Practical Approach to Criticality Assessment

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ABSTRACT

Throughout our career, while working in several different companies, it appeared apparent that every man has his own explanation of the term "criticality", no matter if the company was from petrochemical, energy or automotive industry. Moreover, every man believes that his understanding of that term is the only correct one. Criticality is often used as the most important factor in the decision making process about maintenance strategy, spare parts purchases etc. There is currently no existing definition which can explain criticality in a general way, hence this paper was made to show the different points of view on this term.

This paper presents the practical multi-criterion criticality approach and offers a solution of how to make calculations/evaluations of criticality more universal.

Keywords: Criticality, decision making process, maintenance optimization.

1. INTRODUCTION

The initial impulse to write this paper was the number of encounters when managers asked to make the maintenance process more efficient. The main idea of managers was to save money and they expect more money saving might happen when the optimization process affects more expensive equipment, hence planning of the maintenance should start there. During the economical evaluation of a single machine was found that more expensive machinery is usually more expensive in all types of costs (purchasing price, maintenance cost, operating cost, but also its influence on the related technology). Moreover, more expensive machinery usually has more sophisticated maintenance strategy and it is more difficult to reduce the operational and maintenance costs. When the cost factor became apparent, the last remaining question was to define the criticality of an equipment in such a way that one single indicator would reveal the potential (in)efficiency of the equipment and this would lead to optimization of the equipment's maintenance. The optimization process would take into account more types of economical savings.

The suggested multi-criterion approach to the criticality assessment is based on the authors' many years of experience in different industry sectors. The authors also improved maintenance and operational cost optimization, health & environmental risk reduction and functional safety aspects.

Another key term is "Risk" as "Risk" and "Criticality" correspond each another, however the definition of "Risk" is not unique. For the purpose of this text "risk" will be understood as combination of the probability of an unwanted event and its potential losses. To allow comparison of several different risks it is necessary to convert "risk unit" to the standardized form. It seems to be appropriate to have a unit of risk expressed in a monetary value of 1 EUR per 1 year [1].

2. SPECIFICATIONS

This section describes some points of view to the term criticality based on commonly available literature and on the experiences of the author..

2.1 Criticality in standardization

The fundamental dependability standard IEC 60050-192 [2] defines of criticality of a fault or a failure as a severity of an effect with respect to specified evaluation criteria. This definition suggests that an item (defined as a rotating machine - pump, compressor - as well as whole production unit) may have more than only one criticality and its criticality depends on "specified evaluation criteria". Furthermore the definition suggests that criticality depends not only on the failure, but also on the fault itself, that results from the failure. The main aspect of the fault state which would affect equipment's criticality is the time the item will not be able to perform as required and the corresponding repair costs. The following section describes criticality in more practical and detailed view.

2.2 First type of criticality – safety

It is very trendy and popular to say "safety first" these days, it is only logical that an item must be safe (and secured), but the level of its safety is the matter of many different factors. First of all safety is always evaluated as potential health damage in case of MMI (man-machine-interaction), so in case of automated equipment without the operator no health damage may occur, if all SOPs (Standard Operating Procedure) are adhered to. Different situation occurs when maintenance is scheduled, in that case an interaction between human and machine is usually inevitable. This is a short-term interaction and quite often it is an interaction with so called "dead machine". Dead machine is described as a piece of machinery without any energy inputs. For example ISO 13849 [3] defines the safety level as the potential severity of consequences and the possibility of avoiding an unwanted event. The severity of an injury and the possibility to avoid the event causing the injury might be affected by the usage of personal protective equipment, appropriate marking of dangerous equipment's parts or by administrative actions such as by writing good and understandable service instructions and SOPs (Standard Operating Procedures). These reasons lead to the fact that safety as a point of view has to be taken into account, however it can be influenced in other ways than just by maintenance and therefore it is difficult to decide about the maintenance optimization based on this single criterion.

An additional problem remains; how much money is appropriate to invest into the safety acquisitions of every single item? An equipment manufacturer, owner, operator (not the operative) must eliminate all health hazards, but only to the level of elimination where it is economically viable and technically possible. This paper does not deal with the economical evaluation and impact of health risks resulting from the operation of any technology, however, it is necessary to stress out here, that not all of the potential hazards can be eliminated with 100% certainty and some residual risk remains. It is a matter of management to say how big the level of the residual risk is and it must be in alignment with the legislative limitations [4].

