A Digital Platform for the Risk Assessment of Operating the Production Facilities of an Enterprise Based on Fuzzy Sets of Zadeh and OFN*

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Abstract. In a modern economy, many aspects of the decision-making process require mathematical support. The inability to formalize the initial data for analytical tasks contributes to implementing unconventional approaches in working with incoming data on ongoing business processes. One group of such approaches is fuzzy sets, fuzzy logic, fuzzy arithmetic, which can operate with poorly structured data in conditions of incomplete information. Business management should have tools based on digital platforms to minimize losses. For these purposes, one should substantiate a risk assessment methodology for the general case. The risk assessment itself is a quantitative characteristic of the relationship of two values. This characteristic forms in the context of assessing the lost income from the operation of the machine and the costs of acquisition, maintenance, and repair. The authors propose to utilize a digital platform based on fuzzy sets of Zadeh and their applications for calculating risks under specified criteria and fuzzy arithmetic according to the Zadeh and OFN extension principles for the risk assessment. During the operation of production facilities, particularly the functioning of fixed assets, the issue of risk assessment associated with the service life of machines (operating costs, maintenance costs, increase in the amount of failure, increase in maintenance costs, and the remaining practical resource of vehicles) comes to the fore. In this context, risks associate with losses and missed opportunities. The authors propose a weighing formula that corrects the value of failure depending on the onset of consequences. It makes it possible to adjust risk assessments depending on the severity of the socio-economic consequences of the negative event occurrence.

Keywords: Risks, Risk assessment, Fuzzy set, Fuzzy sets of Zadeh, OFN

1 Introduction

The relationship of results and losses can be determined in absolute or relative units or probability assessments. Absolute values are determined by the possible difference between the planned and obtained results. Although this approach is straightforward, it is less informative for decision-making by business management. The probabilistic approach is the most informative, and it prevents one from considering the initial data. The authors obtain a probabilistic description of the functioning of this element by modeling the operation of an element of production capacity with discrete Markov chains with continuous time.

Based on the results of the carried out calculations, the authors obtain the assessment that there is an excess of the probability of failure over the probability of operation in the ninth year. Therefore, the probabilities of operation [0.156529, 0.329818, and 0.493974], and the probabilities of failure [0.204099, 0.284616, and 0.372416] are two fuzzy triangular numbers (sets). The authors continue further discourse implementing the hardware and software complex [3].

The research sequentially presents the numbers using the scripting language of the http://fuzzycalc.xyz/arithmetic service:

- Fuzzy set probability of operation for nine years of operation

a=0.156529; b=0.329818; c=0.493974;
A=TN(a,b,c);

- Fuzzy set probability of failure (repair) for nine years of operation

i=0.204099; j=0.284616; k=0.372416;
B=TN(i,j,k).

Fig. 1 and Fig. 2 illustrate the appearance of these fuzzy sets.

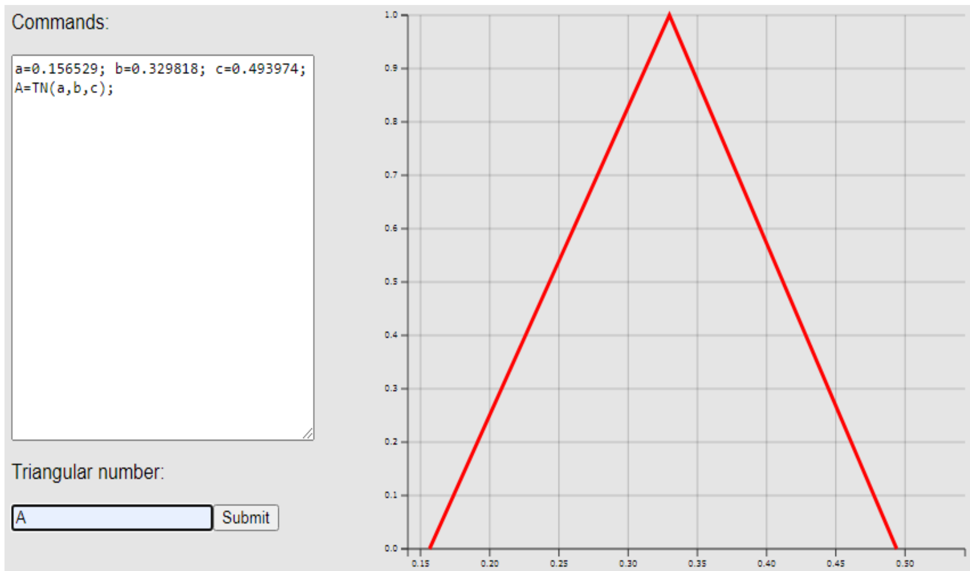

Fig. 1. Fuzzy set probability of operation for nine years of operation. *Source*: Compiled by the authors.

