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PERSONNEL MANAGEMENT ON THE BASIS OF SYSTEM-PARAMETRIC MODELLING

ABSTRACT

The purpose of the article is to use system-parametric modelling in personnel management processes to ensure its effectiveness. To achieve the specified goal, the following methods were used: a systematic approach - to determine the place and role of personnel management in the company's activities; theories of production systems, operations research - when determining the essence of personnel management from the standpoint of the theory of production systems; the deduction method - for the formation of recommendations regarding management decisions regarding personnel; mathematical modelling - for the development of a personnel management model. As a result of the study, the solution to the problem of the effectiveness of personnel management was further developed. On the basis of system-parametric modelling, multi-level personnel management is defined and analyzed. A methodological approach to mathematical modelling of personnel management is proposed, which, unlike the existing ones, takes into account indicators of changes in the functioning of the enterprise based on management decisions. This contributes to the identification of some disturbance in the economic component in the form of a management decision regarding the functioning of the enterprise. The obtained analytical dependencies, as a result of system-parametric modelling, and their application allow for better decisions in the personnel management of the enterprise. The competence approach is analyzed as a new paradigm in personnel management. It has been proven that multi-stage management is unstable and causes a catastrophic increase in production fluctuations. Single-stage personnel management will ensure the stability of production operations.

Keywords: personnel management, mathematical model, parameters, enterprise, structure, competencies

JEL Classification: C19, D29

INTRODUCTION

In modern conditions, issues of personnel management, especially related to production, are becoming more and more relevant. Personnel management, as a type of activity, has undergone certain stages of evolution. The development of modern society has brought the application of the definition of "personnel" to a new level. The latest approaches to the definition of the concept of "personnel" emphasize "... the personality of each employee...". In this sense, personnel management is studied as a social phenomenon, the role of the individual in the production process (Hluschenko, L., Piliavoz, T. & Koval', N., 2022).

Modern rates of production development require every individual employee to demonstrate his professional experience and personal intellectual abilities. Personnel is identified as an economic resource, which is a factor of production and capital of the enterprise. Accordingly, the issue of management of the production resource in the sense of the personnel of the enterprise arises. It is advisable to use a scientific approach to make balanced, objective management decisions regarding personnel. The use of mathematical models and quantitative methods of decision-making with the use of modern means of information technology allows the manager to successfully solve the relevant tasks in the field of personnel management, taking into account factors that can positively affect production results.

In contrast to all other types of resources used at the enterprise, human beings have important features. In general, this type of resource differs from others (financial, material, raw materials, etc.) in that they are "living resources" which are characterized by consciousness and the results of their use are probabilistic. This means that it is difficult to estimate in advance what the return will be from each individual or working group. In general, the unpredictability of the results and the difficulty of formalization are related to the fact that the behaviour of subjects depends on a significant number of various factors. Common among them, the following can be distinguished: social, economic, political, and psychological. Therefore, the success of personnel management depends primarily on the professionalism and knowledge of the personnel manager, as well as personal qualities.

Personnel manager is a fairly young profession. It was born at the end of the last century. The appearance of specialists who had training in the field of industrial sociology and psychology meant a revolution in the direction of work with personnel. The appearance of personnel management as a specialized staff activity in the system of modern management is connected with the formation of personnel management, which gradually integrates and transforms the established forms of personnel work. An important stage of this process was the assimilation of the system approach, the development of various models of the organization as a system - not only the one that functions but also the one that develops - on the basis of which a new approach in personnel.

LITERATURE REVIEW

The concept of personnel management has recently received considerable attention. The authors Gavrish O.A., Dovgan L.E., Kreydich I.M., and Semenchenko N.V. studied modern technologies of team formation. The issue of team building and appropriate technologies in the application of the development of human resources of the enterprise is covered. Peculiarities of the use of management personnel are considered. The authors systematized scientific approaches to the differentiation of human resource management. Proposed approaches to the formation of competency models of managers of domestic enterprises (Havrysh, O. A., Dovhan, L. Ye., Krejdych, I. M. & Semenchenko, N. V., 2017). Authors' collectives Bezpalko O.V., Grynyuk Y.V.M., Gryshchenko D.G. and others in scientific research emphasize the relevance of the problem of the appointment of personnel management and theoretical and practical aspects.