The same approach as described above for the safety area can be used in case of an environmental exposure by the fault or failure of the operated technology. Surely every operator wants to operate his technologies without environmental hazard, but some technologies do not make it possible to eliminate environmental risks with 100% certainty. As can be seen, the criterion of an environmental exposure is not suitable as the main criterion for the money saving maintenance optimization decision making process.

2.3 Second type of criticality - affecting of related technology

Some machines may cause disruption of a related technology in case of their failure or fault. One can imagine such a disruption would be caused by the loss of main functionality of an equipment, but many times a disruption is caused by a false action of safety system (so called "safe failure/false failure"). These false actions mean that safety system stops its process although no reason occurred, simply due to the failure of safety system. The severity of such a problem is usually dependable on the number of components the safety system is created of. Anomaly is when a safety system may be able to perform its main function even in the case of the safe failure/false failure. On the other hand, individual components or whole groups of them in safety related systems may be multiplied (multi channels) to decrease the potential risk of malfunction in case of unwanted event occurrence. This can also decrease the number of safe failures and therefore the number of following technology stoppage.

It is evident that limiting of the criticality evaluation only to the losses from the stoppage of the related technology would be a mistake. Nevertheless the position of the evaluated item in the production process and consequences of its failure to the related technology is important input into the criticality evaluation process. All the factors mentioned above influence the importance of the equipment maintenance, therefore system maintenance should reflect on it. That means two identical items (pumps, pipelines, etc.) might be maintained in different ways, although both maintenance strategies would be optimal. This depends on the position of these items in the production process.

2.4 Third type of criticality - equipment without maintenance

The initial state of the optimization process is usually so called "zero state", what means the state without any type of preventive maintenance, just with breakdown maintenance. The idea of this strategy is quite simple - managers want to know the ROI (Return on Investment) of the analysed equipment maintenance, i.e. how much money they will save as a result of the failure rate decrease [5]. The basic problem of this strategy is also clear and simple - no industrial plant would test the failure rate of operated equipment without maintenance, so the input data are highly uncertain. The most uncertain value is the mean operating time between failures.

On the other hand, one must say that the comparison of the non-maintained equipment/component annual risks may reveal the "critical" equipment, which would cause the biggest annual loss in case of no maintenance. Such an argument can be used against the management pressure to the decrease the maintenance budget. Optimization of maintenance means looking for the cheapest maintenance plan when the sum of maintenance and operational costs is the lowest. In case of a limited maintenance budget, it is possible to postpone the maintenance of a non-critical equipment for a few weeks/months. Searching for the most suitable equipment for the postponed maintenance is matter of searching for the equipment with the lowest risk increase when its maintenance is cancelled.

2.5 Fourth type of criticality - equipment with existing or recommended maintenance

Similarly to the previous type of criticality this type of criticality may be used for the equipment with a known maintenance. In this case, the costs are in fact the sum of two types of costs (per identical time interval, e.g. 1 year). The primary type of costs is the one that represents a preventive/regular maintenance, the secondary type of costs is the one that represents residual risks of failure when providing preventive/regular maintenance. Both types of costs can be added together as they have the same representative value (e.g. 1 Euro per 1 year).

The comparison of summarized total cost of equipment maintenance can be used to rank the equipment based not only on the cumulative cost, but also on the cost of risk of an equipment without a maintenance (paragraph 2.4). As a result once can evaluate the economic efficiency of such each action.

2.6 Fifth type of criticality - the sum of maintenance and operational costs

The fifth type of criticality might by defined as the total sum of all costs that equipment withdrawn from the budget to perform its function. It is important to focus not only on the aspect of the failure rate but also to the aspect of costs regarding to the equipment's operation such as electricity, scheduled catalyst replacement, etc. These operational costs are the integral part of the total costs of operation and maintenance, therefore it is suitable to take them into account. In reality, the company's budget is often divided between operators and maintenance staff.

