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THE APPLICATION OF THE ONE-FACTOR FORECAST FUNCTIONS OF DEPENDENCE OF THE HR-INDICATOR FROM THE TIME ON THE EXAMPLE OF MACHINE-BUILDING ENTERPRISES

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The article investigates the theoretical and practical aspects of predictive models based on the use of the analytical method of trend alignment on the example of important indicators of the functioning of enterprises of the machine-building industry. The attention is focused on the tasks, application features, advantages and disadvantages of the trend extrapolation method. The use of time is substantiated as an integral indicator of the total influence of all factorial features that determine the value of the forecast indicator. The process of adjustment of a number of dynamics by analytical method has been considered according to two stages: the choice of type and evaluation of parameters of the trend function. Predictive one-factor models are built for the number of employed workers in large, medium and small domestic machine-building enterprises. Multiple coefficient of determination is taken as a qualitative criterion for choosing a predictive model. Construction of the forecast of the most important indicators of the industry, in particular using extrapolation methods, is the basis for planning the development of the industry, the definition of scientifically substantiated judgments about the possible value of important indicators in the future period. The necessity of constructing multi-factor forecast models is indicated, which will increase the quality of the forecast for the machine building enterprises.

ЗАСТОСУВАННЯ ОДНОФАКТОРНИХ ПРОГНОЗНИХ ФУНКЦІЙ ЗАЛЕЖНОСТІ HR-ПОКАЗНИКА ВІД ЧАСУ НА ПРИКЛАДІ ПІДПРИЄМСТВ МАШИНОБУДУВАННЯ

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Ключові слова:
машинобудівне підприємство, зайняті працівники, тенденція, однофакторна прогнозна функція, прогноз, множинний коефіцієнт детермінації.

Досліджено теоретико-практичні аспекти побудови прогнозних моделей на основі використання методу аналітичного вирівнювання тренду на прикладі важливих показників функціонування підприємств машинобудівної галузі. Акцентовано увагу на завданнях, особливостях застосування, перевагах та недоліках методу екстраполяції тренду. Обґрунтовано використання часу як інтегрального показника сумарного впливу всіх факторіальних ознак, що визначають величину прогнозованого показника. Процес порівняння ряду динаміки аналітичним способом розглянуто відповідно до двох етапів: вибору типу та оцінки параметрів функції тренду. Побудовано прогнозні однофакторні моделі кількості зайнятих працівників на великих, середніх та малих вітчизняних підприємствах машинобудування. Якісним критерієм при виборі прогнозної моделі узято множинний коефіцієнт детермінації. Побудова прогнозу найважливіших показників галузі, зокрема за допомогою методів екстраполяції, є основою для планування її розвитку, визначення науково обґрунтованих суджень про можливе значення важливих показників у майбутньому періоді. Зазначено необхідність побудови багатофакторних прогнозних моделей, що підвищить якість прогнозу для підприємств машинобудування.

Statement of the problem

The prediction refers to a science-based probabilistic prediction of the paths of development of phenomena and processes for a more or less distant future. Forecasting tasks in the economy and management are very popular, because they can be used, for example, to predict future targets in the field of machine-building, in particular trends in the number of employed workers, the level of wages, labour productivity in machine-building enterprises and so on.

Currently, scientists estimate that there are more than 150 different forecasting methods. The existing sources present various classification principles of forecasting methods. One of the most common methods of short-term forecasting of economic phenomena is the method of extrapolation, in which conclusions about the value of forecast indicators in future periods are developed based on the study of their dynamics in previous periods.

Therefore, practical issues in the introduction of modern methods of forecasting acquire the relevance today in the practice of management and use of forecasts as a basis for planning the industry development, determining scientifically substantiated judgments about the possible value of important indicators of industry targets in the future period.

Analysis of recent studies and publications

In the existing scientific sources, foreign and domestic scientists have discussed in detail the topical issues of providing human resources to machine-building enterprises [1; 2], peculiarities of the personnel management of machine-building enterprises in modern economic conditions [3-6] and so on. The analysis of publications in this area indicates that more deepened study of the practical aspects of the use of modern methods of forecasting is required [7-11] for effective planning, receiving the forecasts of important economic indicators of enterprises of the machine-building industry.

Objectives of the article

The purpose of the article is to study the theoretical and practical aspects of the construction of one-factor predictive models based on the trend and the implementation of forecasting indicators of the number of employed workers in large, medium and small machine-building enterprises.