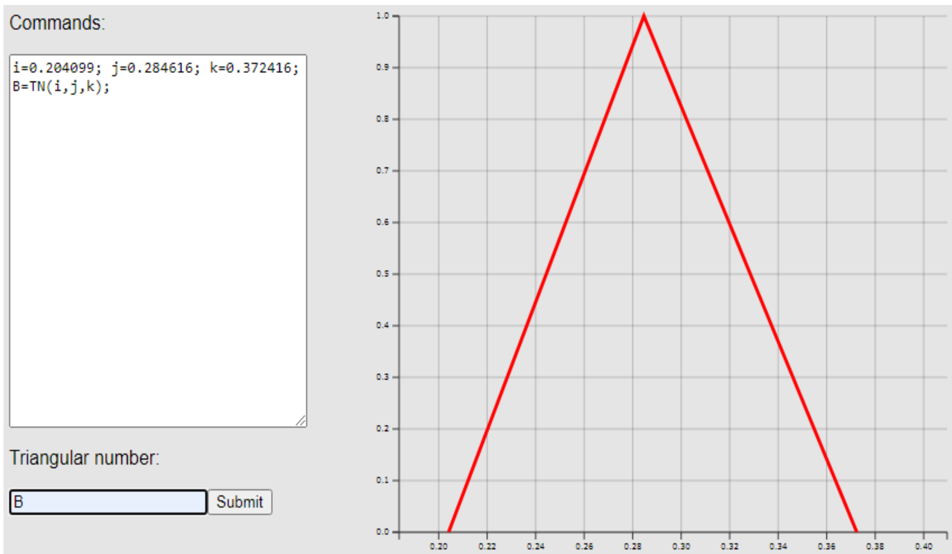

Fig. 2. Fuzzy set probability of failure (repair) for nine years of operation. *Source*: Compiled by the authors.

2 Materials and Methods

To assess the risks of operating the production facilities of the enterprise, the authors compare these two fuzzy sets by performing an arithmetic subtraction operation for the fuzzy arithmetic. If the result is positive, then the probability of operation is more significant than the probability of failure. However, if the result is negative, then the probability of failure is more significant than the probability of operation. If the subtraction yields zero, then these probabilities are equivalent to one another. Therefore, zero is an equivalence criterion that characterizes the transition from a negative outcome to a positive one. Furthermore, the authors conduct a computational experiment comparing fuzzy sets through subtraction. In other words, the authors determine the excess of the probability of operation over the probability of failure. Fig. 3 demonstrates this aspect [2]. The authors implement the mentioned procedure using the following calculation sequence:

- a=0.156529; b=0.329818; c=0.493974;
- A=TN(a,b,c);
- i=0.204099; j=0.284616; k=0.372416;
- B=TN(i,j,k);
- C=TS(A,B);

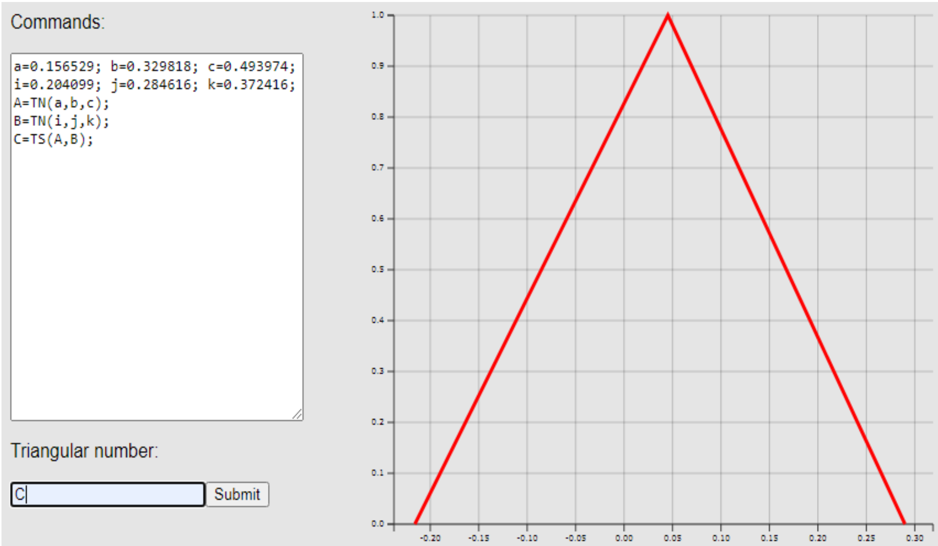

Fig. 3. Result of subtracting fuzzy numbers (sets). *Source*: Compiled by the authors.

