# Management of the Main Production Funds Using the Markov Process Under Conditions of Uncertainty*

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**Abstract:** A variety of operating conditions of the machine and tractor fleet make a decisive contribution to the reliability of agricultural machines. This fact significantly affects the production and economic characteristics of the operation of fixed assets. One should study issues of operation, maintenance, reliability. To solve this problem, we propose to combine two approaches: (1) fuzzy sets to work with the uncertainty of operating conditions and (2) Markov processes to assess the condition of the machine and tractor fleet.

**Keywords:** Markov process, Fuzzy equations, Zadeh extension, basic production assets, BPA

## 1 Introduction

We can describe the functionality of basic production assets [BPA] by the states of these assets and the intensity of transitions. By the intensity of transitions, we understand the probability of a transition to another state as a unit of time. One can use the following characteristics as states: (1) serviceable, working; (2) undergoing maintenance; (3) under repair; (4) standing idle for various reasons. External and internal factors of the organization can significantly influence the intensity of the transition from state to state. For instance, the operating modes of machines are determined by the loading (the production program of the enterprise). The production program is determined by the demand for products and available production capacity (own or leased). The condition and the possibility of transitions are affected by the supply of spare parts and consumables. Internal factors are due to the organization of the operation service and maintenance and repair of machines [1].

A mathematical apparatus can be applied using a system of fuzzy Kolmogorov differential equations and Markov chains to describe such transitions. We described the evaluation apparatus using Russian and international standards GOST R IEC 61165-2019, GOST R 51901.15-2005 (IEC 61165:1995), IEC 61165:2006 [1].

## 2 Materials and Methods

The actual operation of machines is characterized by a variety of conditions such as significant uncertainty in (1) the expenditure of technical resources, (2) the quality of maintenance, (3) repair, and (4) operational materials. This fact imposes significant limitations on the possibilities of mathematical modeling by rigorous methods and requires approximate methods that consider uncertainty. To overcome the uncertainty, we propose to use fuzzy sets that characterize the intensity of the transition from one state to another state of the BPA. Thus, we propose to solve a system of fuzzy Kolmogorov differential equations numerically.

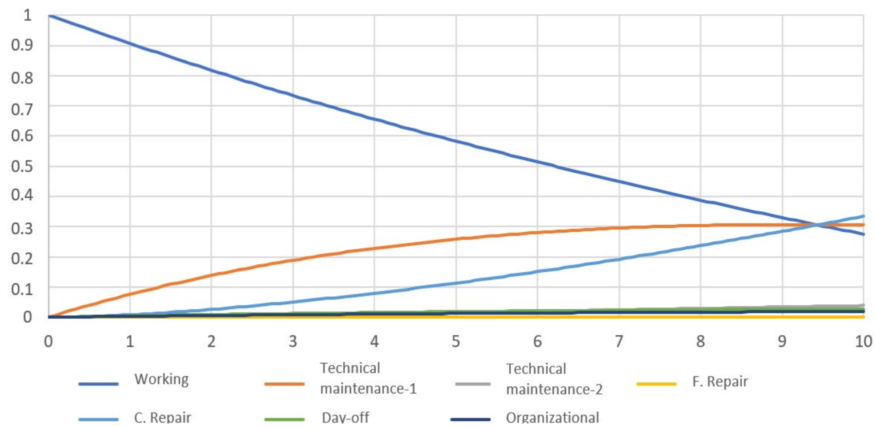
In our opinion, Kolmogorov differential equations are one of the main tools for mathematical modeling of physical, technical objects and processes in dynamics. With the numerical solution, we can obtain the value of the probability of finding the BPA in the designated states at a certain time.

The initial values (initial period) of a system of differential equations are given by a vector. We assume that in the initial state, our modeled BPA element is serviceable and working.

We determined the numerical solution of the system of fuzzy differential equations using the Runge-Kuttu 4 software. We also implemented arithmetic operations on fuzzy numbers using the Zadeh expansion method and the ordered fuzzy numbers [OFN] method.

## 3 Results and Discussion

To visualize the result obtained, we present graphs of states with the degree of belonging “1,” Fig. 1. The results of this degree of membership coincide with a clear solution, and the results are presented using various methods of fuzzy arithmetic.




For the model calculation, we use estimates of the probabilities of transition to states from time to time for a model car. Thus, we obtain the characteristics of the probabilities of staying in the specified states of the object of study at certain time intervals. The ratio of the probabilities of work with the probabilities of downtime or repair determines the operational efficiency of the car. Fig. 1 shows a decrease in the probability of work and an increase in the probability of routine repairs, which leads to a decrease in operational efficiency. Fig. 1 shows the dynamics of the operation of a model car over 10 years [1].

