SIMULATION MODELLING FOR AN ANALYSIS AND PREDICTION OF STOCHASTIC PHENOMENA IN THE OPERATION, MAINTENANCE AND RISK ASSESSMENT.

Alena BREZNICKÁ[1*] – Alexej CHOVANEC[2] – Jiří STODOLA[3]

[1] *Ing. Alena Breznická, PhD., Alexander Dubček University of Trenčín, Pri parku 19,Trenčín,91106,*

[2] *prof. Ing Alexej Chovanec, CSc., Alexander Dubček University of Trenčín, Pri parku 19,Trencin,91106,*

[3] *prof. Ing. Jiří Stodola, DrSc., Alexander Dubček University of Trenčín, Pri parku 19,Trenčín,91106,*

*Corresponding author E-mail address: alena.breznicka@tnuni.sk

Abstract

The paper deals with possibilities of stochastic approaches in risk modelling from a point of costs and data relating reliability aiming to define needed parameters of distribution of stochastic variables. Dependability issue can not been dealt in an insulated way as how it has unfortunately happened till now, but, only in a thorough full system approach in respecting technical, technological, economic and other interactions to assess a risk. The paper shows advantages of simulation techniques of modelling.

Keywords: Analysis, reliability, maintainability, availability.

1 Introduction

Specification of requirements for reliability of a transport means is first of all an issue of looking for an acceptable compromise between a requested level of reliability and a level of costs, which will be needed for its achievement. Provision of reliability in a stage of application is however dependent on allocated sources for a provision of maintenance. If we start from a definition of a reliability, which is understood as an ability of the object in meeting a needed function in given conditions and in a given time interval, we can note, that a main reviewed feature of a reliability is a functionality of the object. The subject-matter of the review was a set composed of 56 personal land-rovers with a different number of failures and kilometres driven by operational units.

2 Methods to define risks and results.

We will use distribution of probability of a failure to generate a rise of a negative phenomenon – a failure and a distribution of probability of some kind of costs to generate amount of costs as a consequence of an unwanted event. Simulated values will be used for graphic display of an intersection of these phenomena in a point, the amount of costs on an y axis and amount of operational units course on x axis. It provides us with data and a perception of a rise of a risk situation [1]. Burst of appearance and their quantification enables comparing of risks and costs for maintenance of objects being assessed.

They provide details for assessment of different risks and their quantification. They are more suitable than qualitative assessment and thy give a better visualization than balance methods resulting from mean values, or semi-quantitative methods of a risk assessment. Mathematic and simulation modelling is for an analysis, modelling and prediction of stochastic phenomena in the operation, maintenance, logistics, risk assessment very favourable, first of all for a possibility of monitoring through graphic outputs, which give more visual perception about stochastic processes [2], [3].

Statistical processing of results of a simulation modeling enables displaying of a frequency, probability and assessment form a point of accepted hypotheses of a distribution kind participating on a risk and parameters of functions. Risk area is defined by a burst of points appearance within the range of the highest probabilities participating in probability density. Standard expression of the risk matrix is formed on a principle of two participating distribution functions and their values in intervals $< 0,1 >$. Thereby, we reach, of course, results that in the probability matrix in the left corner we get small values of risks through a product of small values of a probability of causes and consequences [7].

The elements of the matrix show the areas of acceptation or non-acceptation of the risk. Of course a non-acceptable area is on the right side up. A disadvantage is that a risk area is not defined by parameters of a cause and consequence. In case of a simulation modeling the fact of the phenomena appearance is defined by an appearance of values featured by probabilities of rise of phenomena participating in a risk, but assessed in unit formulation of parameters of participating phenomena. We performed simulation experiments with parameters of distribution of accepted hypotheses, through programmes developed in MATLAB [4].