Modern approaches to personnel management of the organization to ensure its effective development are disclosed and substantiated (*Upravlinnia personalom i ekonomika pratsi: teoriia ta praktyka: monohrafiia* / O. V. Bezpalko, Yu. M. Hryniuk, D. H. Hryshchenko ta inshi / za zah. red. d.e.n., prof. O. I. Drahan., 2014). The basic research was presented by scientists in a scientific study under the leadership of H.G. Savinoi H.G., which summarizes the foreign and domestic experience of human resources management. Peculiarities of humanization and democratization of labour are studied. Personnel management as a social system is presented (*Upravlinnia personalom v umovakh znanniovoi ekonomiky: kolektyvna monohrafiia / pid red. d.e.n., profesora H.H. Savinoi., 2019*), the research of scientists Brych V., Borysiak O., Bilous L., Halysh N. deserves attention. The result, presented in the scientific publication, is devoted to the theoretical and methodological foundations of the transformation of the personnel management system of enterprises and the application of innovative technologies when Wheel management decisions regarding personnel. Diversification in the personnel management system of enterprises has been studied. The formation of the company's personnel is considered an optimization process of personnel management. An optimization approach to the technologies of personnel formation of enterprises is proposed. It is emphasized that "the development of Internet technologies, computer systems, as well as new requirements for personnel management, led to the need for the formation of multifunctional personnel management services in organizations" (Brych, V., Borysiak, O., Bilous, L. & Halysh, N., 2020). The author N.P. Hutsulyak investigates the development of modern personnel management technologies. Emphasis is placed on the need to apply modern management technologies to personnel management. The enterprise development strategy is considered inextricably linked with the integral enterprise development strategy (Hutsuliak, N.P., 2019).

Personnel management becomes especially problematic in modern conditions of state development. The indicated problems were revealed by the authors Sinytsina Yu.P. and Shportko G.Yu. The authors investigated and conducted a comparative analysis of the effectiveness of personnel evaluation methods at industrial enterprises. Ways to improve personnel evaluation are identified. Scientists used correlation regression analysis to determine the influence of the age category of employees on the volume of products sold. In addition, the authors link personnel management with the competitiveness of the enterprise (Sinytsyna, Yu.P. & Shport'ko, H.Yu., 2022). Solovyov A.I. and Ushkarenko Yu.V. investigated the main properties inherent in the personnel management of large corporations. Scientists thoroughly revealed the content of the philosophy of the personnel management system. It is emphasized that "In modern conditions, a clear hierarchy is formed in large companies: a corporate management system, an important subsystem of which is a personnel management system...". Attention is focused on the need for appropriate methodical support. The lack of such provision leads to the

destruction of the integrity of the management system (Solovjov, A.I. & Ushkarenko, Yu.V., 2024). It is natural that the personnel management process involves the definition of the relevant functions. Kharitonenko S.V. and Reshetnyk N.I. have researched such functions in personnel management; they offer the personnel technologies they have developed. The peculiarity of personal technology is that people are the object of their influence. Such a feature involves taking into account psychological and social factors. It is proposed that the experience of personnel technology be used in the corporate training of personnel (Kharitonenko, S.V. & Reshetnyk, N.I., 2018). The application of mathematical methods in evaluating the effectiveness of personnel management is gaining special relevance in the modern economic dimension. For example, Solovyova, A. D. and Tsesliv, O. V. propose to evaluate the effectiveness of personnel work depending on institutional measures of influence. The authors determine the appropriate analytical dependence for solving the problem of calculating the efficiency of personnel work (Solovjova, A. D, & Tsesliv, O. V., 2022).

One of the main components of the personnel management system is the motivation of labour activity. Research of this component is devoted to the research of Azarova A. O. and Kovalchuk O. A. The scientists analyzed the shortcomings of existing approaches to the management of motivation at the enterprise. The authors singled out the basic categories of motivations, proposed mathematical models of motivation management, as well as the motivational process (Azarova, A. O. & Koval'chuk, O. A., 2014).

The problem of personnel management becomes especially relevant in modern conditions, namely in the conditions of martial law. Chornodid I.S., Vasylets N.M., and Petrenko V.M. summarize the main theoretical approaches to personnel management and form their vision of solving the problem of adaptation to the new realities of the modern state. An analysis of the influence of martial law on the quality of management was carried out. The authors proposed practical recommendations for personnel management in the modern conditions of Ukraine (Chornodid, I. S. & Vasylets', N. M. & Petrenko, V. M., 2022). The competence approach can be considered a new paradigm in the direction of personnel management research. It is difficult to overestimate the role of competencies in conditions of external and internal disturbances in the functioning of the enterprise. As noted by the author Synychenko A. V. "...the competence approach describes not so much human knowledge and skills as a model of professional behaviour..." (Synychenko, A.V. (2016). Scientist L.E. Dovgan explained in detail the role of competencies in enterprise development. Formed a model where he combined the personnel management system with the strategic goals of the enterprise using definitions of competencies (Dovhan' & Perminova, 2011).

Without belittling the importance of scientific developments in the field of personnel management, we note that mathematical modelling in the field of effective personnel management is fragmented. After all, it is important not only to organize everything correctly but also to be able to model the relevant processes of personnel management with the help of a mathematical apparatus in order to ensure the appropriate production process. The manager, on whom the further development of the enterprise depends, cannot rely solely on his life experience; he must possess professional knowledge and various techniques and methods of successful enterprise management. Thus, the relevance of the specified problem - the application of mathematical methods and models based on the system-parametric approach in personnel management processes has not lost its relevance.

