Modelling of technological solutions implementation processes at forest industry enterprises with system analysis elements

I I Shanin

Voronezh State University of Forestry and Technologies named after G.F. Morozov, 8, Timiryazev St., 394087, Russian Federation.

E-mail: kingoao@mail.ru

Abstract. Studying the problems and existing realities on the practical application of innovative technologies in the forest business, the author set the task of developing a methodological approach aimed at improving the tools for modelling production and technological processes in enterprises engaged in the forest business. The methodological approach being developed has a vector aimed at introducing the latest and innovative technological solutions into the production process. It is characterized by the combination of the most rational production technologies, the choice of forms of forest business, tools and methods of production and technological development of business structures, on the basis of the developed system of indicators-criteria for assessing the production and technological development of forest business entities. The main tool for managing production and technological development in the forest business, in crisis conditions and the need to save resources is the development and implementation of the most innovative technological solutions. The author proposes an approach to modeling based on changing technological business processes on changing streaming processes with optimal use of working capital, production and material resources, used mechanisms and equipment. The simulation was carried out on the basis of the formed methodological approach with elements of system analysis and construction of situation models, using an epignose forecast. The data were based on statistical data of activity of enterprises of the forest industry, sources of formation of funds for technological direction in the structure of using all available forest industry resources for the purpose of increasing the level of functionalization of technological processes.

1. Introduction

In conditions of formation of effective directions of technological development of production system, the application of approaches to modeling of production and technological processes at enterprises of timber business is of importance. They are aimed at effective management of technological development of enterprises, their provision of innovative types of resources and advanced technological solutions for optimal use of all available resources in circulation. In terms of technological development of timber production, the following can be noted. The enterprises of the timber industry acquire, to a greater extent, imported analogues of production equipment, thus causing a problem for the Russian timber industry, related to the provision of maintenance and operation of imported machines and equipment, not Russian production [1].

The wear and tear of the precision basing and guiding elements of the machines, the failure of part of the components, often made non-removable and non-repairable, require new import purchases due to time losses and high additional costs [2].
In addition to these problems, innovative and technological solutions for the modernization of timber machinery and equipment are needed, on the one hand. Only effective innovative solutions in the direction of technological development can provide a qualitative leap not only in the production direction, to meet Russian forest needs at affordable prices, but also in the introduction of advanced technological solutions into production. First of all, it is necessary to determine the level of technological development of forest industry enterprises. For this purpose the study proposes a methodological approach to modeling on the basis of changing technological business processes with subsequent improvement of streaming processes with optimal use of working capital, production and material resources, used mechanisms and equipment [3,4].

2. Material and methods

In the process of modeling aimed at determining the most effective technological solutions in innovative conditions, the scientific study has identified four groups of enterprises of the K1, K2,..., Kn (logging, woodworking, pulp and paper, furniture) for the period t consisting of n business technological years - t (i = 1,2,..., n). At the same time \( T = \sum t_i \). In order to develop the most efficient technological solutions in innovative conditions, forest industry enterprises have allocated the amount of investment funds S by the beginning of the time period t. At the beginning of each reporting period, it is necessary to finance all elements for technological development of timber enterprises. In the condition there are a number of parameters of the initial state of the y0 system, which are characterized by the number of investment funds raised at the moment for technological development of the timber business enterprises, which are determined by the final value yk [5,6].

The study used computer data analysis, in which data for modelling is presented as a summation of all available investment resources for implementation of the most efficient technological solutions in innovative conditions of timber business enterprises S in order to ensure that up to the final value of period t the total summed income P from the overall production system of the timber business enterprise has values at the maximum level in the final model. At first we denote: \( x_{i0} \) sum allocated at the beginning of the investigated i-th period on j-th business structure (i = 1,2,..., n; j=1,2,..., k) [7,8].

We suppose that at the i-th stage there was a distribution of investment funds for technological development in full, i.e. a number of certain technological resources Bi were formed, characterized by the fact that at the beginning of the i-th year the enterprise of timber business N1 issued investment funds \( x_{i1} \); the enterprise of timber business N2 - funds \( x_{i2} \), etc. The vector \( Z_i = (x_{i1}, x_{i2},..., x_{in}) \) shows the distribution of investment funds at the i-th stage. The value of all invested funds for technological development of timber business enterprises at each step n will get its optimal expression in the system of k-dimensional vector space of vectors [9,10].

\[
\begin{align*}
Z_1 &= (x_{11}, x_{12},...x_{1k}), \\
Z_2 &= (x_{i1}, x_{i2},...x_{ik}), \\
& \vdots \\
Z_n &= (x_{i1}, x_{i2},...x_{in}).
\end{align*}
\] (1)

