MODELING AND PREDICTION OF RANDOM EVENTS IN MAINTENANCE, LOGISTICS, AND RISK ASSESSMENT

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Abstract
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.

Keywords: risk, availability, maintenance, reliability

1 Introduction

Modelling allows comparing of existing maintenance system with a proposed system and to evaluate benefit of a proposed maintenance system based on using individual maintenance men, exploitation of individual machines, time period of machines waiting for repair, time period of repair of particular machines for the reporting period. Simulation is aiming to find an optimal number of personnel providing the maintenance.

2 Quantitative and qualitative methods

Method theory can be divided into two main categories; quantitative and qualitative methods. Olsson & Sörensen (2007) argues that both of these types should be characterized by objectivity in order to be reliable. This means that standpoints and conclusions should be based on factual arguments, which can vary in the qualitative method. The quantitative method examines actual conditions by which data gathering often can be analysed first hand. All workshops and interviews performed during the project have been performed qualitatively. The qualitative method has been used to get an overall picture of the processes at CCES and has been based upon open-ended questions. A negative aspect of the used method is that information and data gathered can be biased by personal opinions. Statements and conclusions which rather would rest on factual argument can therefore vary in the qualitative method[1,3].

Reliability and validity are two conceptions usually used when talking about how trustworthy and useful collected data and information is. According to Burell & Kylén (2003), to obtain data with high reliability it is required that chosen methods are structured in such a way that collected material provides constant data. Validity denotes to the usability of the data and determines whether it fulfils the purpose of the work. To increase the validity, it is important to specify the purpose of the collection. Complications which may be associated with the collection of data can be that the material has a high reliability but unfortunately is impractical for the work. On the other hand, useful information can be unreliable which in return can result in inaccurate and misleading conclusions.

There are many potential sources of risk to a project, both internal and external, as illustrated in Figure 1 (Figure 1 is not a comprehensive list of all risk sources). The paper addresses risks that arise from technical sources, both internally and externally sources.

Risk management is a continuous process that is accomplished throughout the life cycle of a system. It is an organized methodology for continuously identifying and measuring the unknowns; developing mitigation options; selecting, planning, and implementing appropriate risk mitigations; and tracking the implementation to ensure successful risk reduction. Effective risk management depends on risk management planning; early identification and analyses of risks; early implementation of corrective actions; continuous monitoring and reassessment; and communication, documentation, and coordination [5,7].

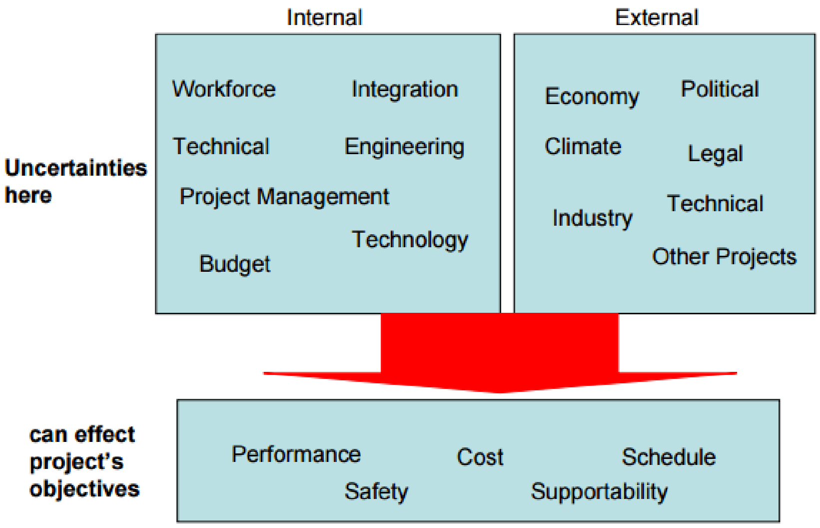

Fig.1 *Sources of risk*

2.1 Risk assessment and impact analysis, the elements of matrix

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 [2].

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 [4].

2.2 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 [6].

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.

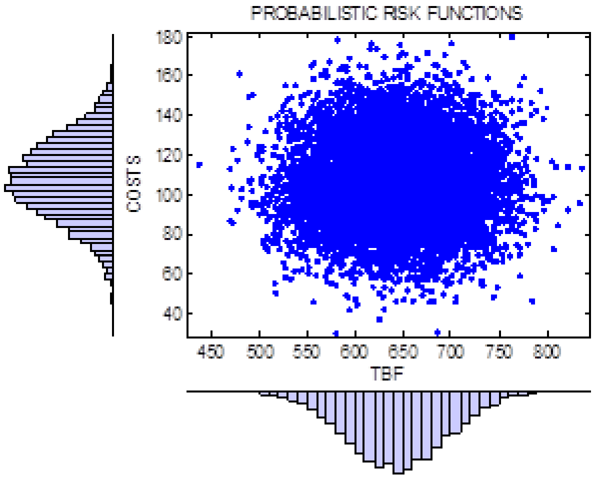

Fig. 2 *Display of an intersection of phenomena and frequency diagrams for 10000 simulations*

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 [10].