Analyzing the review of recent studies and publications, we can conclude that despite their breadth and depth, not enough attention is paid to the application of mathematical methods and models in personnel management. This especially applies to the implementation of adequate parametric mathematical models.

AIMS AND OBJECTIVES

Develop and adapt system-parametric models for personnel management processes. Analyzing the developed models to show non-obviousness. To prove the rationality of the use of system-parametric methods in solving personnel management tasks, in contrast to management methods based on life experience.

METHODS

The modern approach to enterprise personnel management is based on the convergence of management and information technologies.

It seems appropriate to consider how, from an economic point of view, the changes made in the operation of the enterprise through managerial decisions regarding personnel management affect. Let the functioning of the enterprise be characterized by a mathematical model presented in the form of a differential equation (Martylenko, O. V. & Mischenko, I. V., 2019).

$$\frac{dn}{dt} = f(n), \quad (1)$$

where the n -economic component is represented by the volume of products produced.

Let us consider the introduction of some perturbation related to personnel into the economic component \tilde{n} in the form of a management decision regarding personnel in the operation of the enterprise. Then, the mathematical model (1) will be written in the form:

$$\frac{d\tilde{n}}{dt} = f(\tilde{n}). \quad (2)$$

Deviations caused by the relevant management decision regarding personnel will be recorded as the difference (2) and (1):

$$\frac{d\tilde{n}}{dt} - \frac{dn}{dt} = f(\tilde{n}) - f(n). \quad (3)$$

Taking into account the small value of the deviations, it is possible to write down to infinitesimal precision of the second order of smallness:

$$f(\tilde{n}) - f(n) \approx f'(n) \cdot \Delta n + \frac{1}{2} f''(n) \cdot \Delta n^2, \quad (4)$$

where $\Delta n = \tilde{n} - n$.

Then, taking into account (4), formula (3) will take the form:

$$\frac{d(\Delta n)}{dt} \approx f'(n) \cdot \Delta n + \frac{1}{2} f''(n) \cdot \Delta n^2. \quad (5)$$

In the future, to simplify research, we will adopt the notation:

$$f'(n) = a, \quad -\frac{1}{2} f''(n) = b, \quad \Delta n = x \quad (6)$$

With calculation (6), the differential equation (5) will take the form

$$\frac{dx}{dt} = a \cdot x - b \cdot x^2. \quad (7)$$

Equation (7) describes a "soft" logistic mathematical model [Chornous, H. O. (2014)]. Let's find a solution to the differential equation (7). Equation (7) is a first-order differential equation with separable variables [Ohirko, I. V., Yasins'kyj, M. F. & Yasins'ka-Damri, L. M. (2015)]. Therefore, to find its solution, it is necessary to divide the variables:

$$\frac{dx}{a \cdot x - b \cdot x^2} = dt \quad (8)$$

Next, we integrate both parts of equation (8):

$$\int \frac{dx}{a \cdot x - b \cdot x^2} = \int dt \quad (9)$$

For integration, we will carry out successive transformations:

$$\int \frac{dx}{\left(x - \frac{a}{2b}\right)^2 - \left(\frac{a}{2b}\right)^2} \quad (10)$$

We will use the tabular integral (Yarmosh, O. V. (2015):

$$\int \frac{dx}{x^2 - a^2} = \frac{1}{2a} \ln \left| \frac{x-a}{x+a} \right| + C. \quad (11)$$

Considering (11), the integral in equation (10) takes the form:

$$\int \frac{dx}{\left(x - \frac{a}{z \cdot b}\right)^2 - \left(\frac{a}{z \cdot b}\right)^2} = \frac{b}{a} \ln \left| \frac{x - \frac{a}{z \cdot b}}{x} \right| + C. \quad (12)$$

Taking into account (12), equation (10) will be written in the form:

$$\frac{b}{a} \ln \left| \frac{x - \frac{a}{z \cdot b}}{x} \right| = -b \cdot t + C. \quad (13)$$

To find the explicit dependence of the function, we will successively transform the formula (13):

$$\ln \left| \frac{x - \frac{a}{z \cdot b}}{x} \right| = \frac{a}{b} (C - b \cdot t), \quad \left| x - \frac{a}{z \cdot b} \right| = x \cdot e^{\frac{a}{b}(C - b \cdot t)}, \quad \frac{a}{z \cdot b} - x = x \cdot e^{\frac{a}{b}(C - b \cdot t)}, \quad \text{if } \frac{a}{z \cdot b} > x, \quad (14)$$

$$x - \frac{a}{z \cdot b} = x \cdot e^{\frac{a}{b}(C - b \cdot t)} \quad \text{if } \frac{a}{z \cdot b} \leq x. \quad (15)$$

Then, according to (14), we have:

$$\frac{a}{z \cdot b} = x(1 + e^{\frac{a}{b}(C - b \cdot t)}), \quad x = \frac{a}{z \cdot b} \frac{1}{1 + e^{\frac{a}{b}(C - b \cdot t)}}. \quad (16)$$