In the final model it is necessary to define the total yield for n years, which depends on the total amount of invested funds in technological development, which is represented by the function: \( Z_1, Z_2, ..., Z_n \):

\[
\begin{align*}
P_1 &= P(Z_{11}, Z_{12},..., Z_{1k}); \\
P_2 &= P(Z_{21}, Z_{22},..., Z_{2k}); \\
P_3 &= P(Z_{31}, Z_{32},..., Z_{3k}); \\
P_4 &= P(Z_{41}, Z_{42},..., Z_{4k}).
\end{align*}
\] (2)

The main condition is the following task: each level is determined by the necessary technological solution so that the whole volume of planned profitability, from all investment resources for technological development of forest industry enterprises, has the maximum extreme function. The
final model is built by solving the problem by combining all the main stages. The P element as a function in the model depends on the controls considered at each mathematical level:

\[ P = (x_{i1}, x_{i2}, \ldots, x_{in}, y_{1}, y_{2}, \ldots, y_{k}) . \]  

Therefore, a model with a function of multiple variables is formed. In the process of solving the problem, a search is made for a necessary set of search values of arguments \( x_{ji} \), at which, the investigated function \( P \) gets the maximum value. Thus this solution achieves the basic condition of the task. When finding the partial derivatives of function \( P \), all the arguments needed to solve the problem are equated to zero and a system of regression equations \( \frac{\partial P}{\partial x_j} = 0 \), having values \( x_0 \) at which function \( P \) comes to the desired maximum, is solved.

3. Results and Discussion

In order to develop the most efficient technological solutions in innovative conditions, forest industry enterprises, in several production areas, each of four groups of enterprises are given funds in the amount of \( x \) for three years. The value of funds \( y \), directed to the first technological solution, gives the possibility to obtain the yield predicted in one calendar year \( g(y) = 0.374y^2 \) and reduced to the minimum value \( g(y) = 0.374y \). The amount of funds \( x \) and \( y \) allocated for the second process solution allows one to increase in one reporting period of profitability \( \ell(x - y) = 2(x - y)^2 \) and to determine the unbalanced balance to the minimum value \( p(x - y) = 0.45(x - y) \).

It is necessary to distribute the issued resources among the production directions over the projected periods in order to achieve maximum profitability. It should be noted that even in a continuous process, each period of implementation of the process solution is divided into 3 stages, for the sake of illustration, the values of \( x \) and \( y \) in all the process stages will have certain indices.

Finding the optimal solution for the model should begin with the third stage, in which the balances of investment funds \( x_2 \) are first distributed. To do this, there is a valid optimal value for the \( y_3 \) function. As a result, we get the following function solution:

\[ g_3(x_2, y_3) = 3(y_3) + h(x_2 - y_3) = y_3^2 + 3(x_2 - y_3)^2, \]

\[ f_3(x_2) = \max_{0 \leq y_3 \leq x_2} \left\{ y_3^2 + 3(x_2 - y_3)^2 \right\}. \]

The simulation used differential calculus to find the \( y_3 \) value. Based on this, the differential function in square brackets on line \([0, x_2]\) takes the most optimal \( y \) value. It should be noted that \( x_2 \) at the 3rd stage is constant and unchanged. On the basis of this we will get a mathematical description of the model:

\[ \frac{Z}{Zy_3} \mathbb{R}_3(x_2, y_3) = 0; \quad y_3 = \frac{2}{3} x_2; \]

\[ \frac{Z}{Zy_4} \mathbb{R}_4(x_1, y_4) = 0; \quad y_4 = \frac{2}{3} x_2; \]

\[ \frac{Z^2}{Zy_3} \mathbb{R}_3(x_2, y_3) = 6 > 0; \quad \mathbb{R}_3(x_2, \frac{2}{3} x_2) = \frac{2}{3} x_2^2; \]

\[ \frac{Z^2}{Zy_4} \mathbb{R}_4(x_3, y_4) = 6 > 0; \quad \mathbb{R}_4(x_3, \frac{2}{3} x_3) = \frac{2}{3} x_3^2. \]

The function \( y_3 = (2/3) x_2 \) acts as the extremum of the minimum. Next, we get the values of the extrema of the function at the end of the line \([0, x_2] \):

\[ \mathbb{R}_4(x_2, y_3) = 2x_2^2 \text{ at } y_3 = 0, \]

\[ \mathbb{R}_4(x_2, y_3) = x_2^2 \text{ at } y_3 = x_2. \]

We note that the function \( 2x_2^2 > x_2^2 > (2/3)x_2^2 \) where the extremes of the \( g_3(x_2, y_3) \) function have maximum values throughout the \([0, x_2]\) segment where \( y_2 = 0 \), we get the following function solution.
for the model: \( f_1(x) = 2x^2 \). Therefore, the predicted maximum yield at the final stage can be achieved provided that the entire amount of remaining funds is transferred to the next technological solution.

Further, in the process of solving, it is necessary to find the optimal ways to allocate financed funds to technological development in the next two stages.

