USE OF A DISCRETE SIMULATION FOR AN ASSESSMENT OF THE MISSION COMPLETION FROM A VIEWPOINT OF MAINTENANCE COSTS

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ABSTRACT

An anticipated simulation is an experimental method of study, using probability dynamic approaches using experimentation with a computer model generated in Matlab. Simulation is seen as a process of a gradual building up of a mathematical and logical model described with computer algorithms of a simulation program representing a model of a reviewed system and subsequently experimentation with such a model aiming to obtain estimates of results of the system activity. There are many positive reasons why to perform a simulation study, as for example a missing analytic description of a system or an assessment of a capacity value of an existing system within other operational conditions. Major problems, rising in respect to a model implementation in a program, are recording the model structure, obtaining random parameter values, recording the dynamic features of models. Additional issues are added as experimentation with a model or development of resulting output in a suitable form.

1 ANALYSIS OF COSTS AND A RATE OF THEIR RISK

We used the distribution parameters obtained for simulation of the same numbers of values as it is for number of data we had processed and assessed. Through comparing we can see that results from simulation of an exponential distribution and Weibull distribution of probability match with hypotheses. Of course, they do not significantly differ with regard to the parameter of a shape of the Weibull distribution being close to 1 value.

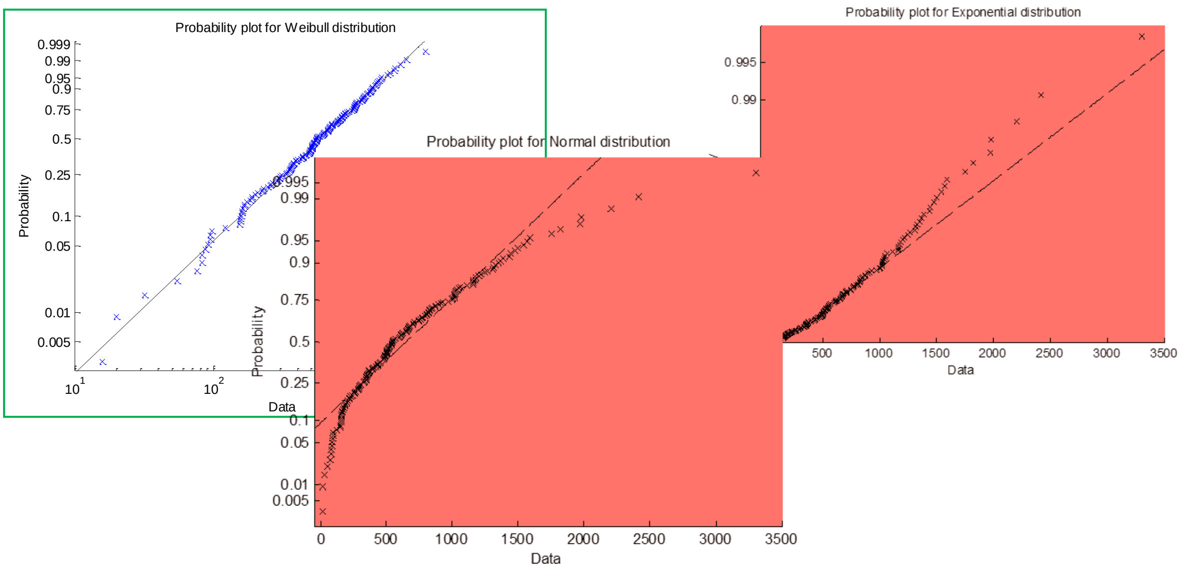

Figure 1. Verification of hypotheses for an exponential distribution from generated data.

Simulated values of a normal distribution with calculated parameters proved an assumption, that a standard deviation approaching to a mean value will cause an occurrence of negative values.

Hypothesis of a non-acceptation of a normal distribution was validated. We chose the most suitable hypothesis of the Weibull distribution of probability we had verified and stated parameters of probability distribution of input parameters for failure-less operation with a 99.9%, level of reliability

Maintenance costs for particular groups of vehicle statistically processed and they show the distribution parameters illustrated in the Figure 4 and Figure 5.
and courses of function for a probability of density and distribution function in the Figure 2 and Figure 3.

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 Figure 6 and Figure 7.