In turn, according to (15), we have:

$$\frac{a}{z \cdot b} = x(1 - e^{\frac{a}{b}(C - b \cdot t)}), \quad x = \frac{a}{z \cdot b} \frac{1}{1 - e^{\frac{a}{b}(C - b \cdot t)}}. \quad (17)$$

Combining (16) and (17), we obtain a general expression:

$$x = \begin{cases} \frac{a}{z \cdot b} \frac{1}{1 + e^{\frac{a}{b}(C - b \cdot t)}}, & \text{якщо } x < \frac{a}{z \cdot b} \\ \frac{a}{z \cdot b} \frac{1}{1 - e^{\frac{a}{b}(C - b \cdot t)}}, & \text{якщо } x \geq \frac{a}{z \cdot b} \end{cases} \quad (18)$$

To find the constant C, which is included in formula (18), it is necessary to use the initial condition, that is, to solve the Cauchy problem.

In the first case, when $x < \frac{a}{z \cdot b}$, e set:

$$x(t = 0) = 0.1 \frac{a}{z \cdot b} \quad (19)$$

Such problem (19) is connected with the fact that uncertainty appears at $x(t = 0) = 0$.

Substitute condition (19) into the upper formula of expression (18):

$$0.1 \cdot \frac{a}{z \cdot b} = \frac{a}{z \cdot b} \frac{1}{1 + e^{\frac{a}{b}C}}, \quad 0.1 = \frac{1}{1 + e^{\frac{a}{b}C}}, \quad 1 + e^{\frac{a}{b}C} = 10, \quad e^{\frac{a}{b}C} = 9, \quad \frac{a}{z \cdot b} \cdot C = \ln 9,$$

$$C = \frac{b}{a} \ln 9. \quad (20)$$

By substituting (20) into the upper formula of expression (18), we consistently obtain:

$$x = \frac{a}{z \cdot b} \frac{1}{1 + e^{\frac{b}{a} \ln 9 (1 - bt)}}, \quad x = \frac{a}{z \cdot b} \frac{1}{1 + e^{\ln 9 (1 - bt)}}, \quad x = \frac{a}{z \cdot b} \frac{1}{1 + 9e^{-at}} \quad (21)$$

In the second case, when $x \geq \frac{a}{b}$, we ask:

$$x(t = 0) = 1.5 \frac{a}{b} \quad (22)$$

Substitute condition (22) into the lower formula of expression (18):

$$1.5 \cdot \frac{a}{b} = \frac{a}{b} \frac{1}{1 - e^{\frac{a}{b} C}}, \quad 1.5 = \frac{1}{1 - e^{\frac{a}{b} C}}, \quad 1 - e^{\frac{a}{b} C} = \frac{2}{3}, \quad e^{\frac{a}{b} C} = \frac{1}{3}, \quad \frac{a}{b} \cdot C = -\ln 3, \quad C = -\frac{b}{a} \ln 3. \quad (23)$$

By substituting (23) into the lower formula of expression (18), we consistently obtain:

$$x = \frac{a}{b} \frac{1}{1 - e^{\frac{a}{b}(-\frac{b}{a} \ln 3 - b t)}}, \quad x = \frac{a}{b} \frac{1}{1 - e^{(-\ln 3 - a t)}}, \quad x = \frac{a}{b} \frac{3}{3 - e^{-a t}} \quad (24)$$

Combining formulas (21) and (24), we obtain a general expression taking into account the initial conditions (19) and (22).

$$x = \begin{cases} \frac{a}{b} \frac{1}{1 + 9e^{-a t}}, & \text{ЯКЩО } x < \frac{a}{b}, \\ \frac{a}{b} \frac{3}{3 - e^{-a t}}, & \text{ЯКЩО } x \geq \frac{a}{b} \end{cases} \quad (25)$$

Figure 1 shows graphs of function (25). The analysis of the given graphs shows that they asymptotically approach point A. The model assumes that over time, a stationary mode A is established, which is stable: if it is greater, then the value decreases; if it is smaller, then the value increases.

