functional scheme of the planning process in the form of an IDEF0-diagram has been developed. The step-by-step solution of the planning task is proposed: data forecasting, estimation of possible risks, estimation of forecast data based on risks. An analytical review of short-term forecasting methods is conducted. Using of Brown and Wade models to determine the next values of time series has been proposed. A model for assessing possible risks based on the use of a matrix of criteria important to the company has been developed. The process of estimating forecast data based on the possible risks using the developed technology has been improved. The conducted experiments confirmed the importance of the proposed technology of short-term planning in the face of uncertainty and allow to recommend it for a practical use.

Keywords: Short-Term Planning, Adaptive Forecasting Methods, Risk Assessment, Brown Model and Wade Model, Forecast Data Estimation.

1 Introduction

The success of any business depends on the well-defined mission and objectives of the company. The platform for the implementation of the mission is a professional business plan of the enterprise. The business plan is a document that presents an analysis of internal and external environments, analysis of possible risks and problems, development of strategic goals, forecasting the state of the market, forecasting own economic indicators, forecasting and developing measures leading to profit [1, 2]. Therefore, forecasting is a decision-making key moment in management planning of the enterprise, because it reduces risk in decision-making, forecasts uncontrolled aspects of the sequence of events that follow the decision and makes the best choice for the enterprise. There are many different forecasting methods, which can be used for planning tasks depending on the goals and objectives that the company's managers face with. For instance: long-term forecasting methods are used for development the strategic business plan of the company; short-term methods can be useful for solving current problems. Management of enterprises is faced with issues of short-term planning quite often. For example: to make a production plan, to develop a turnover plan,

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to plan work for the month, to forecast costs, to plan resources, etc. Therefore, it makes sense to use such forecasting methods that provide the required accuracy in solving of short-term planning tasks, thereby reducing uncertainty in decision-making. The choice of forecasting method is also influenced by the form of forecast, forecasting horizon, data availability, method complexity, availability of resources. Today, there are two main approaches to solving forecasting problems: expert methods and methods that use mathematical apparatus [3, 4]. Expert methods require highly qualified specialists with knowledge and experience in the cases when it is impossible to obtain direct information about the process, and it is necessary to conduct a logical analysis of the problem with quantification of judgments. But mostly, short-term forecasting tasks operate by specific numbers, so it is appropriate to use mathematical methods of decision making. A negative point is that using of such methods requires more resources than expert judgment. However, it also increases the accuracy of the forecast and reduces the losses associated with uncertainty of decision-making. The decision-making process based on forecast data is associated with a series of events that may have a positive or negative impact. That is, the decisions are made in the face of uncertainty, so there is a task of risk assessment. Therefore, the task of the short-term forecasting and further assessment of the obtained data based on possible risks is important and essential today. It helps to increase the efficiency of managerial decision-making processes for planning the development of the enterprise.

Thus, the purpose of this work is to develop short-term planning technology to solve the problems with high level of uncertainty on an enterprise.

2 Problem statement

The short-term planning task consists of two stages:

- to solve the forecasting task of the data obtained as a result of analysis of a certain business process for the given planning horizon;
- to assess the uncertainty in planning decisions.

The formalization of the forecasting problem can be represented as follows. Let the time series $x_1, x_2, ..., x_t$ is a data of the analysis of the certain business process, that x_t is a member of this series observed at the moment t. Then the forecasting task is to find the following elements $x_{t+\tau}\ (\tau = \overline{1,n})$ of the time series, that describes the behavior of the particular business process, where τ – the forecast planning horizon.

To reduce uncertainty, it is necessary to identify a list of events that influence planning decisions. Let $K = \{k_1, ...k_m\}$ is a set of events associated with a particular business process. Then the problem of estimating uncertainty is the identification of the function $Uncertainty = f(k_1, ...k_m)$ of the set of events, where $Uncertainty$ is the quantitative measure of uncertainty in the selected units of measurement.

To solve the short-term planning problem, it is necessary to:

- develop a model for solving the short-term planning task;
- choose a short-term forecasting method;

- suggest a method for assessing of possible risks of the short-term planning task;
- develop a model for assessing of forecasting results based on possible risks.

