MATHEMATIC AND SIMULATION MODELING FOR ANALYSIS PREDICTION OF RISK

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ABSTRACT

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.

1 GENERAL INSTRUCTIONS

The results of a simulation modeling provide for an intuitive perception on an implementation of small numerous events and on an approach to risks. It is obvious if we research them and implement in a large amount of simulation runs and so a long period of operation of mobile assets will approximate to statistic results. 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. 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. 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.

1.1 Type area

However in technical areas by scientific approaches we can obtain assessments of probability of a rise of an unwanted event and data on its consequences that can be statistically processed and evaluated with rule of distribution of a random variable of a reviewed of an assumed event. In the same way we can express statistically other factors as well, e.g. time exposition, i.e. time period when the conditions last to generate a negative event or a value of an opportunity for application of protective measurements in stage of a threat.

That is an approach of a stochastic expression of a risk that can be used. Stochastic optimization issues utilize results of analyses in the final stage of solution. The input data of risk and influencing factors are real ones, their quantification through distribution of random variables complies with reality and the risk assessment and measures are quantified. The assessment algorithms are based on statistic results. In addition to a basic definition of a risk from a cause and consequence, we can statistically express additional factors, e.g. time exposition, i.e. time period of lasting conditions for a rise of a negative event and eventually a value of a possibility to apply protective measures in stage of a threat .

Then a risk function will look as follows:

$$R(t) = f / P(t), D(t), E(t), O(t), \ldots\ldots\, Z(t) \tag{1}$$

where:
R (t) ... risk,
P (t) ...probability of a rise of an unwanted event,
D (t) ... probability of a consequence,
E(t) ... time exposition /time period of lasting conditions for a rise/,
O (t) ... application of protective measures in stage of a threat [5].

The risk of meeting a mission supposing a fulfillment of transport tasks depends on:
- An anticipated drawing of operating units /overrun in kilometers, operating hours, time of operation,..../ vehicles,
- Failure-less operation of vehicles,
- Funds assigned,
- Maintenance provision.

Provision of readiness supposes an adequate volume, amount of funds.
The sources are allocated in the categories:
- Material costs
- Labor costs

Total costs are an aggregate of previous sources.

In practice there exist many probability models of distribution of random values being used in description of particular practical problems. For continuous values there are e.g. exponential, normal (Gaussian), regular, Student´s, Fisher – Snedocor´s Weibull and other distributions. For discrete random values there are e.g. alternative, binomial, Poisson, hypergeometric distributions. We statistically evaluated data on failure-less operation and on costs. From the results we defined hypotheses of research of a probable distribution of probabilities. There were used hypotheses of a normal distribution, exponential distribution and Weibull distribution of probability. 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.

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.

2 THE ELEMENTS OF THE MATRIX

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. 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.

2.1 Simulation capabilities risk matrix

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. Burst of appearance and their quantification enables comparing of risks and costs for maintenance of objects being assessed.

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.

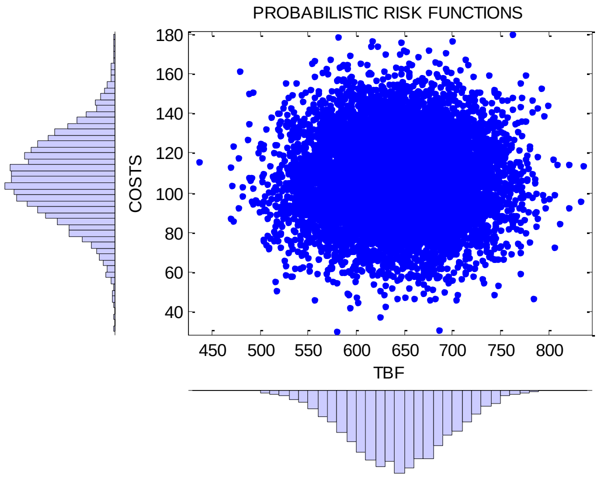

Figure 1. Display of an intersection of phenomena and frequency diagrams for 10000 simulations

2.2 The possibility of risk analysis

Risk analysis is a technique used to identify and assess factors that may jeopardize the success of a project or achieving a goal. This technique also helps to define preventive measures to reduce the probability of these factors from occurring and identify countermeasures to successfully deal with these constraints when they develop to avert possible negative effects.

- Categorize each hazard, threat, or peril according to how severe it is, how frequently it occurs, and how vulnerable you are.
- Develop strategies to deal with the most significant hazards, threats, or perils.
- Develop strategies to prevent hazards, threats, or perils that impact or might impact your organization and its people, operations, property, and environment.
- Develop strategies to mitigate hazards, threats, or perils that impact or might impact your organization and its people, operations, property, and environment.
- Develop strategies to prepare for hazards, threats, or perils that impact or might impact your organization and its people, operations, property, and environment.
- Develop strategies to respond to hazards, threats, or perils that impact or might impact your organization and its people, operations, property, and environment.
- Develop strategies to recover from hazards, threats, or perils that impact or might impact your organization and its people, operations, property, and environment.