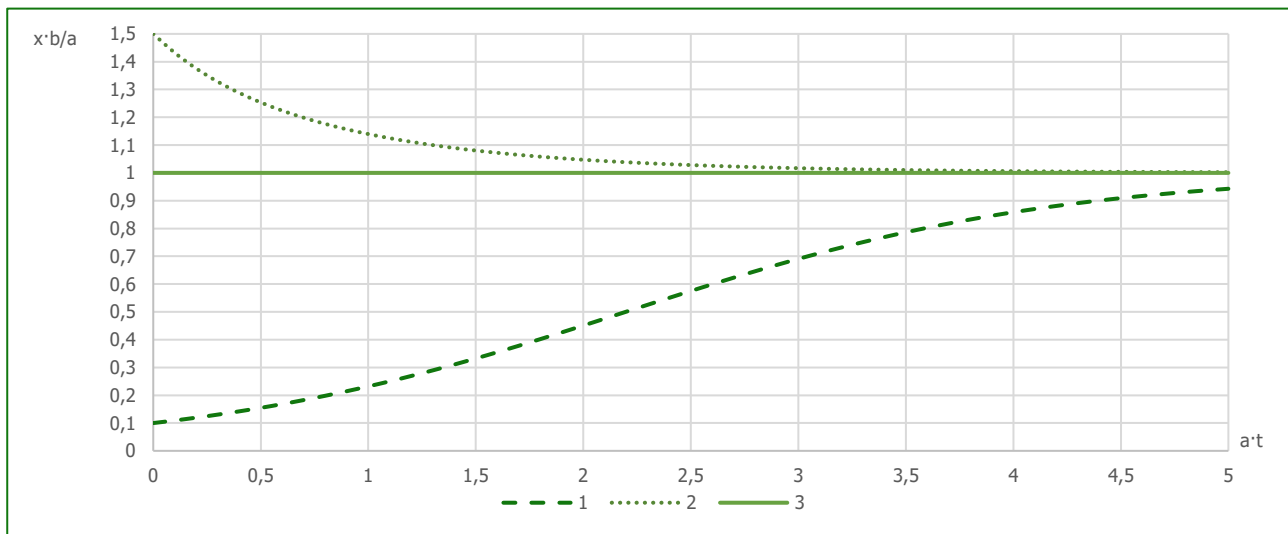


Figure 1. Graphs of the logistic model (25) (1- upper formula (25), 2- lower formula (25), 3- stationary mode $x=a/b$).

Thus, it can be concluded that when making managerial decisions regarding the company's personnel, it is necessary to take into account the nature of dependence (1), which is expressed through parameters a and b.

For the interpretation of parameters, a and b in the process of personnel management and the corresponding mechanisms, the following characteristic is essential - the structure of personnel management is determined according to the hierarchical principle. That is, the personnel management system is a multi-level set of subsystems with limited independence of the lower level. In the personnel management system, the main dimensions of the subsystems should be controlled, and individual components of the system or subsystems should be given some autonomy in choosing decisions. Note that system-wide and proprietary constraints should be considered (Chornous, H. O. (2014)). An elemental component of the management system is the personnel carrying out the activity, the subject of management. The entity embodies management decision-making. Such decisions cannot be formalized through management functions. They accumulate an elementary cycle of the management process. The behaviour of active elements of systems-subjects is determined to a certain extent by the mechanism of enterprise functioning.

The obtained logistic model (25) describes the phenomenon of saturation, which is observed during the synthesis of the studied mathematical model. The process of saturation means the need to make management decisions in the realm of personnel management.

Thus, it can be concluded that when making managerial decisions regarding the company's personnel, it is necessary to take into account the nature of dependence (1), which is expressed through parameters a and b .

The situation during personnel management changes dramatically if a constant value is added to the formula (1). That is, dependence (1) will be written in the form:

$$\frac{dn}{dt} = f(n) + d, \tag{26}$$

where d is a constant value.

Let's consider the introduction of some disturbance $\tilde{}$ in the economic component in the form of a management decision, such as a change in the level of competence of personnel in the performance of professional duties in the functioning of the enterprise. Then, the mathematical model (26) will be written in the form:

$$\frac{d\tilde{n}}{dt} = f(\tilde{n}) + \tilde{d}. \tag{27}$$

The deviations caused by the management decision regarding personnel will be written as the difference (27) and (26)

$$\frac{d\tilde{n}}{dt} - \frac{dn}{dt} = f(\tilde{n}) - f(n) + \tilde{d} - d. \tag{28}$$

Using appropriate analytical transformations, we can obtain the following dependence:

$$\frac{dx}{dt} = ax - bx^2 - c. \tag{29}$$

Differential equation (29) allows to model such a phenomenon as a catastrophe. Catastrophe is sudden changes that occur as a sudden response of the system to a smooth change in external conditions. For example, an established stable economic regime usually perishes when faced with an unstable regime. That is, changes in ill-considered managerial decisions regarding personnel management can negatively affect the functioning of the enterprise.

The enterprise is a centralized system. It contains a control center, the main functions of which are: forming planned tasks and issuing them to subsystems; accounting, control and evaluation of the results of execution of planned tasks by subsystems; making decisions and providing management actions, ensuring the stability of the implementation of plans.

That is, changes in ill-considered management decisions in the personnel management system can negatively affect the functioning of the enterprise in general.