Probability analysis overcomes the limitations of sensitivity analysis by specifying a probability distribution for each variable, and then considering situations where any or all of these variables can be changed at the same time. Defining the probability of occurrence of any specific variable may be quite difficult, particularly as political or commercial environments can change quite rapidly. As with sensitivity analysis, the range of variation is subjective, but ranges for many time and cost elements of a project estimate should be skewed toward overrun, due to the natural optimism or omission of the estimator.

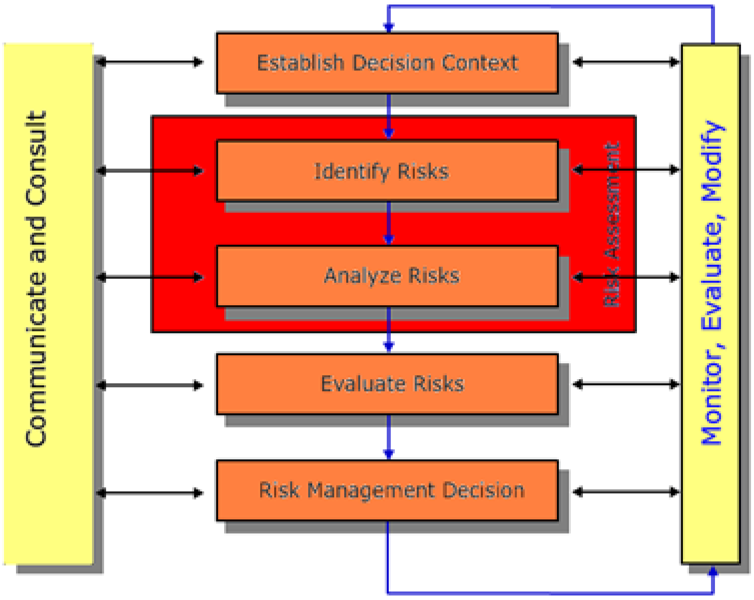

Fig. 3 *The risk assessment process*

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. 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.

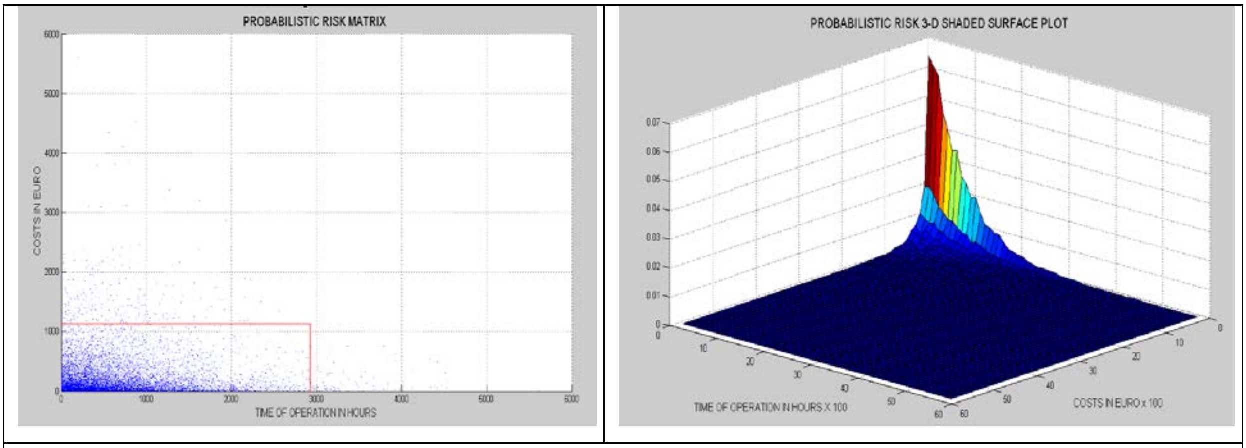

Fig. 4 *For example calculated values for 99 percent quantiles for 10000 simulations*

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.

3 Conclusion

The risk evaluation of technical systems and processes is often a very difficult task. Risk is defined as a function of the probability and the extent of damage. Risks occur in various forms for all possible systems: damage to machinery, injury to persons or environmental damage, as well as economic damage resulting from the payment of damages or loss of reputation. Risk analysis was originally intended for investigation of the damage caused by a complete system, but there is no reason in principle why it should not be used on subsystems in cases where the resulting damage caused by failure cannot be directly observed [8].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 [9]. 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.

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