The main material of the research

In scientific-technical and economic forecasting time is usually used as the main factor-argument. It is obvious that it is not the fluidity of time that determines the magnitude of the predicted indicator, but the effect of many factors has an impact on it. However, each moment of time has certain characteristics of the set of factorial features that change with time to a greater or lesser extent. Thus, time can be considered as an integral indicator of the total influence of all factorial features [7].

Let us consider the dynamics of the indicator of the number of employed workers in machine-building enterprises for 2012-2017 and determine the dependence of this indicator on the time factor by constructing one-factor functions.

In the process of analysis of statistical data on the number of employed workers in machine-building enterprises for 2012-2017 [12], monotonous trends in the trend over the period of time were found, including in the context of the size of the enterprises (Table 1).

Table 1 – Dynamics of the number of employed workers in machine-building enterprises, thousands people

Indicator \ Years	2012	2013	2014	2015	2016	2017
Number of employed workers in large machine-building enterprises	213,2	190,8	148,1	111,0	93,4	86,7
Number of employed workers in medium-sized machine-building enterprises	270,1	258,5	239,7	226,7	226,7	237,0
Number of employed workers in small machine-building enterprises	37,5	39,5	34,5	32,7	33,5	35,1
Total number of employees in large machine-building enterprises	520,8	488,8	422,3	370,4	353,6	358,8

Note: developed by the author (State Statistics Service of Ukraine)

Thus, there is a general steady trend towards a reduction in the number of employees in domestic machine-building enterprises. In particular, the analysis of the number of employees in the context size of the enterprises indicates a downward trend in large machine-building enterprises and certain fluctuations in the dynamics of the indicator of the number of employees in small and medium-sized machine-building enterprises.

In studies of management situations, extrapolation (from lat. extra – over and polire – make smooth, trim) is applied as a forecasting method. One of the limitations in the use of extrapolation methods is that the extrapolation forecast can be obtained for a period in the time interval of not more than 1/3 of the base.

The simplicity and availability of the method make it possible to widely use it in forecasting for the near future with adjustment for other (non-forecasting parameters) factors affecting the studied process.

Disadvantages of the method are the ability to transfer the negative trends of the past into the future, as well as the inability to take into account current trends in the development of the forecasting object. To improve the efficiency of extrapolation in the analysis of the situation, it is necessary to clearly determine the parameters of the situation, quantitative indicators are projected and how they can change in the future [9, pp. 62].

The methods of predictive extrapolation include the following methods: extrapolation based on the average level of the series, extrapolation by the average absolute growth, extrapolation by the average growth rate, analytical trend alignment, exponential smoothing, moving average, adaptive smoothing, autoregressive transformation, harmonic weights [7; 10].

One-factor forecast functions are those functions in which the predicted indicator depends on only one factorial characteristic. Not only time, but also another factor can be used as an argument factor in the one-factor forecasting function, if its quantitative assessment for the future is known.

Analytical trend alignment is one of the simplest and most common forecasting methods. The trend characterizes the process of change of the indicator over a long period of time, excluding random fluctuations. The trend of the phenomenon is found by approximating the actual levels of the time series based on the selected function [7].

The process of adjusting a number of dynamics by analytical way consists of two stages: the choice of the curve type, evaluation of the curve parameters. Extrapolation of the trend can be applied only if the development of the phenomenon is well described by the constructed equation and the conditions, that determined the trend of development in the past, will not undergo significant changes in the future. When these conditions are used, extrapolation is carried out by substituting into the trend equation (1) the value of the independent variable t, which corresponds to the value of the forecast horizon.

$$y_{t+p}^{\text{pred}} = f(t_{n+p}), \quad (1)$$

where: y_{t+p}^{pred} – is the predicted value of the function;

t – an independent time variable;

n – number of observations (periods of observations in the past);

p – the value of the forecast horizon (the periods for which the forecast is made).

The trend equation can be described by a wide range of dependencies, in particular:

the trend of the indicator can be expressed using a linear equation:

$$\text{Ypred} = \text{a0} + \text{a1} * \text{t}, \quad (2)$$

where: a_0, a_1 – unknown parameters of the function;

t – the sequence number of periods or moments of time.

the tendency of the exponent can be expressed by a power polynomial, such as a quadratic equation:

$$Y_{pred} = a_0 + a_1 * t + a_2 * t^2, \quad (3)$$

where: a_0, a_1, a_2 – unknown parameters of the function;

t – the sequence number of periods or moments of time.

the trend indicator can also be found by using parabolic, exponential (exponential), exponential, logarithmic functions, combinations of linear and logarithmic functions, functions of Conusa, Tornquist function, logistic (sigmodontine), hyperbolic functions, combinations of linear functions and hyperbolas, and so on.