3 Literature review

The management in each company chooses how to resolve the planning problem in the face of uncertainty depending on the current situation, on the allocated resources, on the required accuracy. For some enterprises, it is enough to predict data for a specific business process. Others need not only a numerical forecast, but also an assessment of possible risks. Today, companies often assess risks using expert methods, and a short-term forecast is conducted using different mathematical approaches. Let's consider the most effective forecasting methods in more details. There are many different methods: autoregressive models, fuzzy logic, artificial neural networks, regression models, exponential smoothing models.

Autoregressive forecasting models are widely used in practice [5-9]. They are based on the assumption that a value of the time series linearly depends on a number of previous values of the series. The order of the autoregressive equation is equal to the number of used retrospective observations. This approach also can be used for identifying trends, seasonality, and other features. The most commonly used models are the autoregressive model, the moving average model, the autoregressive moving average, the autoregression integrated moving average extended, the generalized autoregressive conditional heteroscedasticity, and the autoregression distributed lag model. The advantages of using of these models include the speed of obtaining results, the availability of intermediate calculations, and the relative simplicity of the models. The disadvantages are the complexity of determining the parameters of the model, the possibility of modeling only linear processes, the inability to use them for mixed input data.

The fuzzy logic can be used to solve short-term forecasting tasks for two problem statements: single time series and multiple time series [5, 7, 10-11]. In both cases, it is necessary to create a fuzzy base of production rules in the form of "If…, then…". In the first case for the time series $x_1, x_2, ..., x_t$ the rules have the following form: $x_1 \to x_2; x_2 \to x_3; ...; x_{t-1} \to x_t;$ for the second case the base has rules: $f(x_i, y_i, z_i ...) \to output_i$, $i = \overline{1,t}$, where $x_i, y_i, z_i ...$ is the value of the i-th input variables. The fuzzy inference mechanism allows to calculate the predicted value on the basis of the proposed set of rules. The advantage of this approach is the possibility to formalize mixed inputs, because each variable, regardless of the type of data, can be represented by linguistic variables, which are the basis for creating a database of rules. The disadvantage of using fuzzy logic for the forecasting task is the limitation of the outputs domain.

The technology of artificial neural networks is widely used for prediction problems [6, 8, 12-13]. The input data can be a single time series, and there can be several variables with mixed nature. The parameters of the selected network architecture are recalculated when new information arrives. It is a feature of an adaptation to the external environment. Other advantages of this approach are: generalization – the network

response after training can be insensitive according to small changes in input signals, and abstraction – the network can be trained to generate what it has never seen. The disadvantages of this approach are the complexity of calculations, the large training template, the problem of choosing a network architecture and training method, and the complexity of software implementation.

The practice of using regression analysis shows that it can be used for short-term data prediction [14-16]. The basis of this method is the hypothesis that the complex dependencies between the input data can be approximately linear due to the small prediction interval. Therefore, the linear regression equation adequately describes the subject area and gives good forecasts. There are the following issues of using regression analysis: the selection of input data, the verification of the correlation between input variables, and model identification. The advantages are simple calculations, linearity of the model and a good interpretation of the results. Limitations of using this approach are the sensitivity to outliers and forecasting for several time series.

Time series trend analysis and short-term forecasting are often performed using exponential smoothing methods or adaptive forecasting methods [17-18]. Empirical studies had showed that simple exponential smoothing very often gives a fairly accurate prediction [19-22]. This method allows to take into account the obsolescence of data. Depending on the objectives of the forecast and the availability of information, different exponential models can be used. For example, the Brown model and the Wade model make it possible to make a forecast for a series without a trend, the Holt model is needed to determine the trend, the Holt-Winters model also allows to take into account the seasonality of the series. The advantages of using of these models are: simplicity of calculations, the array of past information is reduced to one value, the ability to predict on one time series, the heterogeneity of time series is reflected in the adaptive evolution of the model parameters. The disadvantage is that they are used only when the environment is relatively stable.

The conducted analytical review of mathematical methods and features of the subject area allows to choose adaptive forecasting methods to solve the problem of short-term forecasting in the face of high level of uncertainty.

4 Materials and methods

The short-term planning task in the face of uncertainty is a complex task. The main purpose of resolving of this problem is to ensure the effective functioning and development of the company. A model for solving this task can be represented as a functional model in IDEF0 notation, which allows to describe business processes in the domain area (Fig. 1).

The short-term planning task consists of several parts:

- Determine forecast data: determination of forecast data for the considered business process;
- Determine possible risks: analysis and assessment of possible risks that may affect decision-making related to this business process;
- Assess forecasted result: adjustment of forecast values based on possible risks.