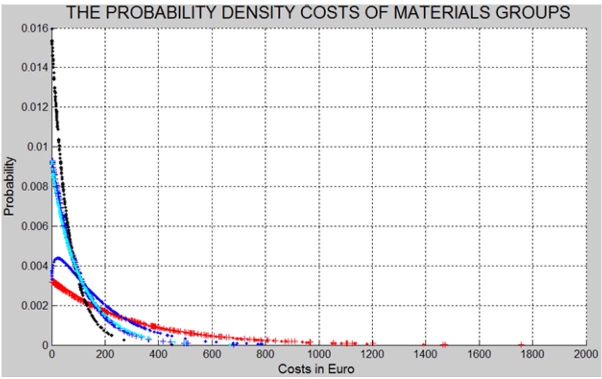

Figure 2. The probability of density costs of material groups

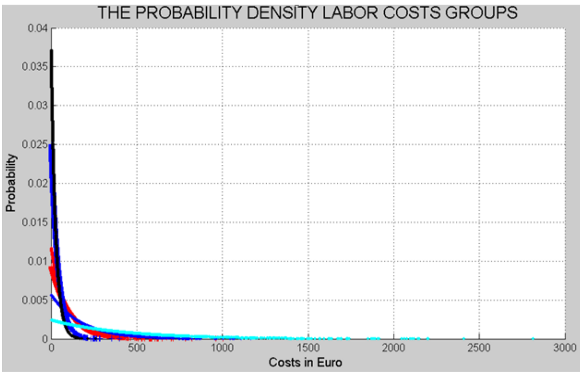

Figure 3. Probability of density of labor costs groups

At labor costs the order is electric installation, steering, gear system, an engine with systems, a braking system, body and a frame Figure 5.

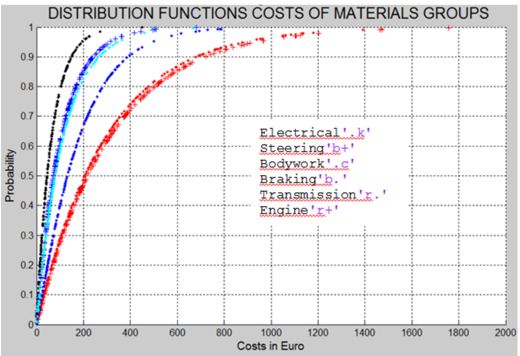

Figure 4. Distribution functions of costs of material groups.

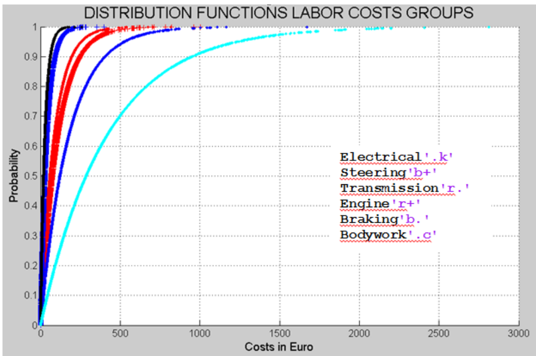

Figure 5. Distribution functions of labor costs groups

We use a function of density of a failure probability as a rise of a negative event – a failure and an amount of total costs as a result of an unfavourable event.

Visual expression of an intersection of these events gives us a notion about a rate of rise of critical situation. We can quantify this fact and to express it by probability of risk matrix.

We will use a distribution of a failure probability to generate a rise of a negative event – a failure and a distribution of a probability of costs to generate the amount of costs resulted from an unwanted event.

Graphic expression of an intersection of these events in a point of costs matrix and operation in hours provides us with a perception relating with quantification if a risk situation rises. Aggregations of their occurrence and their quantification on the legs enable comparing the risks from costs for maintenance of objects being assessed.