To solve the differential equation (29), we use the method of separation of variables, writing it in the form:

$$\frac{dx}{ax - bx^2 - c} = dt. \tag{30}$$

Then, we integrate this equality:

$$\int \frac{dx}{x^2 - \frac{a}{b}x + \frac{c}{b}} = -b \int dt \tag{31}$$

According to (31), we obtain an implicit general solution of the differential equation (29)

$$\frac{1}{2\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}} \ln \left| \frac{x - \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}}{x + \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}} \right| = -b \cdot t + A \tag{32}$$

where A is an arbitrary constant

Let us transform the implicit general solution (32) so as to obtain the explicit general solution of the differential equation (29). We get consistently

$$x = \frac{\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}} \frac{1+e^{2\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}(A-b)t}}{1-e^{2\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}(A-b)t}}}{\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}} \quad (33)$$

Consider the effect of the parameter value on the character of the solution of the differential equation (30).

To find the constant value A , we will introduce the initial conditions, that is, we will consider the Cauchy problem, $x(t=t_0)=x_0$.

Then, according to (32), we find the value of A :

$$A = bt_0 + \frac{1}{2\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}} \ln \left| \frac{x_0 - \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}}{x_0 + \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}} \right| \quad (34)$$

By substituting (34) into formula (33), we determine the solution of the Cauchy problem

$$x = \frac{\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}} \frac{1+e^{2\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}b(t_0-t)} \frac{x_0 - \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}}{x_0 + \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}}}{1-e^{2\sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}b(t_0-t)} \frac{x_0 - \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}}{x_0 + \sqrt{\frac{a^2}{4b^2} - \frac{c}{b}}}} \quad (35)$$

Consider the case when the top of the parabola touches the axis Ox . For this, it is necessary to consider a system of two equations with respect to the unknowns x and c .

$$\begin{cases} ax - bx^2 - c = 0 \\ a - 2bx = 0 \end{cases} \quad (36)$$

From the second equation of system (36), we find:

$$x_0 = \frac{a}{2b} \quad (37)$$

We substitute (37) into the first equation of the system (36), which allows us to calculate the parameter:

$$c = \frac{a^2}{4b} \quad (38)$$

Point

$$B\left(\frac{a}{2b}, 0\right) \quad (39)$$

at the value of the parameter (38) will be the point of contact of the parabola of the differential equation (29). Thus, the value of the parameter (38) is optimal. At the same time, such a value of the parameter, as emphasized in [Yarmosh, O. V. (2015)], leads to the instability of the established regime determined by point (39) and further to the catastrophe - the destruction of the established regime by small random fluctuations. We can come to the disappointing conclusion that with the most rigid plan, the system loses stability and self-destructs, that is, it always leads to disasters. Therefore, it is important that those who make responsible personnel decisions are personally affected by the consequences of these decisions.

That is, the management of the enterprise establishes certain parameters, which, as a rule, are common to a group of functionally homogeneous elements (for example, prices, standards of deductions, coefficients of fines and incentives,

etc.). The main task of management, which is decided by the management, is the formation of management plans and parameters. The means of building management parameters and plans determine the law of management.

The issue related to multi-level personnel management is of some interest (Ohirko, I. V., Yasins'kyj, M. F. & Yasins'ka-Damri, L. M., 2015). Let the production of the product be managed by a manager who makes a decision about the rate of change in the level of professional competence of an employee:

$$\frac{dx}{dt} = y. \tag{40}$$

In turn, the behaviour of leader y is governed by the second-rank leader, who decides how to change the corresponding speed:

$$\frac{dy}{dt} = z. \tag{41}$$

The personnel management system is a multi-purpose system, that is, it consists of elements that make decisions and have their own local goals. The element of such a system is given the right to make decisions within the given limits and plan its profit (loss) in accordance with the goals formed by the management of the enterprise. In this way, a certain management hierarchy is formed. It is logical that the speed of decision-making depends on a person's competencies.

The behaviour of the second-rank manager is controlled by the third-rank manager, which is the last link in this chain. The last manager in our model implements feedback: his decision is not based on the desire to fulfil the superior's order (as in managers of previous ranks) but on the interests of the case. For example, he may want to reach the level of value x_0 and will influence the manager of the previous rank in a positive direction if the level of x_0 is not reached and in a negative way if it is exceeded. Again, we theorize that the personnel management system is hierarchical and monitor its rational functioning at the enterprise. Then, the mathematical model will take shape:

$$\begin{cases} \frac{dx}{dt} = y \\ \frac{dy}{dt} = z \\ \frac{dz}{dt} = -k \cdot (x - x_0) \end{cases} \quad k > 0. \tag{42}$$

The system of differential equations (42) can be rewritten as a linear differential equation of the third order:

$$\frac{d^3x}{dt^3} = -k \cdot (x - x_0). \tag{43}$$

Equations of the model (43) are easily solved in an explicit form (Yarmosh, O. V., 2015). To do this, let's present equation (43) in the form:

$$\frac{d^3x}{dt^3} + k \cdot x = k \cdot x_0. \tag{44}$$

According to the theory of finding the solution of a linear differential equation, the general solution of a linear differential equation is represented as the sum of the general solution of a homogeneous differential equation and a partial solution of an inhomogeneous differential equation, i.e.:

$$x = x_{3.o.} + X, \tag{45}$$

where: $x_{3.o.}$ – general solution of a linear homogeneous differential equation; X is a partial solution of a linear inhomogeneous differential equation.