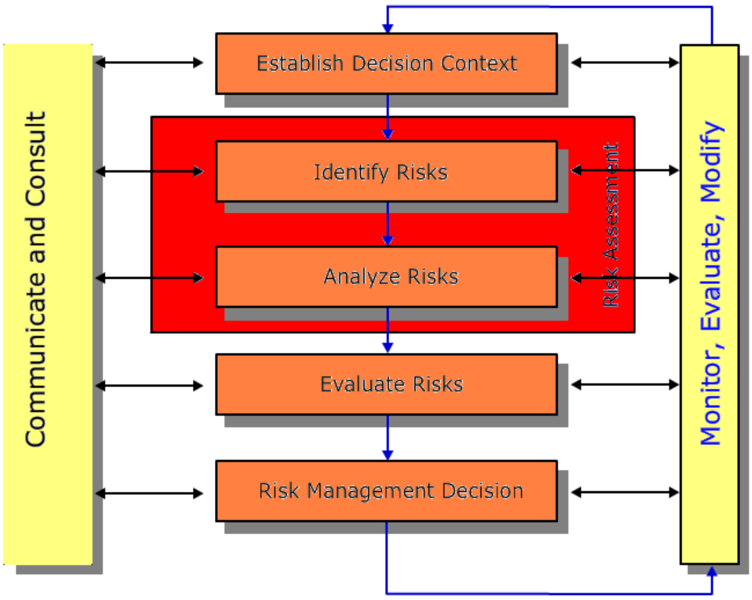

Figure 2. The risk assessment process

In case of a two-dimensional area described by vectors of a simulated probability of probability density we can change a scope of an acceptable risk of both participating functions through defining the quantiles. 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: $\boldsymbol{P = \frac{n}{N}}$ (2)

where

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

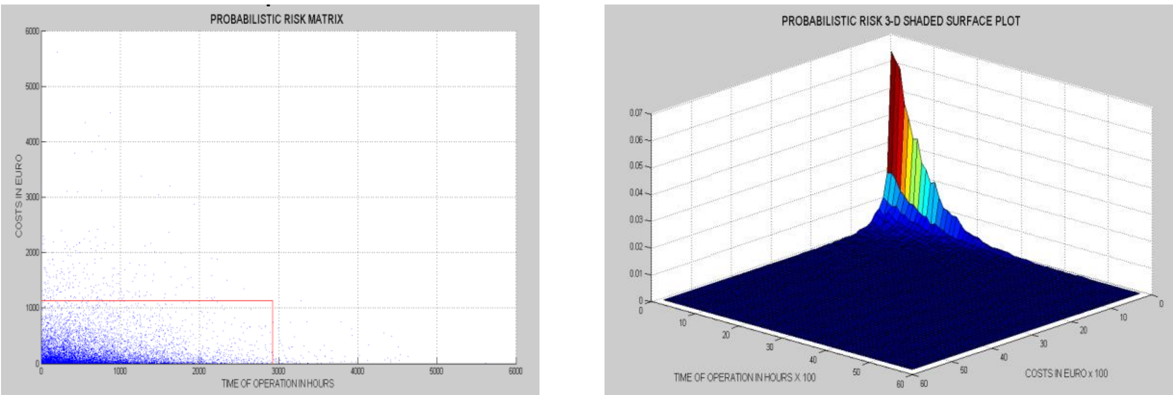

Figure 3. For example calculated values for 99 percent quantiles for 10000 simulations

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.

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.

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

With an increased number of simulated events, representing a longer distance of kilometres driven, the ranges of affected risks increase as well.

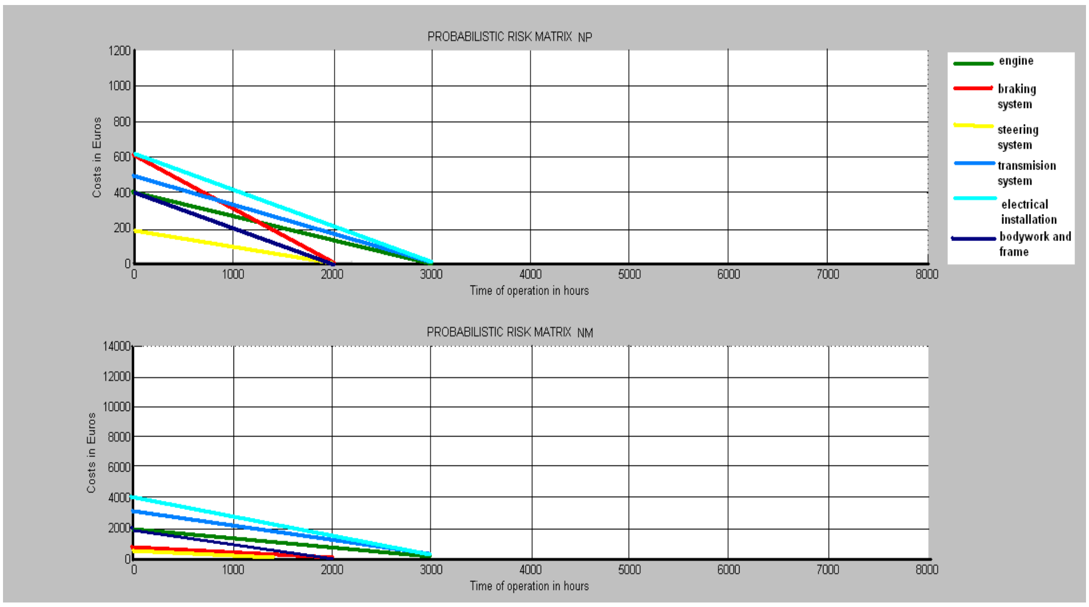

Figure 4. Probablistic risk matrix

Risk matrices are widely used in risk management. They are a regular feature in various risk management standards and guidelines and are also used as formal corporate risk acceptance criteria. It is only recently, however, that scientific publications have appeared that discuss the weaknesses of the risk matrix.

A sense of a mathematic expression of an availability factor has been supported, that relationship between reliability and maintainability expresses possibilities of an increase of availability of designed and operated devices that interfere with technological limits of periods when the activities are performed. Availability can be increased practically only through shortening of intervals of components of the device maintainability that interferes with technological limits of the action being performed. Asymptotic availability of a terrain vehicle is lower than the availability of groups, it becomes stabilized on 0.958- 0.966 level.

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.

3 CONCLUSIONS

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.

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