Table 1 Hypothetic examples of options for results and input values processing

Variant	Value statement	Kind of distribution	Distribution parameters
N-N	Time period between failures in hours Costs for operational hours in Euros	Normal Normal	μ=643 σ=52 μ=107 σ=20
N-E	Time period between failures in hours. Costs for operational hours in Euros.	Normal Exponential	μ=643 σ=52 μ=107
E-E	Time period between failures in hours. Costs for operational hours in Euros.	Exponential Exponential	μ=643 μ=107

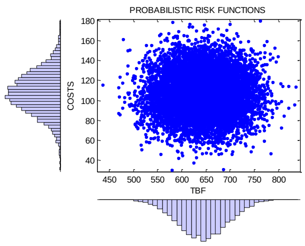
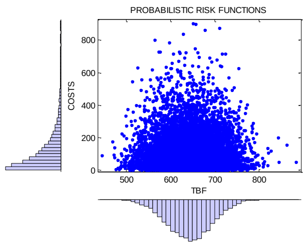
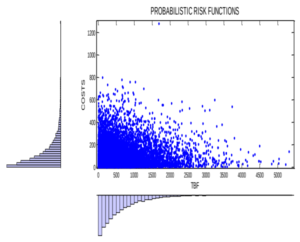
Variant N-N	Variant N-E	Variant E-E
		

Fig. 1 Display of an intersection of phenomena and frequency diagrams for 10000 simulations

We can assume that at N-N distribution of cause and consequence probability is a critical area marked with the highest occurrence in area of a mean value. An intersection of other distributions, mainly those ones, whose densities of probability we are unable to visualize in such a simple way as it is for a normal distribution, cannot be assessed so easy. Visualization of a marginal distribution of a reason and consequences of a risk is changing depending on variants of combination of probability distribution participating in input distributions.

To define a rate of risk only intersections of generated events starting from a minimum value up to the defined values of quantiles are counted in. The relation for a computation is:

$$\boldsymbol{P} = \frac{\boldsymbol{n}}{\boldsymbol{N}} \tag{1}$$

where
- *n is* a number of executions being included into an area defined by quantiles,
- *N* number of simulated values.

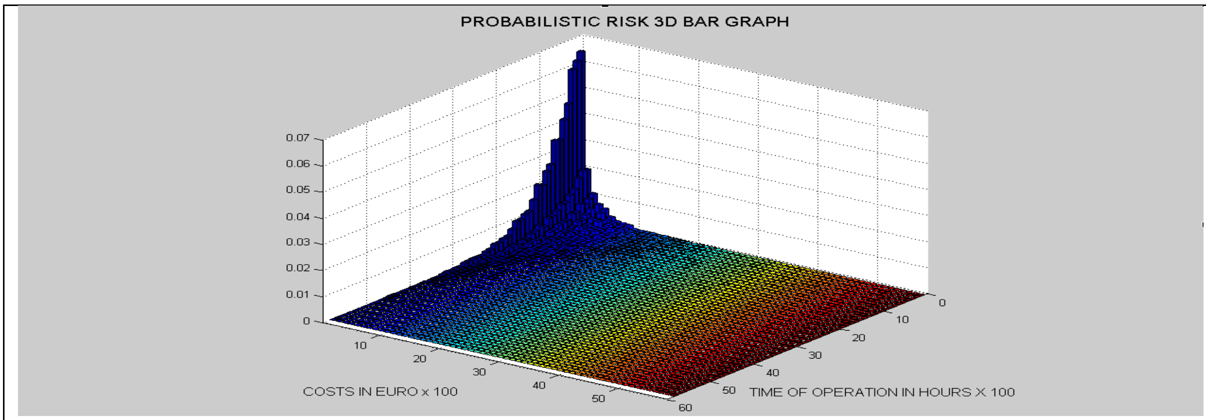


Fig. 2 Image of the risk probability with a 3D diagram

Time period between failures in operational hours defined by a 99 percent quantile is 2922 hours. The costs per an operational hours defined by a 99 percent quantile are 113,5 Euros. Probability of a risk in this limited area is expressed through a value of 0.9657.