2.7 Sixth type of criticality - ratio between the costs of maintenance, operation and the purchasing costs

Generally it is not suitable to compare absolute value of costs. It is evident that a simple equipment like a thermocouple usually has much lower cost than more complicated equipment such as a pump even though the small equipment may suffer from faults more often. It is possible to standardize total costs of equipment's maintenance and operation by the purchase price of the equipment to minimize these inaccuracies. The criticality will be then a non-dimensional quantity, quite similar to the risk priority number well-known from the FMECA (Failure Mode, Effect and Criticality Analysis). Such a criticality value would be used for a comparison of different items from asset register and it might identify these items with the biggest criticality regardless their purchase price. Pareto principle can be used in this procedure to analyse the group of the most critical equipment to find the starting point of the economic cost optimization of the whole asset register.

2.8 Decision making process

Managers need to make a decision based on the good knowledge of the problem [6], [7], however time can be critical, moreover these two factors are contradictory. The Table 1 below summarizes the information from the previous sections into a semi-quantitative matrix, where the rank represents the criticality for the same equipment based on the type of criticality.

The last row of the table above (Overall Criticality Control Sum) contains three different values. The first value (number 1.0) is a control sum of all weight coefficients defined by the manager and must be always equal to 1. The second value (number 3.5) can be understood as weighted value of equipment's criticality, which allows to sort the whole list of equipment (asset register) by this attribute. Last number is again just a control sum. The most important is the second value (3.5) which is fully dependable on the semi-quantitative rank and the weight coefficient assigned to the particular type of criticality by the manager. A graphical representation of values from Table 1 can be seen in Figure 1 as a radar chart.

Table 1: Semi-quantitative evaluation of all criticality types

Criticality type	Semi-quantitative ranking of criticality for the same equipment (1-10)	Weight coefficient	Proportional amount of a particular criticality on the overall criticality	Proportional amount of a particular criticality on the overall criticality [%]
1st criticality - Safety	7	0.1	0.7	20.0
2nd criticality - Affecting of related technology	5	0.2	1	28.6
3rd criticality - Equipment without maintenance	2	0.5	1	28.6
4th criticality - Equipment with maintenance	6	0.05	0.3	8.6
5th criticality - Sum of maintenance and operational costs	1	0.1	0.1	2.9
6th criticality - Ratio between maintenance and operational and purchasing costs	8	0.05	0.4	11.4
Overall Criticality Control Sum		**1.0**	**3.5**	**100.0**

The values of each criticality can be presented in different units. At the picture above the values are non-dimensional numbers from the interval <0, 1>. The comparison of more criticalities one must obtain the area delimitated by the chart; in mathematical jargon it is equal to the integral of the function. To make it simpler one can sums up the weighted values of all types of criticalities (in this case the number 3.5, mentioned in Table 1). Due to the fact that all input parameters of the criticality calculation are real values in fully-quantitative forms, e.g. production loss [EUR, resp. EUR/h], MTBF [h, year], MRT [h] etc., it is efficient to make quantitative evaluation first.

The values can be transformed into semi-quantitative ranking of criticality if needed.

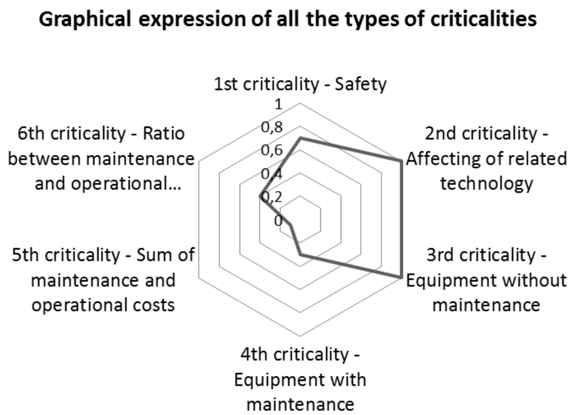

Figure 1: Radar chart of criticality

Similar approach can be used in different branches where exact decision making is not possible. This way is applied for criticality evaluation of critical infrastructure components, for example [8].

3. CONCLUSIONS

This paper showed different points of view of the term criticality and suggested a practical approach to criticality evaluation. The presented principle is generally valid and it depends on the manager what weight coefficients will be used for different types of criticality.

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