The authors acquire a set (a triangular number) with the [-0.215888, 0.045201, 0.289875] parameters based on the subtraction results. As one can observe, this set includes negative, positive, and zero values. The authors develop the "Assessing the risk of operating the production facilities" methodology to overcome such uncertainty. The authors continue further discourse implementing the http://fuzzycalc.xyz/risk hardware and software complex.

3 Results and Discussion

The authors present the data of calculating the exceeding of the probability of operation over the probability of failure [-0.215888, 0.045201, and 0.289875] as a figure and denote the figures ABC and AEF (Fig. 4).

The risk assessment is made concerning the relationship of the areas of the figures. The position of the zero criterion determines the area of the AEF figure. If the zero criterion lies on point A or is located to the left (i.e., point A is a positive number deviating from zero), then the area of the AEF figure is zero. If the zero criterion is on point C or is located to the right (i.e., point C is a negative number), then the area of figure AEF is equal to the area of figure ABC. The amount of risk is determined by the relationship of the areas of figures according to the following formula:

$$R = S_{AEF} / S_{ABC}, \quad 1$$

where:

R is the magnitude of the risk of exceeding the probability of failure over the probability of operation,

S AEF is the area that characterizes the subset of the excess of the probability of failure over the probability of operation,

S ABC is the area that characterizes the set of exceeding the probability of operation over the probability of failure.

If the area of the AEF figure takes the zero value (when the probability of operation is guaranteed to exceed the probability of failure), then for any area of the ABC figure, the risk value takes the zero value (there is no operational risk).

If the area of the AEF figure takes the value of the area of the ABC figure (when the probability of operation is guaranteed to be less than the probability of failure), then for any area of the ABC figure, the risk value takes the value 1 (the operational risk is absolute) [1].

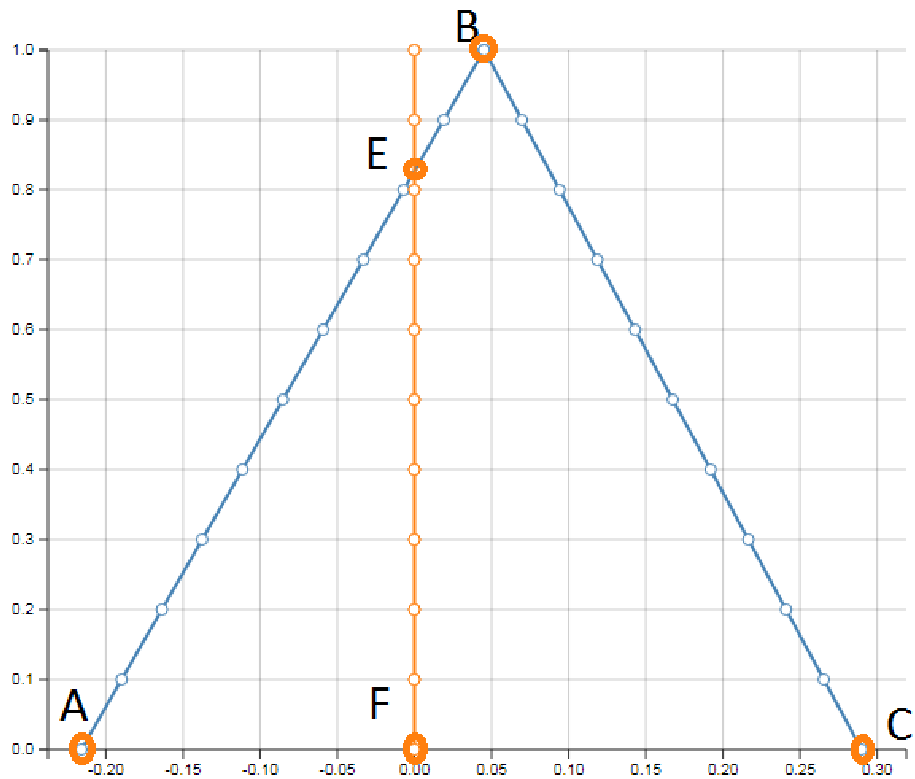

Fig. 4. Designated figures. *Source*: Compiled by the authors.

Incidentally, the authors distribute the risk of exceeding the probability of the "In operation" over the "Undergoing maintenance" probability sets in the interval from zero to one.

In the current example, the result of calculating the risk will have the following form (Fig. 5).