To find the general solution of a linear homogeneous differential equation:

$$\frac{d^3x}{dt^3} + k \cdot x = 0 \tag{46}$$

The general solution of the linear homogeneous differential equation (46) will be written in the form

$$x_{3.0.} = C_1 e^{-\sqrt[3]{k} \cdot t} + C_2 e^{\frac{\sqrt[3]{k}}{2}(1+i\sqrt{3})t} + C_3 e^{\frac{\sqrt[3]{k}}{2}(1-i\sqrt{3})t}, \text{ or } x_{3.0.} = C_1 e^{-\sqrt[3]{k} \cdot t} + e^{\frac{\sqrt[3]{k}}{2}t} (C_2 e^{i\frac{\sqrt[3]{k}}{2}\sqrt{3}t} + C_3 e^{-i\frac{\sqrt[3]{k}}{2}\sqrt{3}t}), \quad (47)$$

where C_1, C_2, C_3 are arbitrary steels.

We look for a partial solution of a linear inhomogeneous differential equation in the form:

$$X = A, \quad (48)$$

where A is a constant.

We substitute (48) into equation (44)

$$\frac{d^3 A}{dt^3} + k \cdot A = k \cdot x_0, \quad 0 + k \cdot A = k \cdot x_0, \quad A = x_0,$$

i.e.:

$$X = x_0. \quad (49)$$

Taking into account (47) and (49), the general solution of the linear differential equation according to (42) will be written in the form:

$$x = C_1 e^{-\sqrt[3]{k} \cdot t} + e^{\frac{\sqrt[3]{k}}{2}t} (C_2 e^{i\frac{\sqrt[3]{k}}{2}\sqrt{3}t} + C_3 e^{-i\frac{\sqrt[3]{k}}{2}\sqrt{3}t}) + x_0. \quad (50)$$

Desired stationary state:

$$x = x_0, \quad y = 0, \quad z = 0, \quad (51)$$

allows solving the Cauchy problem with initial conditions (51).

In this case, to find arbitrary constants C_1, C_2, C_3 , it is necessary to solve a homogeneous system of linear algebraic equations:

$$\begin{cases} C_1 + C_2 + C_3 = 0 \\ -2C_1 + (1 + i\sqrt{3})C_2 + (1 - i\sqrt{3})C_3 = 0, \\ 4C_1 + (1 + i\sqrt{3})^2 C_2 + (1 - i\sqrt{3})^2 C_3 = 0 \end{cases} \quad (52)$$

then system (52) has a trivial solution, i.e.:

$$C_1 = C_2 = C_3 = 0. \quad (53)$$

In real conditions, with three-stage control, the desired stationary state (51) is not fulfilled, which leads to the violation of the condition. Further, since:

$$Re(\lambda_{2,3}) = \frac{\sqrt[3]{k}}{2} > 0, \quad (54)$$

then there is instability during management. As a result, it can be concluded that the multi-stage personnel management described by model (28) is unstable and causes a catastrophic increase in fluctuations.

True sustainability is provided only by one-level management, in which the manager, who directly manages the personnel, is more interested in the positive direction of solving production problems than in encouragement from the superiors.

The effectiveness of the enterprise's activity depends significantly on how justified the choice of economic policy is. The justification of management decisions is directly related to the conduct of a complex technical and economic analysis. The choice of the best option regarding the management of the enterprise in general and the personnel personally is usually carried out on the basis of a comparative analysis of the evaluation of the economic efficiency of decision options. Such a comparison can be made on the basis of the proposed model, highlighting certain parameters that characterize the stability and instability of the personnel management system.

Management tools are means of organization, adaptations for solving the task within the framework of the formed real situation, resource and other limitations. Thus, the personnel management tool is focused on sustainability. In other words, this is a way of solving the problem of adaptation in the existing situation.

A rational structure of personnel management assumes the presence of relationships between certain components. Naturally, with an increase in degrees or intermediate links in the structure of personnel management, more resources are spent on the management apparatus, management costs increase, while the efficiency of the system decreases. Otherwise, the reduction of components in the management structure leads to an increase in the load, which reduces the effectiveness of the management system as a whole and the personnel separately. The choice of a rational personnel management structure should ensure the rational efficiency of the management system in general at the enterprise. Yes, a distinctive feature of enterprise personnel management systems is the presence of subjects. In this case, management systems provide for a wide range of principles of moral and material stimulation.