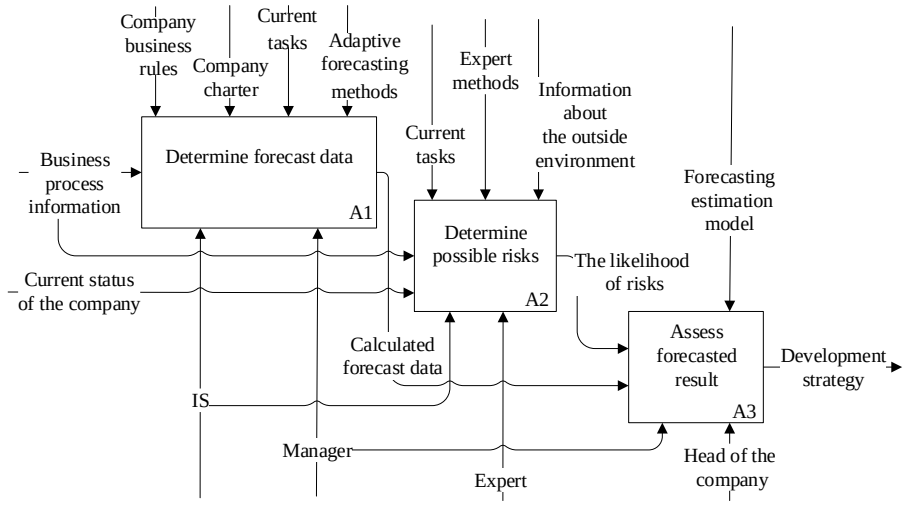

Fig. 1. The model of solving the short-term planning task

The solution of the first task is as follows. Firstly, manager should analyze the business process, which a specific task is formulated for. Secondly, he should build a time series. The results of the analysis will allow to determine a forecasting model that is more suitable for the current business process. For example, if the time series describes the business process without a trend, then manager should use the Brown model or the Wade model, and if a seasonal trend is observed, then the Holt-Winters model is more suitable [17, 18, 23].

Making decisions in the face of high level of uncertainty means choosing a solution when the probability of an outcome is unknown. To reduce uncertainty, it is necessary to solve the problem of risk identification. It consists in determination of the list of events or risks that are associated with the considered business process, and then assessing them quantitatively by expert methods that are used in this company. For example, the probability of occurrence of risks can be estimated on a certain scale, or with the method of pairwise comparisons, or with the method of analysis of hierarchies, etc. [24].

The task of estimation of the forecast data is to evaluate the time series based on the available information: the forecast results and assessments of possible risks. The resulting assessment is the basis for making managerial decisions for the current tasks of the enterprise and for management planning of the enterprise as a whole.

On the basis of the foregoing discussion, it is possible to present the technology of short-term planning for resolving the problems with high level of uncertainty on the enterprise in the form of a decomposed functional model (Fig. 2). The components A11, A12, A13 describe the resolving of the short-term forecasting task. The functions A21 and A22 represent the activity for assessing possible risks of the short-term planning task. The blocks A31 and A32 characterize the forecasting estimation task based on the obtained results from previous issues.