Risk:
0.26562403545740665

-0.215888	0.045201	0.289875
0	0	0

Fig. 5. Result of risk calculation. *Source*: Compiled by the authors.

The authors calculate the risk value of exceeding the probability of the "In operation" over the "Undergoing maintenance" probability sets on the interval of operation of vehicles (automobiles) from 0 to 10 years. The authors observe the beginning of an increase in the risk value from the eighth year of operation, which is caused by natural wear processes and an increase in failure (Fig. 6).

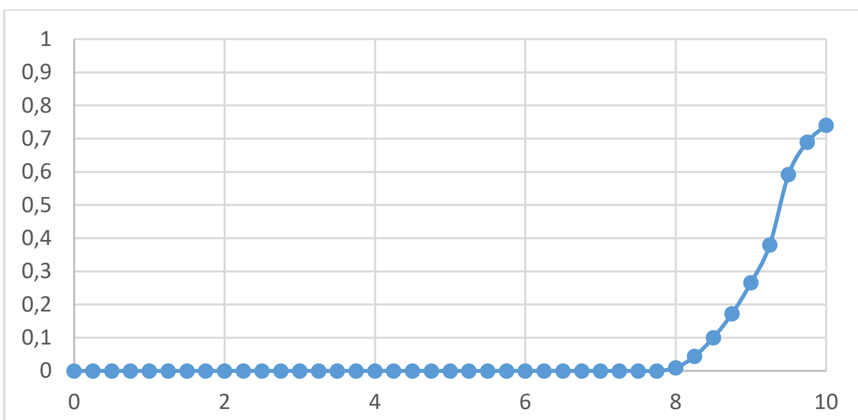

Fig. 6. Risk assessment of exceeding the probability of the "In operation" over the "Undergoing maintenance" probability sets. *Source*: Compiled by the authors.

4 Conclusions

The calculated linear risk assessment of exceeding the probability of failure over the probability of operation is not acceptable in practice since, in various spheres of the economy, the values of probability, operation, and failure may have different significance for the decision-maker. Therefore, the risk of failure of a tractor, a car, or an airplane carries various social and economic consequences. Therefore, the requirements for the reliability of the non-stop operation of vehicles may vary. To provide an assessment of the risks of the vehicle operation, the authors propose to introduce a weighing formula of the following form into the methodology,

$$f(E,R) = E - k*R, \qquad 2$$

where

f is the function (mathematical rule);

E is the set of probabilities of a positive outcome (operation, technical readiness;

R is the set of probabilities of a negative outcome (failure, the occurrence of technical impacts;

k is the coefficient of the undesirability of a negative outcome.

According to the analysis results, the authors have determined that there is an excess of the probability of failure over the probability of operation in the ninth year of operation. The probability of failure fuzzy set (repairs for nine years of operation i=0.204099; j=0.284616; k=0.372416, and the coefficient of the undesirability of a negative outcome is represented by a singleton (a set consisting of one number) a=2; b=2; c=2; a fuzzy set consisting of one value (Fig. 7).

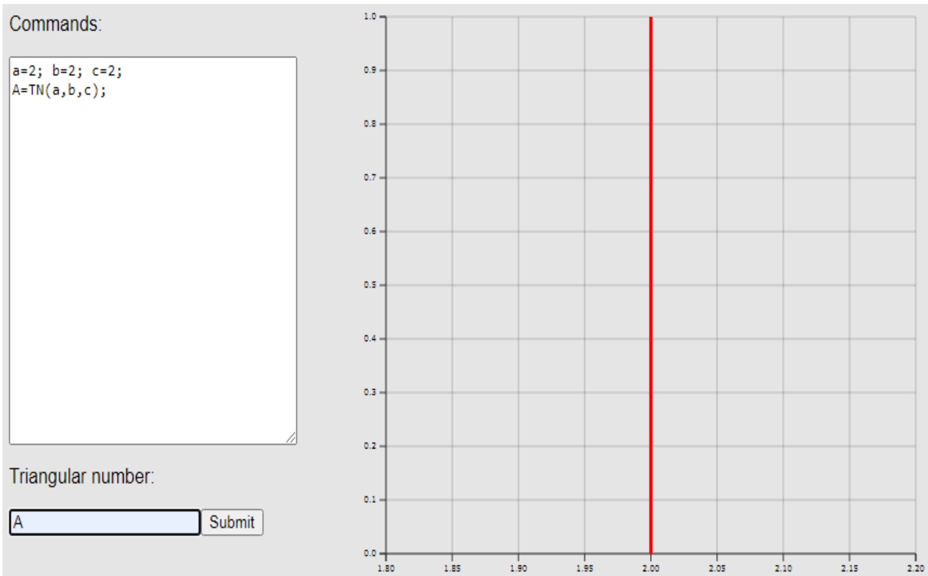

Fig. 7. Graphical representation of the “2” singleton. *Source*: Compiled by the authors.