Management of the production activities of mining enterprises is a multifaceted process that includes functions of planning, accounting and analysis by years, quarters and months, functions of operational management - weekly and daily planning, accounting, analysis and dispatching management of production processes. Implementation of these functions is impossible without a rationally organized personnel management system. Three levels can be distinguished in the management structure of mining enterprises: plant management (directorates and functional departments), workshop management (heads of workshops and departments), and site management (heads of sites and services). Indicators that characterize the enterprise's production activity, resource management, and profitability provide the manager with the necessary analytical and information volume for making appropriate decisions. The management level of decision-making should also be taken into account. The proposed formalized parameters of the model will allow the analysis of disruptive actions on the management system in general and personnel separately. The analysis of the ratios given by the parameters a and b constitutes the information basis for building the model of each level.

It is especially necessary to single out such a phenomenon as disasters - sudden changes that occur in the form of a sudden response of the system to a smooth change in external conditions. For example, a stable economic regime that has been established usually perishes when faced with an unstable regime (Novosad, Z. H., Yakubiv, V. M. & Zahorodniuk, A. V., 2022).

Thus, the formalization of the personnel management system based on parametric modelling is the basis for making rational management decisions.

RESULTS

The use of mathematical modelling of personnel management made it possible to obtain non-obvious results. The examples showed the ineffectiveness and even the disastrous nature of personnel management from general considerations. Thus, in the first example, the mathematical model, during its investigation, revealed the properties of saturation, which was not obvious during the implementation of management. The second example of the implementation of personnel management showed the instability of the stationary point, which would eventually lead to the instability of the management process, even to catastrophe. The third example shows the viciousness of multi-level management, which is characteristic of certain methods of management in general and personnel separately. Even with three-stage control, instability is manifested, which leads to catastrophe. Thus, the impossibility of effective personnel management based on general considerations, even in the presence of practical experience, was explained using examples using system-parametric modelling.

DISCUSSION

The main trends in personnel management at the current stage are oriented towards taking into account socio-economic and socio-psychological factors. There are general practical approaches to personnel management problems. Despite significant differences in approaches in different enterprises and in different management and corporate cultures, successful enterprises adhere to some similar views. Along with this, the application of system-parametric modelling in personnel management is used quite slowly, which is confirmed by the analysis of relevant literary sources. There is expediency in specific analytical examples to argue the results of using system-parametric models to obtain effective but not obvious solutions. The ability to forecast management results with the help of system-parametric models is an essential part of the implementation of the personnel management process. A particularly important property of using system-parametric modelling in personnel management is the possibility of using modern management tools, in particular, elements of artificial

intelligence. Unfortunately, as the review of scientific publications shows, insufficient application of mathematical methods during personnel management inhibits the application of practically effective management methods.

CONCLUSIONS

The application of mathematical methods during decision-making in enterprise personnel management showed that the obtained results are not obvious. The obtained analytical dependencies, as a result of system-parametric modelling, allow rational decisions to be made in the management of the company's personnel. This indicates the expediency of further development of the use of system-parametric modelling methods in personnel management processes. It is clear that the transition to more advanced methods of mathematical modelling based on modern information technologies will make it possible to achieve further achievements in solving problems related to personnel management. The directions of further research should be aimed at adapting the methods of mathematical modelling of personnel management for the real conditions of the functioning of enterprises.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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The Authors declare that there is no conflict of interest.

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УПРАВЛІННЯ ПЕРСОНАЛОМ НА ЗАСАДАХ СИСТЕМНО-ПАРАМЕТРИЧНОГО МОДЕЛЮВАННЯ

Метою дослідження є вивчення застосування системно-параметричного моделювання в процесах управління персоналом задля забезпечення його ефективності. Для досягнення означеної мети використано методи: системний підхід – щодо визначення місця й ролі управління персоналом у діяльності підприємства; теорії виробничих систем, дослідження операцій – при визначенні сутності управління персоналом із позиції теорії виробничих систем; метод дедукції – для формування рекомендацій щодо управлінських рішень стосовно персоналу; математичного моделювання – для розробки моделі управління персоналом. У результаті дослідження набуло подальшого розвитку розв'язання проблемного питання щодо ефективності управління персоналом. На засадах системно-параметричного моделювання визначено й проаналізовано багатоступеневе управління персоналом. Запропоновано методологічний підхід до математичного моделювання щодо управління персоналом, який, на відміну від існуючих, ураховує показники внесення змін у функціонування підприємства на основі управлінських рішень. Це сприяє визначенню деякого збурення в економічній складовій у вигляді управлінського рішення щодо функціонування підприємства. Отримані аналітичні залежності як результат системно-параметричного моделювання, їх застосування дозволяє ухвалити більш якісні рішення при управлінні персоналом підприємства. Проаналізовано компетентнісний підхід як нову парадигму в управлінні персоналом. Доведено, що багатоступінчасте управління нестійке й викликає катастрофічне наростання коливань виробництва. Одноступінчасте управління персоналом забезпечує стійкість функціонування виробництва.

Ключові слова: управління персоналом, математична модель, параметри, підприємство, структура, компетенції

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