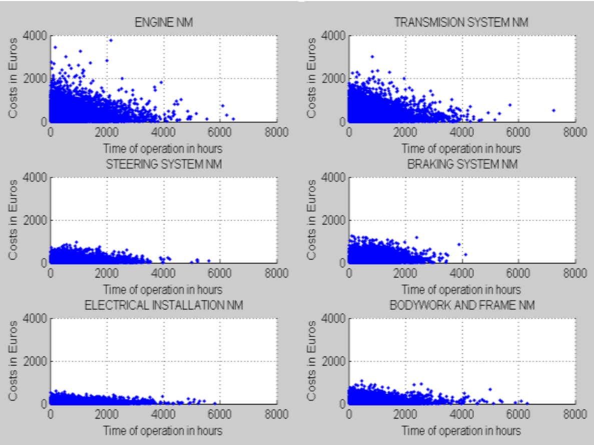

Figure 6. Probable risk matrix of costs of materials

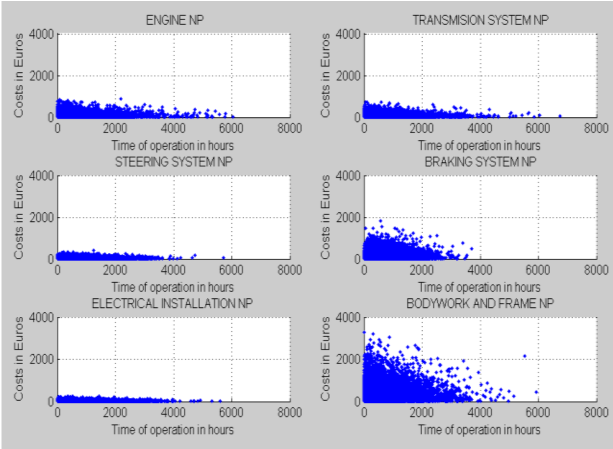

Figure 7. Probable risk matrix of labor costs groups

We can quantify this probability and to define it with a probability of elements, lines or columns of the risk matrix.

2. DISCRETE SIMULATION WITH A VARIABLE TIME STEP IN ASSESSING COSTS TO MISSION

A previous way of risk assessment resulting from costs to maintenance shows that it was made a provision for a whole life cycle phase. In some way it takes a time factor into consideration. 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.

Essence of simulation consists in performing of following activities:

1. Substitution of initial terms and specification of values of variables in an initial simulation time period.
2. Generating the intervals of rise of failures, maintenance period and amount of particular costs from probabilities distribution.
3. Shift of a time axis by a failure interval and a maintenance interval. Increase of costs amount by a generated value.
4. To collect and to process statistical methods on input and output parameters.
5. Testing of terms of simulation course completion. If a value of a simulation time reaches a TEND value having been defined in advance, a simulation course stops. Otherwise the activities in 2-4 points repeat.
6. Outputs of results on a display and a printer. Completion of a simulation experiment after having completed all simulation courses matching a number of vehicles being asessed.

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 is obvious from illustration of 5 simulations. Course and a way of displaying the simulation experiments is obvious from illustration of 10 simulations.

Parameter, distribution, input parameters
TBF Weibull *a= 676.1854287560616* *b= 1.0655900608402*
TTR Exponential *l= 6.974398734177213*
NM Weibull *a= 158.4948195963805* *b= 0.6430315567794*
NP Weibull *a= 52.33794187645434* *b= 0.7037168761996*

Figure.8 Parameters of input data

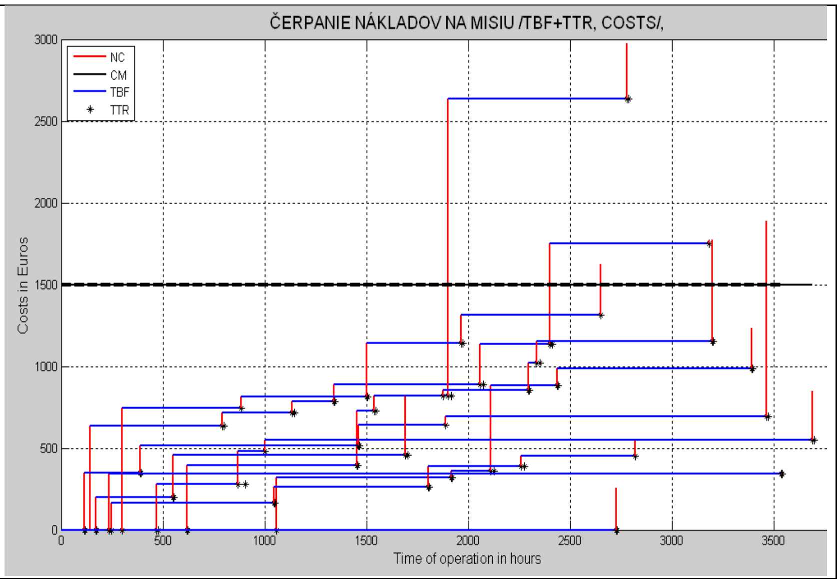

Figure.9 Course of simulation of 10 vehicles, probability of a mission completion is 0.8838

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 km illustrated 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.