Let us summarize the results obtained. We added up the probabilities of maintenance and repair, which gave us the probability of technical impacts. If the car does not undergo technical influences, it is serviceable. This statement gives us the probability of technical readiness and characterizes the model car's technical readiness coefficient. The characteristic of the probability of work determines the coefficient of output to the model car line. The difference between the probability of technical readiness and the probability of operation of a model car will characterize the stock of carrying capacity. Other probabilities of downtime will characterize possible losses. Fig. 2 shows this grouping of calculated data [1].

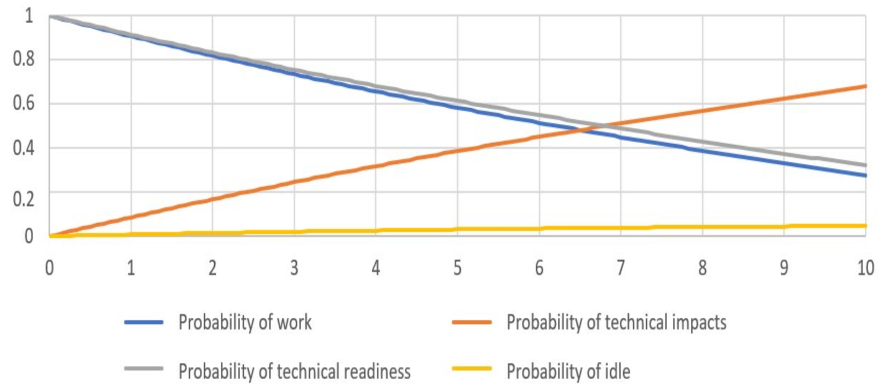



**Fig. 2.** Aggregated estimates of the probability of being in the specified states of the object of study with the degree of belonging "1." *Source*: Compiled by the authors.

In the example, such characterizing indicators were the probability of work (the coefficient of car output to the line) and the probability of technical readiness (the coefficient of technical readiness of the car).

We present an infographic of the results of calculating the probabilities of the state for various degrees of belonging, characterizing the operating conditions of the object of study in Fig. 3 and 4 [3].

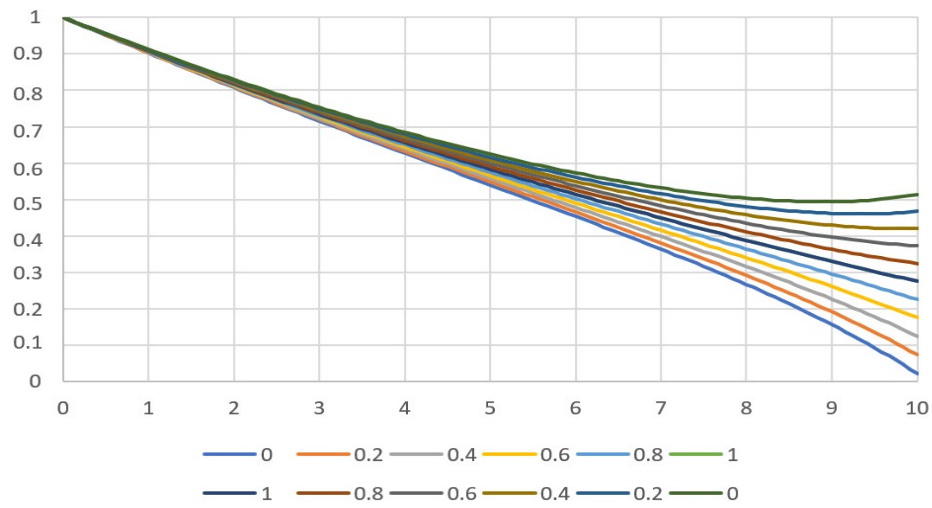



**Fig. 3.** The graph of the change in the probability of being in the state S1 "works" for different degrees of membership (the Zadeh extension method). *Source*: Compiled by the authors.

The expansion of the Zadeh leads to a significant dispersion of the result. It corresponds to all possible variants of the development of the situation described by the Kolmogorov system of fuzzy differential equations. This fact makes a rigorous mathematical analysis of the obtained probabilistic results impossible. To overcome this disadvantage, we use the OFN method, Fig. 4 [2].