3 Analysis of cost and rate of their risk

Mathematic and simulation modelling is for an analysis, modelling and prediction of stochastic phenomena in the operation, maintenance, logistics, risk assessment very favourable, first of all for a possibility of monitoring through graphic outputs, which give more visual perception about stochastic processes [5].

There is a certain rate of uncertainty connected with each function of transport means, that it will be carried out in a different way than requested and that possible deviations from an expected function will have an unwanted consequence on a result of the function of the object as a whole [6].

Therefore there is a certain risk, understood as a combination of probability, that a certain event occurs (a failure) and consequences (costs), which would occur, if an event would happen. From a course of costs distribution functions we can conclude a range in which the costs would occur. The costs for material, assessing a mean of probability 0.5, define an increasing order for costs in cost groups as electric installation, steering, body, and a frame, braking system, gear system, engine with systems Fig. 3 and Fig. 6

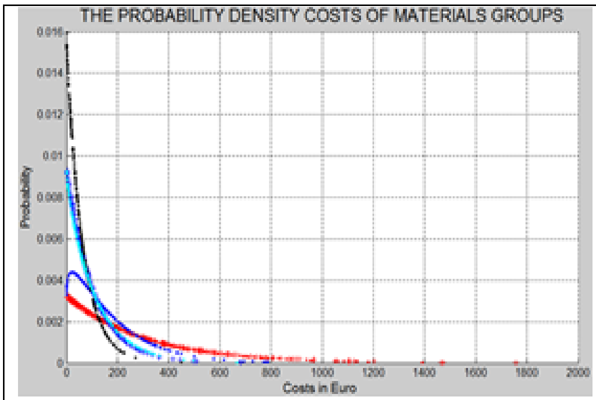


Fig. 3 The probability of density costs of material groups

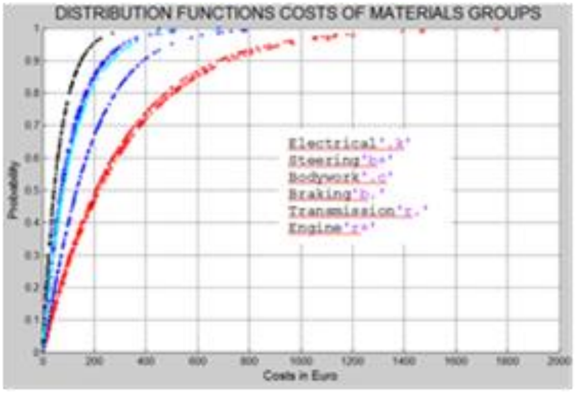


Fig. 4 Distribution functions of costs of material groups.