We consider the numerical evaluation of the unknown parameters (a_0,a_i) of the trend equations to use it as a forecasting tool.

The parameters of the trend function equation are determined using the least squares method:

$$\sum (yt - yt\ calc)2 = min, \quad (4)$$

where: y_t – the actual value of the function;

$y_{t\ calc}$ – the calculated value of the function determined on the basis of the selected equation.

For a linear equation, the dependence can be written as follows:

$$\sum (y_t - a_0 - a_1 t)^2 = min, \quad (5)$$

In equation (5), the variables y_t and t are known quantities and the parameters of the equation (a_0,a_i) are unknown quantities. After the corresponding transformations we obtain a system of normal equations for the linear trend equation have the form:

$$\begin{cases} \sum y_t = a_0 n + a_1 \sum t \\ \sum y_t t = a_0 \sum t + a_1 \sum t^2 \end{cases} \quad (6)$$

For the quadratic equation $y = a_0 + a_1 t + a_2 t^2$, the system of normal equations is as follows:

$$\begin{cases} \sum y_t = a_0 n + a_1 \sum t + a_2 \sum t^2 \\ \sum y_t t = a_0 \sum t + a_1 \sum t^2 + a_2 \sum t^3 \\ \sum y_t t^2 = a_0 \sum t^2 + a_1 \sum t^3 + a_2 \sum t^4 \end{cases} \quad (7)$$

Also, analysing the graphically visual form of the initial series of dynamics, you can choose the equation of the curve or straight line, which reflects the initial series on the chart as much as possible, then the calculation of the parameters of this equation is carried out.

To build the one-factor forecast of models the number of employed workers, we consider the dynamics of the number of employed workers in large, medium and small machine-building enterprises in 2012-2017 (Table 1).

Linear forecast model of the number of employed workers in large machine-building enterprises (according to statistics of the State Statistics Service of Ukraine):

$$y_{t1} = -27{,}48\ t + 236{,}7 \quad (8)$$

Note: developed by the author

where: y_{t1} – the number of employed workers in large machine-building enterprises, thousand people;

t – the sequence number of the study period or time points.

Linear forecast model of the number of employed workers in medium-sized machine-building enterprises (according to statistics of the State Statistics Service of Ukraine):

$$y_{t2} = -7{,}818\ t + 270{,}4 \quad (9)$$

Note: developed by the author

where: y_{t2} – the number of employed workers in medium-sized machine-building enterprises, a thousand people;

t – the sequence number of the study period or time points.

Linear forecast model of the number of employed workers in small machine-building enterprises (according to statistics of the State Statistics Service of Ukraine):

$$y_{t3} = -\ 0{,}908\ t + 38{,}64 \quad (10)$$

Note: developed by the author

where: y_{t3} – the number of employed workers in small machine-building enterprises, thousand people;

t – the sequence number of the study period.

The adequacy of the regression model is estimated on the basis of the coefficient of determination. The coefficient of determination R^2 is the proportion of variance in the dependent variable that is explained by the explanatory variables. More precisely, it is unity minus the proportion of unexplained variance (the variance of a random model error or conditional variance of a dependent variable) in the variance of the dependent variable. It is considered as a universal measure of the dependence of one random variable and many others. In the particular case of linear dependence, the coefficient of determination is the square of the so-called multiple correlation coefficient between the dependent variable and explanatory variables [8, pp. 262]. In particular, for the pair linear regression model, the coefficient of determination is equal to the square of the usual correlation coefficient between y_{ti} and t.

The values of the determination coefficients (R^2) for the constructed predictive models of the number of employed workers in large, medium and small machine-building enterprises are presented in Table 2.