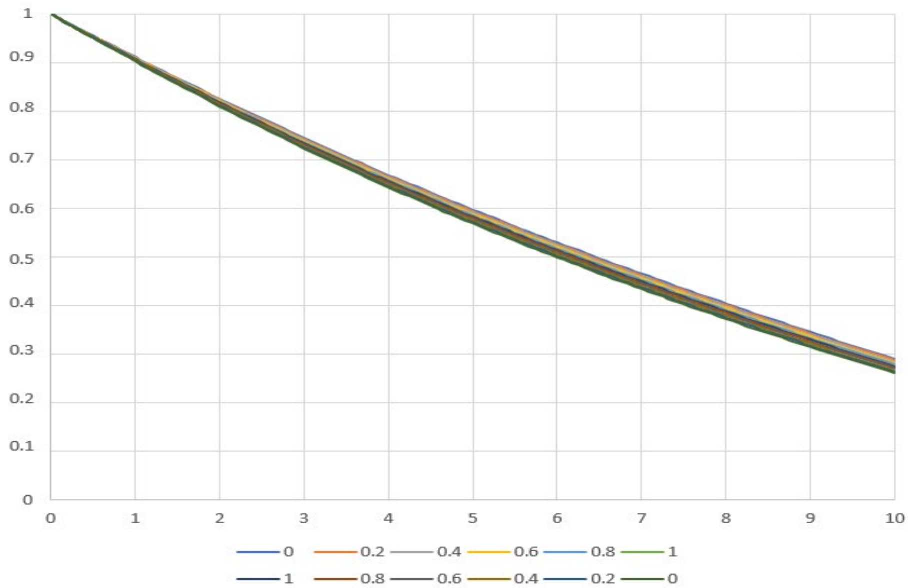



**Fig. 4.** The graph of the change in the probability of being in the state S1 “works” for different degrees of membership (OFN ordering method). *Source*: Compiled by the authors.

The OFN method has no significant dispersion due to keeping the result analytically interpreted. It allows us to verify the correctness of the calculation through analytical interpretation analytically. We proceed from the rule that the sum of the probabilities of states is equal to one for any moment.

# 4 Conclusion

To check the correctness of the solution of Kolmogorov’s systems of fuzzy differential equations, we used the OFN arithmetic method. Based on the thesis that the sum of the probability of states of an object should be one. We get the following results for 10 years of operation (Table 1).

Table 1. Results of checking the correctness of solving systems of fuzzy differential equations by the method of fuzzy arithmetic OFN.

| mui\ui | Degrees of belonging to the set | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| YA | 0.2904 | 0.2873 | 0.2842 | 0.2812 | 0.2783 | 0.2753 | 0.2753 | 0.2725 | 0.2696 | 0.2668 | 0.2641 | 0.2613 |
| YB | 0.2988 | 0.3002 | 0.3016 | 0.3029 | 0.3042 | 0.3055 | 0.3055 | 0.3068 | 0.3081 | 0.3093 | 0.3105 | 0.3117 |
| YC | 0.0354 | 0.0360 | 0.0366 | 0.0372 | 0.0378 | 0.0385 | 0.0385 | 0.0391 | 0.0397 | 0.0404 | 0.0410 | 0.0416 |
| YD | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 |
| YE | 0.3278 | 0.3291 | 0.3303 | 0.3316 | 0.3328 | 0.3339 | 0.3339 | 0.3351 | 0.3362 | 0.3373 | 0.3384 | 0.3395 |
| YF | 0.0284 | 0.0283 | 0.0282 | 0.0281 | 0.0280 | 0.0278 | 0.0278 | 0.0277 | 0.0276 | 0.0275 | 0.0274 | 0.0273 |
| YG | 0.0191 | 0.0190 | 0.0190 | 0.0189 | 0.0188 | 0.0187 | 0.0187 | 0.0187 | 0.0186 | 0.0185 | 0.0184 | 0.0184 |
| Sum | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

*Note*: mui – Degrees of belonging to the set, ui – Elements of the Kolmogorov system of differential equations. *Source*: Compiled by the authors.

Where YA is "working,":

- YB is "undergoing technical maintenance-1";
- YC is "undergoing technical maintenance-1";
- YD is "undergoing FR (full repair)";
- YE is "undergoing CR (current repair)";
- YF is "idle due to the day-off ";
- YG is "idle for organizational reasons."

The results obtained in the table confirm the correctness of the work of the developed software and hardware complex in relation to the OFN method and by virtue of its architectural solutions and calculations performed and for the Zadeh extension method. Thus, we justified the use of the Zadeh extension for further research.

We can draw many conclusions from the calculations carried out and the data obtained. Due to the nonlinear change in the failure rate inherent in the uncertainty model of operating conditions, the probabilities of BPA states are characterized by variability. The calculated probabilities of operational conditions fully allow us to assess the model's operational efficiency and transfer this technique to another machine fleet of organizations, considering their production and operational cycle.

Thus, we can effectively manage engineering and production processes using elements of information technology and design modeling. The model of the ten-year operation of the BPA showed that the probabilities of technical readiness, the probability curve of operation decreases, and the curve describing the probability of technical impacts increases and the probabilities of technical impacts equal with the service life of the car about 6–7 years (Fig. 2) [1].

In our opinion, by this period of operation, an agricultural enterprise should attend to the issue of reserving production capacities due to an increase in the probability of failures of worn-out BPAs and to ensure a given continuity of agricultural production. With this development and further, there is an increase in the probability of downtime for technical reasons and an increase in operating costs for technical maintenance and repair.

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