Table. 1 Probabilities of mission completion with 6 vehicles in 10 simulation courses

SIM. COURSE	Probabilities of a mission completion with vehicles						
	1	2	3	4	5	6	MEAN
1	0.8472	0.6591	0.0891	1.1328	2.6407	0.8636	1.0388
2	1.0379	3.5237	0.7768	1.1540	1.3789	0.2427	1.3523
3	0.5262	2.4834	2.0140	0.4064	0.3243	0.1223	0.9794
4	1.0966	0.3014	1.0631	0.3395	0.3297	0.9167	0.6745
5	0.6773	0.3837	0.6154	0.5474	0.5136	1.0200	0.6262
6	1.6672	2.4367	0.5955	1.4356	2.6404	1.5050	1.7134
7	0.7552	0.4496	0.4994	2.4372	0.6153	1.8709	1.1046
8	0.5868	0.7583	0.7027	0.1376	2.4066	0.4078	0.8333
9	1.3435	0.7022	0.7442	0.7951	1.8390	1.3646	1.1314
10	2.6011	1.1555	0.3043	0.8724	0.2607	1.3646	0.8772

Table.2 Total statistical indicators of a mission simulation courses

SIM. COURSE	TOTAL STAT INDICATORS				
	MAX	MIN	MEAN	STD	MED
1	2.6407	0.0891	1.0388	0.8589	0.8554
2	3.5237	0.2427	1.3523	1.1328	1.0960
3	2.4834	0.1223	0.9794	1.0030	0.4663
4	1.0966	0.3014	0.6745	0.3894	0.6281
5	1.0200	0.3837	0.6262	0.2170	0.5814
6	2.6404	0.5955	1.7134	0.7423	1.5861
7	2.4372	0.4496	1.1046	0.8390	0.6853
8	2.4066	0.1376	0.8333	0.8030	0.6448
9	1.8390	0.7022	1.1314	0.4577	1.0693
10	2.6011	0.0692	0.8772	0.9392	0.5883
MEAN S	2,2688	0,3093	1,033	0,7556	0,7613

A more complicated case is illustrated in the following picture. It illustrates a course of a simulation experiment for 56 vehicles.

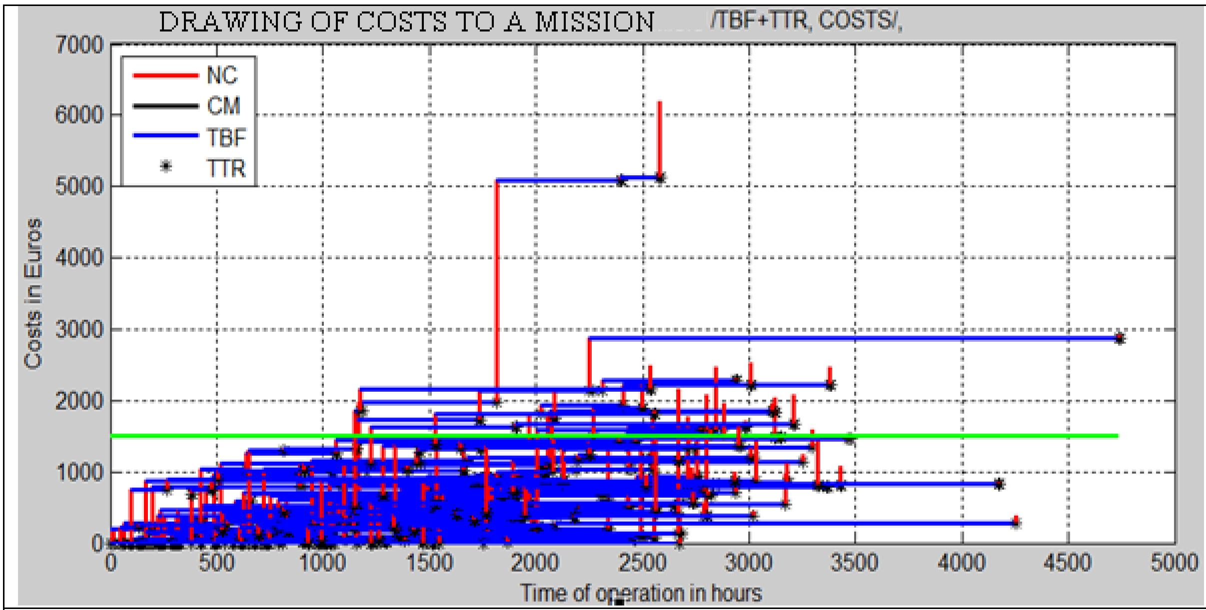

Figure. 10 Flowchart of a simulation experiment.

Probability that the vehicles will not exceed an assigned limit per a vehicle for a mission amounting 1500 Euros is 0.9894. Graphical illustration requires computer equipment with a large memory and a swift processor. If we remove the graphic we can assess and statistically process more simulation courses or to use other graphical means.