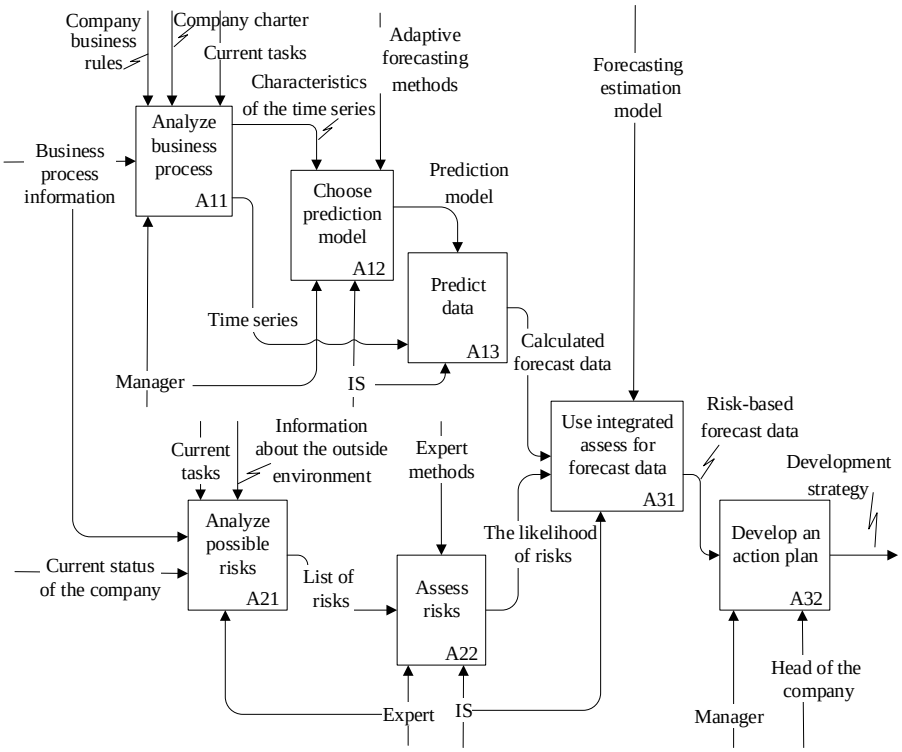

Fig. 2. The technology of short-term planning in the face of high level of uncertainty

Let's consider the aforementioned tasks in more detail way.

The analytical review of forecasting methods allows to choose adaptive forecasting methods for solving **the short-term forecasting task**. The main idea of these methods is the following: the element x_{t+1} of the time series $x_1, x_2, ..., x_t$ can be calculated by the hypothesis that researched business process is a n-th parabola, and the forecast for τ steps forward is expressed by the decomposition of the process into a Taylor series, where $a_i\ (i = \overline{1, n+1})$ – unknown coefficients:

$$x_{t+1}(\tau) = a_1 + a_2\tau + \frac{1}{2!}a_3\tau^2 + ... + \frac{1}{n!}a_{n+1}\tau^n. \quad (1)$$

The polynomial adaptive model (1) in the Braun's model has the $n = 2$ order:

$$x_t = a_{1,0} + a_{2,0}t + \frac{1}{2}a_{3,0}t^2, \quad (2)$$

where the indexes of $a_{i,j}$: i – number of the coefficient (in this case $i = \overline{1,3}$), j – number of the iteration ($j = \overline{0,t}$, t – number of observations).

The algorithm of using of the Braun's model is the following.

Step 1. Assign initial values:

- for the coefficients $a_{i,0}\,(i=\overline{1,3})$ of the adaptive polynomial model;
- for the smoothing parameter α in the range from zero to one. High values of α give more weight to the latest observations, if $\alpha=1$, then previous observations are completely ignored, lower values give weight to older observations, and if $\alpha=0$, then current observations are ignored;
- for the forecast horizon τ.

Step 2. Calculate $\beta=1-\alpha$.

Step 3. Calculate the initial conditions for exponential smoothing:

$$S_0^{[1]}=a_{1,0}-\frac{\beta}{\alpha}a_{2,0}+\frac{\beta(2-\alpha)}{2\alpha^2}a_{3,0},$$

$$S_0^{[2]}=a_{1,0}-\frac{2\beta}{\alpha}a_{2,0}+\frac{\beta(3-2\alpha)}{\alpha^2}a_{3,0}, \qquad (3)$$

$$S_0^{[3]}=a_{1,0}-\frac{3\beta}{\alpha}a_{2,0}+\frac{3\beta(4-3\alpha)}{2\alpha^2}a_{3,0}.$$

Step 4. Iterative calculation of the exponential averages. The number of iterations is equal to the number of observations $t=\overline{1,T}$:

$$S_t^{[1]}=\alpha x_t+\beta S_{t-1}^{[1]};\ S_t^{[2]}=\alpha S_t^{[1]}+\beta S_{t-1}^{[2]};\ S_t^{[3]}=\alpha S_t^{[2]}+\beta S_{t-1}^{[3]}. \qquad (4)$$

Step 5. Calculate coefficients of the adaptive polynomial model (2):

$$a_{1,T}=3S_T^{[1]}-3S_T^{[2]}+S_T^{[3]},$$

$$a_{2,T}=\frac{\alpha}{2\beta^2}\left[(6-5\alpha)S_T^{[1]}-2(5-4\alpha)S_T^{[2]}+(4-3\alpha)S_T^{[3]}\right], \qquad (5)$$

$$a_{3,T}=\frac{\alpha^2}{\beta^2}\left[S_T^{[1]}-2S_T^{[2]}+S_T^{[3]}\right].$$

Step 6. Calculate the forecast data according to the forecast horizon $j=\overline{1,\tau}$:

$$x_{T+j}=a_{1,T}+a_{2,T}j+\frac{1}{2}a_{3,T}j^2. \qquad (6)$$

If the expert has doubts about determining the initial values of the coefficients $a_{i,0}\,(i=\overline{1,3})$ of the adaptive polynomial model and the smoothing parameter α, then it is necessary to use the Wade model, which is a modification of the Brown model.