We will fix the system of the functional equation for the following stages:

\[
\begin{align*}
    f_2(x) &= \max_{0 \leq y \leq 1} \{ \mathbb{R}_2(x_2, y_2) + f_1(x_2) \} = \max_{0 \leq y \leq 1} \left\{ y_2^2 + 2(x_2 - y_2)^2 + 2x_2^2 \right\} \\
    f_3(x) &= \max_{0 \leq y \leq 1} \{ \mathbb{R}_2(x_2, y_3) + f_4(x_2) \} = \max_{0 \leq y \leq 1} \left\{ y_3^2 + 2(x_2 - y_3)^2 + 2x_3^2 \right\}
\end{align*}
\]

(12) (13)

Provided that \( x_2 = 0.374y_2 + 0.45(x_1 - y_2) \), we get:

\[
\begin{align*}
    f_2(x) &= \max_{0 \leq y \leq 1} \left\{ y_2^2 + 2(x_1 - y_2)^2 + 2\left[0.374y_2 + 0.45(x_1 - y_2)\right]^2 \right\} \\
    f_3(x) &= \max_{0 \leq y \leq 1} \left\{ y_3^2 + 2(x_1 - y_3)^2 + 2\left[0.374y_3 + 0.45(x_1 - y_3)\right]^2 \right\}
\end{align*}
\]

(14) (15)

On the basis of solved systems of equations (12-15) by the method of simulation with application of epignose forecast, correlation dependence of change of technological solutions implementation rate at enterprises of timber business in relative indicators is formed. The results of calculations and simulation are shown in Figure 1.

**Figure 1.** Correlation relationship of change of technological solutions implementation rate at forest industry enterprises

According to Figure 1, the annual change in the correlation dependence of the change in the rate of implementation of technological solutions at forest industry enterprises is (-0.7%) at logging enterprises. At furniture enterprises the trend is almost unchanged, according to the results of 2019 wood processing enterprises show the largest increase by 1.6%, and pulp and paper enterprises show growth by 0.5%, which is insufficient.
4. Conclusion

Based on the results of the simulation and computer analysis of the data, it can be concluded that a number of circumstances determines the optimal implementation of effective technological solutions in innovative conditions at forest industry enterprises. First, at the initial stage, investment funds for technological development of timber business enterprises should be aimed only at the first production and technological direction. Second, during the predicted periods, it is necessary to implement effective technological solutions in the second production and technological direction of development. At the same time, it is necessary to take into account the compliance of the model condition, in which the optimal solution is correct for all values of forecast values $x > 0$. Therefore, in the process of implementation of technological solutions for a specific value $x$, the value of investment funds, which should be redistributed to the implementation of the following technological solutions in innovative conditions to forest industry enterprises for each forecast period, is determined.

References

[1] Drapalyuk M V, Bartenev I M, Midges M A, Druchinin D Yu, Markov O B and Klubnichkin E E 2012 Mathematic model of process of giving and emission of soil by working bodies of the combined car for suppression of forest fires Polythematic network electronic scientific magazine of the Kuban state agricultural university 84 232-246

[2] Morkovina S S, Rezanov V K, Panyavina E A and Sukhova V E 2018 Function value analysis in forestry practice Innovation Management and Education Excellence through Vision 2020 Proceedings of the 31st International Business Information Management Association Conference (IBIMA) 1 4419-4425

[3] Bezrukova T L, Borisov A N and Shanin I I 2018 Management methodology of effective development of furniture industry enterprises Advances in Economics, Business and Management Research (ICEMW 2018) 61 227-232

[4] De Melo F., Maslennikov V.V., Popova E.V., Bezrukova T.L. and Kyksova I.V. 2015 Quantitative analysis in economics based on wavelet transform: a new approach. Asian Social Science. 20 66-73.

[5] Yakovleva E A and Subkhonberdiev A Sh 2019 Implementation of "green" economy principles in the forest sector IOP Conference Series: Earth and Environmental Science 392 012016

[6] Kirillova S S, Borisov A N and Bezrukov B A 2019 Transformation of the structure of the timber industry complex on the path to new industrialization IOP Conference Series: Earth and Environmental Science 392 012061

[7] Morkovina S S, Drapalyuk M V, Sibiryatkina I V and Torzhkov I O 2017 Priorities of diversification in forest complex growth Proceedings of the 30th International Business Information Management Association Conference. Editor: Khalid S. Soliman. 1 2856-2862.

[8] Shanin I I 2019 Modeling of technological processes at enterprises of timber processing industry IOP Conference Series: Materials Science and Engineering 560 012042

[9] Shanin I.I., Boris O.A. 2018 Modeling operation of mechanism of holistic management of technological processes at enterprise. IOP Conference Series: Materials Science and Engineering conference proceedings 327 022095.

[10] Vasiltsova V.M., Dyatlov S.A., Vasiltsov V.S., Bezrukova T.L. and Bezrukov B.A. 2015 Methodology of management innovation hypercompetition Asian Social Science 20 165-169.