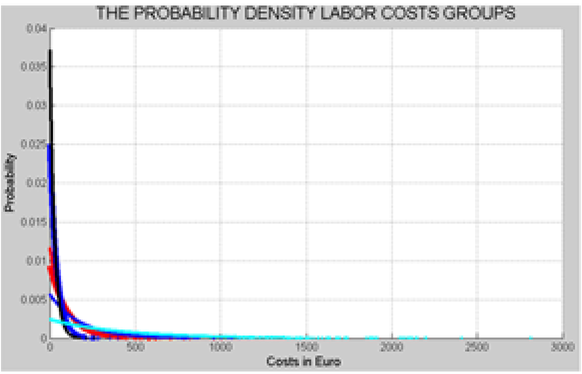


Fig. 5 Probability of density of labor costs groups

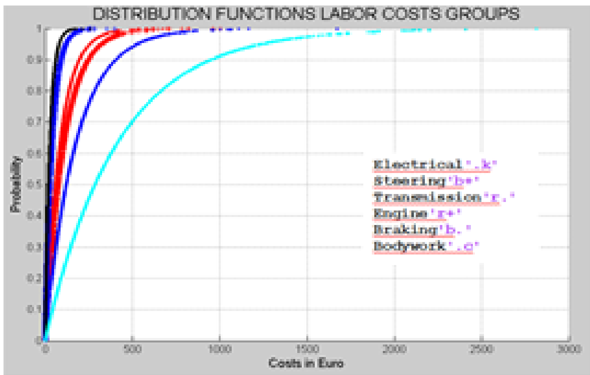
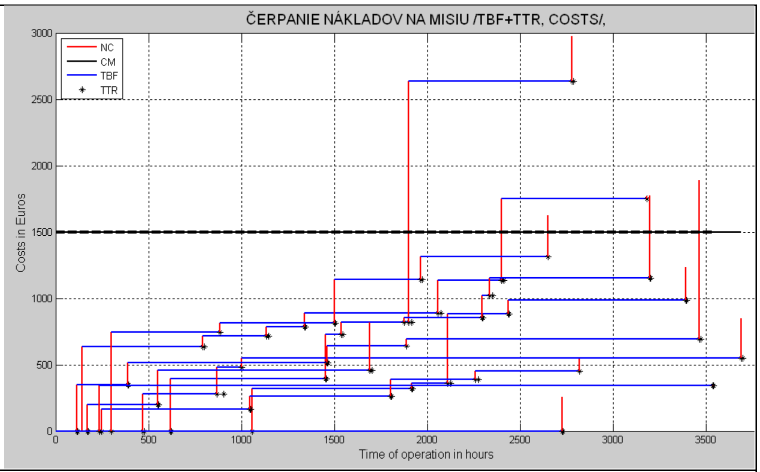


Fig. 6 Probability of density of labor costs groups

From density of probability and their course we can see the probabilities and values of costs that the groups can achieve Fig. 6 and Fig. 8.

4 Simulation with a variable time step in assessing costs

In a practical risk definition within a defined time period, expressed by consumed operational units and limited funds for maintenance, it is more suitable to use a discrete simulation with a variable time step. In models there are used the parameters of input data obtained from previous experiments and from articles having been published before. Course and a way of displaying the simulation experiments are obvious from illustration of 10 simulations.

<table>
<tr><td>Parameter, distribution, input parameters</td><td rowspan="5">
</td></tr>
<tr><td>TBF Weibull
a=676.1854287560616
b= 1.0655900608402</td></tr>
<tr><td>TTR Exponential
l= 6.974398734177213</td></tr>
<tr><td>NM Weibull
a=158.4948195963805
b= 0.6430315567794</td></tr>
<tr><td>NP Weibull
a=52.33794187645434
b= 0.7037168761996</td></tr>
<tr><td>Fig. 3 6 Parameters of input data</td><td>Fig. 4 Course of simulation of 10 vehicles, probability of a mission completion is 0.8838</td></tr>
</table>

Total costs are illustrated as an addition of generated costs – labor costs and material costs. The intervals in the TTR maintenance implementation are short, we marked them with an /*/ asterisk. The assigned funds in Euros for a maintenance of a vehicle during a mission are *CM=1500* Euros. An expected number of operational hours of the vehicle, Time of operation = 2500 hours, i.e. 150000 kmillustrated with a completion of simulation when an event exceeding this time period has been completed. The numerical statistical values of probability that the assigned funds will not overrun the funds assigned for all mission vehicles are processed in addition to a graphical illustration. A simple case of a statistical processing of data is shown in a following table.

5 Conclusion

The statistic characteristics of a failure-free operation of vehicles and particular groups and statistic characteristics of costs are used for application of theory of risks and solution of tasks related to issues of maintenance and logistics issues [9], [10]. The probabilistic reliability approach is the most widely used method for reliability analysis. The recent research shows that the reliabilities of structural systems strongly depend on the parameters of the probability model. It is possible that the little error in the estimation of the parameters may lead to the remarkable error of the resulting probability.

Acknowledgements

This publication was created in the frame of the project "Alexander Dubček University of Trenčín wants to offer high-quality and modern education", ITMS code 26110230099, based on the Operational Programme Education and funded from the European Social Fund.

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