The initial values in the Wade's model are calculated in another way:

$$S_0^{[i]} = \alpha S'^{[i]}_0, (i = \overline{1,3}), \tag{7}$$

where $S'^{[i]}_0$ are the initial conditions for exponential smoothing calculated by (3).

The exponential averages for the Wade model are calculated as follows:

$$S_t^{[1]} = \frac{\alpha x_t + \beta S_{t-1}^{[1]}}{\alpha + \alpha\beta},\ S_t^{[2]} = \frac{\alpha S_t^{[1]} + \beta S_{t-1}^{[2]}}{\alpha + \alpha\beta}, S_t^{[3]} = \frac{\alpha S_t^{[2]} + \beta S_{t-1}^{[3]}}{\alpha + \alpha\beta}. \tag{8}$$

The activity diagram of the resolving of the task of short-term forecasting based on the Brown or Wade models is presented on Fig. 3.

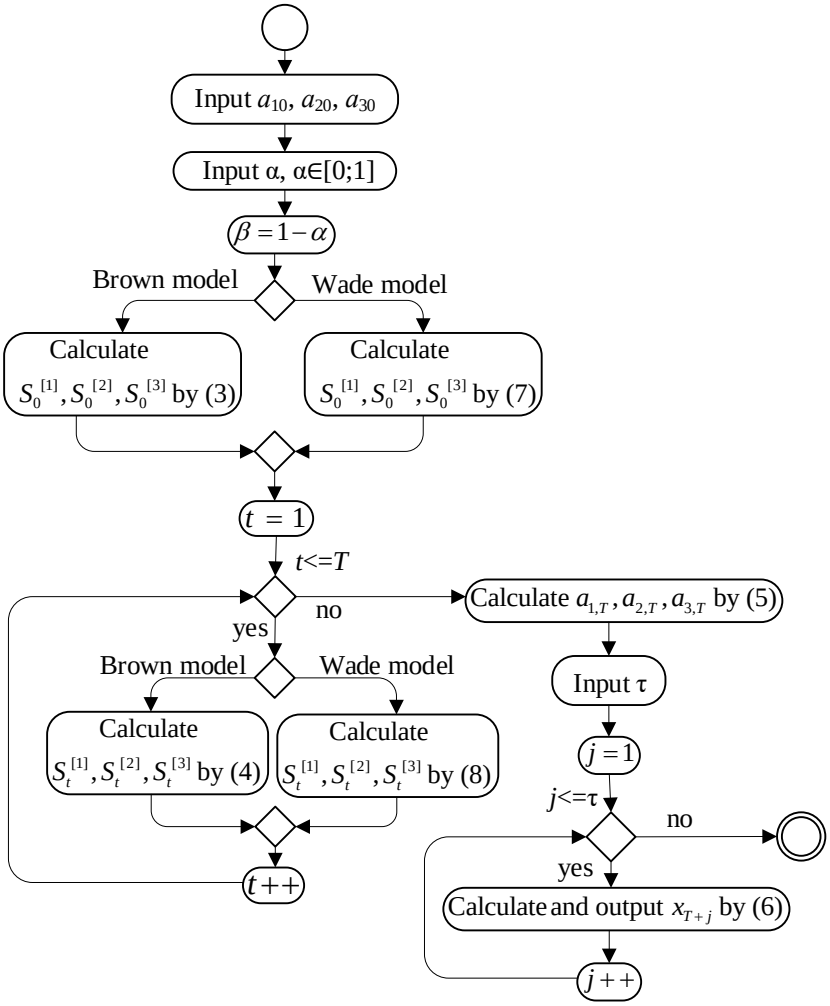

Fig. 3. Forecasting method activity diagram

Consider **the risk assessment task** in more detail. When manager analyzes the particular business process, she has to determine a list of events or risks that may affect the short-term planning, and then she should evaluate them. There are different risks. It could be negative (damage, loss), zero and positive (benefit, profit). For instance, budget cuts or employee loss (dismissal, retirement) adversely affected company's operations, and an appreciation of the dollar can be a positive risk for evaluating a company's profit. The different expert methods can be used depending on the expert's experience and knowledge, as well as financial capabilities. Let's consider the approach to risk assessment from the [25]. It is proposed to assess risks from the point of view of the selected criteria that are important for a particular enterprise. If only one criterion is selected, then the risk evaluates by the selected scale. When it is necessary to assess two criteria, then an assessment matrix is used. If there are more than two criteria, then the evaluation can be carried out using various convolution criteria. The results are interpreted depending on the goals.

Let's consider two evaluation criteria:

- $P_k\,(k \in K)$ is a probability of occurrence of k-th event or risk, where K is a set of events, which are connected with particular business process;
- $w_k\,(k \in K)$ is a weight coefficient of the k-th event – the degree of influence of this event on the business process.

It is proposed to evaluate each criterion on a 4-point scale: $Scale = \{Low; Middle; High; Very\ high\}$, where Low is the smallest value of probability or weight, and $Very\ high$ – is the biggest one accordingly. Suppose $r_k\,(k \in K)$ is a numerical value of the k-th risk. Than r_k is determined by a matrix $R = (r_k)_{4\times 4}$ of the size $P_k \times w_k = 4 \times 4$, since a 4-point scale for evaluating criteria is selected. Each risk is interpreted as a percentage, which allows to reduce or increase the data obtained in solving the short-term forecasting problem.