Table 2 – Characteristics of forecast models

Indicator \ Forecast model	Value		
	Forecast model of the number of employed workers in large machine building enterprises (8)	forecast model of the number of employed workers in medium-sized machine building enterprises (9)	forecast model of the number of employed workers in small machine building enterprises (10)
Initial sample size (n)	6 observations	6 observations	6 observations
Multiple coefficient of determination (R^2)	0.953	0.689	0.437

Note: developed by the author

Despite the fact that some of the obtained models are not reliable enough, they, for lack of others, before the accumulation of values of longer time series, are shown in Table 2 for the purpose of comparison. Thus, the level of multiple coefficient of determination indicates that the most reliable is the forecast model of the number of employed workers in large machine-building enterprises (R^2 = 0.953), the forecast model of the number of employed workers in medium-sized machine-building enterprises has an acceptable quality (R^2 = 0.689), and the quality of the forecast model of the number of employed workers in small machine-building enterprises (R^2 = 0.437) indicates the impossibility of its use for the forecast. Therefore, we consider and construct a predictive model of the number of employed workers in small machine-building enterprises using exponential, logarithmic, power polynomial, power function of the trend (Table 3).

Table 3 – Nonlinear predictive models of the number of employed workers in small machine-building enterprises

Trend function	Type of one-factor forecast functions	Multiple coefficient of determination (R^2)
Exponential	$y = 38{,}64e^{-0{,}02t}$	0.434
Logarithmic	$y = -2{,}69\ln(t) + 38{,}42$	0.484
Polynomial	$y = 0{,}378\ t^2 - 3{,}558\ t + 42{,}18$	0.6
Power	$y = 38{,}42t^{-0{,}07}$	0.486

Note: developed by the author

Estimation of reliability of predictive models of the number of employed workers in small enterprises by the value of the multiple coefficient of determination obtained in the Table 3. It shows that the acceptable reliability has a polynomial (2-nd power) forecast model of the number of employed workers in small machine-building enterprises (R2 = 0.6). Other predictive models of the number of employed workers in small machine-building enterprises are based on the exponential, logarithmic and power functions of the trend, taking into account the value of the multiple coefficient of determination (R2 < 0.5), there is such their quality that it is not recommended to use them for forecasting.

To calculate the estimated (smoothed) and forecast values for 2018, the obtained trend equations should be substituted with the ordinal number of the period for which the forecast is made.

Substituting the sequence number of the period, which will be implemented by the forecast (t=7) in linear predictive model (8) we calculate that in 2018, the projected number of employed workers at the large machine-building enterprises will be 44.34 thousand persons. Substituting the sequence number of the period, which will be implemented by the forecast (t=7) in linear predictive model (9) we calculate that in 2018, the projected number of employed workers at medium-sized machine-building enterprises will be 215.674 thousand persons. Substituting the sequence number of the period for which the forecast will be made (t=7) in the polynomial forecast model (Table 3) we expect that in 2018 the projected number of employees at medium-sized machine-building enterprises will be 35.796 thousand. Thus, the forecast data on the number of employed workers in large, medium and small machine-building enterprises are shown in Table 4.

Table 4 – Results of forecasting the number of employed workers in machine-building enterprises, thousand people

The forecast year	Number of employed workers in large machine-building enterprises	Number of employed workers in medium-sized machine-building enterprises	Number of employed workers in small machine-building enterprises
2018	44.34	215.674	35,796

Note: developed by the author

So, according to Table 4, we can conclude that in 2018 it is expected to reduce the number of workers in large and medium-sized machine-building enterprises, due to the negative trend in the number of employed workers during 2012-2017 and the unsatisfactory state of the machine-building industry as a whole. The forecast of the number of employed workers in small machine-building enterprises is more optimistic in 2018, a slight increase in the number of employed workers by 696 people is expected.

Conclusion

The article deals with the use of modern methods of forecasting, in particular, the practical aspects of forecasting the number of employed workers in the machine-building industry on the basis of the method of analytical alignment.

In the constructed one-factor predictive models of the number of employed workers in large, medium and small machine-building enterprises the time has been used as the main factor the argument. The fluidity of time has been considered as an integral indicator of the total influence of all factorial features that determine the value of the predicted indicator. To assess the quality and determine the accuracy of the forecast, the coefficient of multiple coefficient of determination has been used. Thus, from the above calculations of the multiple coefficient of determination, it is clearly shown that the proposed linear models to predict the number of employed workers in large and medium-sized machine-building enterprises have a sufficiently high reliability of the forecast, and the most appropriate model to predict the number of employed workers in small machine-building enterprises is a model based on the polynomial trend function.

To improve the quality of the forecast, it is important to take into account the influence of external and internal factors on the studied HR-indicators for the enterprises of the machine-building industry, so the prospect of further research is the construction of multifactor forecast models.

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