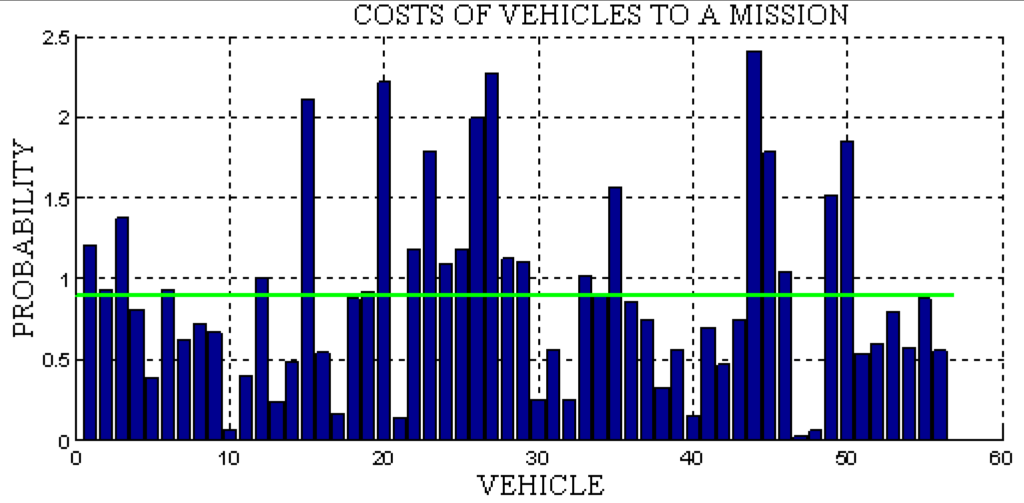

Figure. 11 Illustration of a simulation experiment with a histogram for 56 vehicles.

Probability that the vehicles will not exceed an assigned limit per a vehicle for a mission amounting of 1500 Euros is 0.8960. The largest possible number of simulation courses is needed for a serious assessment of results; the graphics is unable to provide suitable predicative information.

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In Table there are shown statistical results for an increasing number of simulation courses for assessment of 56 vehicles. Previous way of expression with tables as in a previous simple case is not possible. We are processing only aggregate statistical indicators.

Table.3 Processing of aggregate statistical indicators

Num.of sim. courses	AGGREGATE STAT. INDICATORS				
	MAX	MIN	MEAN	STD	MED
10	2.8555	0.0675	0.8561	0.6055	0.7102
100	2.9676	0.0725	0.8835	0.6191	0.7438
1000	2.9841	0.0717	0.8891	0.6221	0.7520
10000	3.0097	0.0720	0.8908	0.6239	0.7537

We can see that values of aggregate statistical indicators usually increase. It means and it proves that an affected area enlarges with an increased number of simulations as well as values of risk indicators. In taking the MEAN value into consideration ranging from 10 up to 10000 simulations by a value of 0,0347 i.e. 3.47 %.

3. CONCLUSIONS

The above mentioned outputs and data processing from the performed experiments result in the following conclusions. Statistical characteristics of a failure-free operation of vehicles, particular groups and statistic characteristics of costs are more suitable for an application of risk theory and solution of tasks related with maintenance, logistic problems than quantitative assessment or semi-quantitative methods of risk assessment. Mathematical modeling and simulation is for an analysis, modeling and prediction of random events in operation, maintenance, logistics, and risk assessment very favorable, first of all for a possible visualization and monitoring through graphical outputs providing better perception and display of stochastic processes.

In practice it is very difficult to take all system characteristics into consideration in a model. It can be caused by a fact, that there are many random variables entering into simulation or there exists incomplete knowledge and information about these events. Therefore we have to count for a certain rate of uncertainty, which is always present in defining a preliminary hypothesis. The hypothesis, being a base of a model and values of its parameters can lead to uncertainty in a general model of output that must be quantified on a realistic system statement. Expressed in a mathematic way, a probability of a system failure can be expressed as a multi-dimensional integral. However a risk assessment requires realistic modeling of structures and mechanical parts of a system and comprehensive modeling of particular states representing behavior, loading conditions and mechanisms of defects and failures, we anticipate, that will rise during system lifecycles.

Thanks to performance, flexibility and a relatively easy use the simulation program, or software is a popular and an efficient tool in a wide range of areas. A next advantage is a possible application of mathematical and logical data expressing flowcharts and activities of elements of a system being modelled (with respect to a simulation goal) or substitution of complicated and unknown relations and procedures. Random influences are included in form of probability characteristics, time included of course. The model enables repeated calculations and adjustment of input data. We believe, that this paper will inspire for improvement of standard methods of research in a submitted issue.

4. REFERENCES

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