Solving the short-term forecasting problem using the adaptive forecasting methods, namely, the Brown or Wade models, gives a point forecast. It is the simplest prediction because it contains the least amount of information. To solve the short-term planning task with high level of uncertainty, it is not enough to obtain a point forecast, therefore, in practice, an interval forecast is usually used. Interval forecast involves setting boundaries within which the projected value of the indicator will be. Thus, the solution of **the task of assessing forecasting results**, taking into account possible risks, can be represented as a confidence interval:

$$Confident\ interval\ for\ x_t = \left[x_t \pm Uncertainty\right] \tag{9}$$

Uncertainty is determined when solving the risk assessment task:

$$Uncertainty = \sum_{k \in K} r_k$$

This study has suggested that risks are determined as a percentage. Then formula (9) can be represented as:

$$Confident\ interval\ for\ x_t = \left[x_t \pm x_t \cdot \sum_{k \in K} r_k \right] = \left[x_t \left(1 \pm \sum_{k \in K} r_k \right) \right] \quad (10)$$

Denote K' is a set of negative risks, and K'' is a set of positive risks, in so doing $K = K' \cup K''$. Then the interval forecast (10) for the value x_{T+j} $(j = \overline{1,\tau})$ obtained by solving the short-term forecasting problem for the time series $x_1, x_2, ..., x_T$ can be represented as follows:

$$x'_{T+j} = \left[x_{T+j} \left(1 - \sum_{k \in K''} r_k \right); x_{T+j} \left(1 + \sum_{k \in K'} r_k \right) \right] \quad (11)$$

Thus, using of short-term planning technology in the face of high level of uncertainty allows to generate additional information for managerial decisions.

5 Experiments and results

Let's consider the developed technology for planning the dynamics of an IT-company. To gain a useful forecast information for decision-making according to the proposed technology, the IT-company must be stable, operate for at least 10 years on IT-market, the company must employ at least 100 people, offices must be in several countries. Any IT-company is characterized by a large number of specific parameters that reflect the various aspects of company activities. It allows to objectively assess the dynamics of company development at any time. Consider one of the main indicators that allows to assess the dynamics of growth and position of the company in the market of IT-services. It is the man-hour (m/h). It shows the amount of work done by one employee in one hour. This indicator is important for the company, because it consist of two parts. The employees can be included into the unbillable inner projects or in the billable client projects. The inner projects are an expense item. So, let's look at number of man-hour, which customers have paid. To build a forecast for the company's services, it is necessary to analyze data from the previous period. Data describe the man-hour amount of services provided by specialists, which were ordered and paid by the clients (Table 1). To produce plans for the company's development, it is necessary to obtain data for the next quarter, thus, the forecast horizon is 4 months.