The authors employ the developed software and calculate the risk of failure, considering the coefficient of the undesirability of a negative outcome. The program code will possess the following form:

- a=2; b=2; c=2;
- i=0.204099; j=0.284616; k=0.372416;
- A=TN(a,b,c);
- B=TN(i,j,k);
- C=TM(A,B);

Fig. 8 presents a graphical representation of the performed calculation.

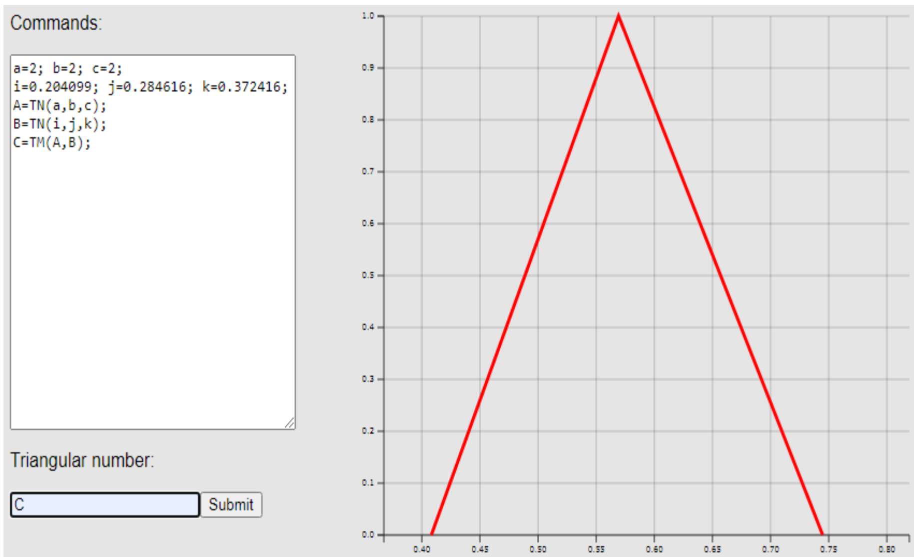

Fig 8. The result of calculating the risk of failure considering the coefficient of the undesirability of a negative outcome. *Source*: Compiled by the authors.

Fig. 8 demonstrates that an undesirable outcome is guaranteed, and production facilities require replacement (purchase of new vehicles).

The authors carry out similar calculations on the interval from 0 to 10 years of operation. The result of calculating the risk assessment in the context of the weighing formula of the decision-maker is presented in figures (Fig. 9).

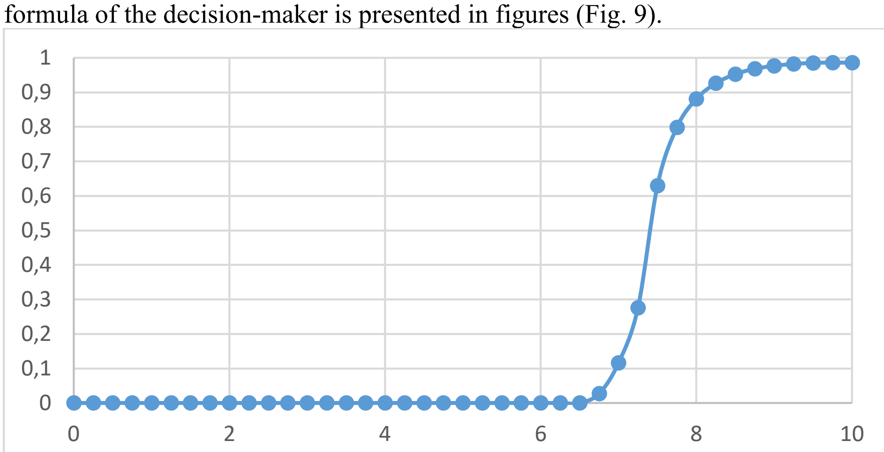

Fig. 9. Risk assessment of exceeding the probability of the "In operation" over the "Undergoing maintenance" probability sets considering the weighing formula of the decision-maker. *Source*: Compiled by the authors.

In conclusion, one can carry out long-term planning of the operation of fixed assets in conditions of multiple operation options and assess the risks of transient processes of reliability and loss of operational qualities of machines, which determines the order and plan of replacement of vehicles.

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