Table 1. A snippet of the input data

Date	08.19	09.19	10.19	11.19	12.19	01.20	02.20	03.20	04.20
$m/h \cdot 10^3$	56,60	55,90	53,99	53,54	52,91	52,29	51,67	51,05	50,13

There are many practical studies of adaptive forecasting methods. They allow to get the recommended values of parameters that can be used to predict the number of required man-hour:

– the initial coefficients of the polynomic equation: 0.2, 0.5, 0.8;

– the smoothing parameter 0.8 (the parameter has received large value so that the effect of the initial value decreases rapidly, because there is no confidence in the validity of the initial value S_0).

Table 2 shows the results of forecasting using the Brown and Wade models.

Table 2. Results of short-term forecasting

Models	05.20	06.20	07.20	08.20
Brown model	50,103	49,900	49,220	49,206
Wade model	50,101	50,007	49,220	49,204

To form the interval forecast, it is necessary to assess the risks that are present in the formation of demand for the company's services:

- r_1 – the reduction of the company's profit. It is the main indicator for assessing the company's development for the future.
- r_2 – the increasing of the US dollar exchange rate. Today, US dollar is almost the main currency to which most companies are pegged, so market fluctuations of this currency affect the dynamics of the company.
- r_3 – the reduction of the number of active clients of the company. It allows to estimate the breadth of coverage of diverse industries in the market of IT services.
- r_4 – the reduction of the company's staff. The reasons of it may be illness (at this time it is very important in the universe), switching to another company, or the client's refusal of the project due to financial or other reasons.
- r_5 – the flexible adaptation to the current situation in the world. It includes the widespread use of IT for all business processes in the IT-company, new offers, and discounts for current customers.
- r_6 – the establishing mutually beneficial partnerships with various companies.
- r_7 – the expansion the circle of its clientele.
- r_8 – the improvement of corporate culture. It allow to increase the morale and dedication of employees.

The experts proposed the following matrix for numerical risk assessment in terms of the probability of occurrence and the degree of influence on the formation of demand for IT-services (Table 3).

Table 3. The risk assessment matrix

$r_k = f(w_k, P_k)$		P_k			
		Low	*Middle*	*High*	*Very high*
w_k	*Low*	0,005	0,01	0,015	0,02
	Middle	0,01	0,02	0,02	0,03
	High	0,025	0,025	0,03	0,04
	Very high	0,03	0,04	0,045	0,05

The following value of the reduction of the company's profit was obtained according to the evaluation matrix $r_1 = f(Middle, High) = 0,02$. Similarly, other numerical values of risks were found:

$$r_2 = 0,04; r_3 = 0,05; r_4 = 0,02; r_5 = 0,03; r_6 = 0,01; r_7 = 0,04; r_8 = 0,025.$$

Some risks are positive, others negatively affect the dynamics of growth of IT-services: $r_1, r_2, r_3, r_4 \in K''$, $r_5, r_6, r_7, r_8 \in K'$. So, the interval estimate of the predicted value of the number of man-hour can be found by (11) (Table 4).

Table 4. The assessment of the forecasting results

Models	Limit values of man-hour, $[m/h \cdot 10^3]$	Date			
		05.20	06.20	07.20	08.20
Brown model	Lower limit	43,590	43,413	42,821	42,809
	Upper limit	55,364	55,140	54,388	54,373
Wade model	Lower limit	43,588	43,506	42,821	42,807
	Upper limit	55,362	55,258	54,388	54,370

The analysis of the input and obtained data shows the tendencies of decrease in the required number of man-hour recently. It can be explained, first of all, by the epidemiological situation in the world, as well as mistakes in the management of the company, or existing problems with the staff. The obtained results can be used by project management executives and managers to develop further behavioral strategies in the IT-industry and within the company itself.

6 Conclusion

In this research work, the technology of short-term planning for resolving the problems with high level of uncertainty on an enterprise has been proposed. The functional model of the planning process has been developed, which reflected the three stages of solving the problem. The analysis of methods for predicting time series values has been performed. The comparative characteristics of these methods have allowed to choose the adaptive forecasting methods, namely the Brown and Wade models. The risk assessment model and the assessing forecasting results model have been developed. They permitted to provide additional information for planning decisions.

The scientific novelty of the obtained results is in the improvement of the process of short-term planning with the help of the proposed technology, which allows to take into account possible risks that may arise. Numerous studies have shown the possibility of using the proposed technology on enterprises to improve the efficiency of management decisions.

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