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## ESTABLISHING THE ACCEPTABLE RISK LEVEL IN OCCUPATIONAL ACCIDENTS AND DISEASES BASED ON A FORMAL ANALYSIS

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### Abstract

The occupational safety is that state of the working system where there is no possibility that occupational accidents and diseases should occur.

Considering the specific features of the component elements there are no such full safe working systems for men because there is always a hazard of occupational accidents and diseases.

Generally speaking, all the component parts of the system, together with the relations built among them have been conceived, designed and produced so that there is no possible occurrence of occupational accidents and /or diseases; nevertheless, the carrying out of the working process shall wear out these component parts. In addition, no matter how well the performer may be selected, his behavior cannot be taken into consideration because it depends on the variables of his momentary state of mind.

*Key words:* acceptable risk level, cost, formal analysis

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### 1. Introduction

Each real system displays a wider or narrower deviation from the ideal state of occupational safety. This deviation shall be in the long run in relation to the status and evolution of the component elements of the system.

Consequently, the optimum shaping of the occupational safety in a working system involves the following targets: a permanent awareness of the deviation magnitude; establishing the maximum accepted deviation from the ideal state; correcting the magnitude of the deviation and bringing it to the maximum accepted limit by preventive and protective measures.

Establishing the magnitude of the deviation means an evaluation of the occupational health and safety risk i.e. establishing the real amplitude of this status.

If the overall costs of the occupational safety (made up of the following elements: costs involved

by the risk study reports and by the safety gears – a priori costs – and costs related to the results of occupational accidents and diseases – a posteriori costs) are taken into consideration, an „economically” reasonable value can be established, by considering the previously evaluated levels of the residual occupational lack of safety and the investment costs and the costs related to the efforts made to rehabilitate the working system that has been damaged.

### 2. Experimental establishing the background for the occupational risk

Starting from the idea that there are no absolutely safe working systems, it has to be established the extent to which the occupational safety of the system is acceptable, considering the possible occurrence of occupational accident and diseases.

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In order to be able to adopt a decision, it is necessary to get a means to express occupational safety, which should meet two conditions:

The highest possible level of impartiality;

It should allow comparison among different status of the some system, as well as among different working systems.

These two conditions can be observed when an iterative correlation is identified, irrespective of the specific parameters of real situations, between a quantitative or qualitative dimension and the extent to which there is no probability of occupational diseases or accidents.

As the absolute quantitative indicators basically provide a more impartial expression compared to the relative quantitative ones and to the qualitative indicators, the ideal situation is to establish a quantitative dimension („level of occupational risk”) that can be expressed by the same value for all the systems that provide the same safety level. During practice, there has to be considered a minimum occupational risk, i.e., a level of this risk distinct from zero, but sufficiently low to consider the working system as safe, and a maximum limit of occupational risk that should be equal to such a low level of occupational safety so that the operation of the system is no longer allowed.

Consequently, in order to establish these limits it is necessary to find a means to quantify the occupational risk and the levels of occupational risks. This operation gives two problems:

- the manner used to establish the coordinates of the occupational risk (the pair between seriousness probability);
- what coordinates for the occupational risk are to be selected in order to part the acceptable areas from the unacceptable ones.

According to the literature on occupational health and safety (Kaplan and Garrik, 1981; Moraru and Băbuș, 2000; Vasilescu, 2008), risk is the combination between the probability of occurrence and seriousness of a possible injury or health damage during a hazardous situation and shows the frequency and seriousness of possible consequences which may come up during a working process.

In order to describe risk in relation to seriousness and probability, IEC 812 defines a “curve of acceptability” (Fig. 1) which is a decreasing exponential that allows a division between the acceptable risk and the unacceptable risk. In compliance with this idea, the risk of occurrence for an event  $E_1$ , with serious consequences but low frequency, situated under the curve of acceptability, is considered as acceptable, while the risk posed by the event  $E_2$ , with less serious consequences, but with a higher probability of occurrence, located above the curve, is considered as unacceptable.

Consequently, the occupational risk can be expressed as:

$$R_{\text{occupational}} = f(P_{G_{\text{max}}}, G_{\text{max}}) \quad (1)$$

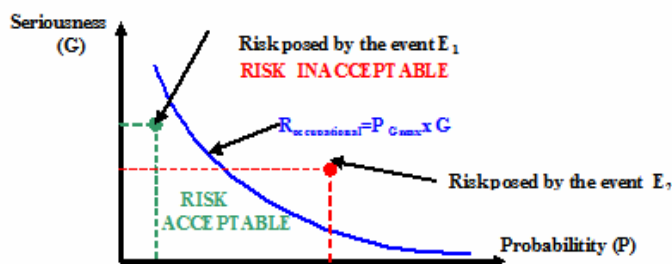


Fig.1. Risk acceptability curve

where:

$R_{\text{occupational}}$  = occupational risk related to hazards for occupational accidents and diseases;

$P_{G_{\text{max}}}$  = probability of occurrence for risk of occupational accidents and diseases;

$G_{\text{max}}$  = seriousness of the maximum envisaged consequence due to the occurrence of the occupational risk.

The values on the ordinate of the curve are symbolically, but they can be individualized as values expressed in financial losses (money) or human and material damages expressed from a quantitative point of view etc.

The study of the risk acceptability curve gives the relative nature of „acceptability”; consequently, it can be noticed that the unwanted events with a „high seriousness but with a very low probability of occurrence” are accepted the same as the unwanted events with „low seriousness but high probability of occurrence”, because the values of the former situate under the curve.

A risk study can answer to several questions:

- *What might go wrong?*
- *What can happen?*
- *How often does it happen?*
- *What might the results be?*
- *What can be done so as to avoid?*

As an evaluation assigns real values to hazards on occupational diseases and accidents, it is possible to establish a risk level for the working process which relates to a certain activity; this risk level can be subsequently compared to the acceptable occupational risk but for grounding a decision, it is necessary to define „acceptable”.

Whether the acceptable occupational risk represents a level of risk admitted by a social agreement based on the experience gathered, on occupational safety for a certain type of activity, this notion shall have to comply with the results and benefits.

The mechanism regarding the material and human efforts necessary for providing occupational health and safety depends on the ratio between acceptable and unacceptable and the accuracy for establishing this ratio gives the success of the implemented measures.

As a result, the experts in occupational health and safety work to improve and multiply the

methods used to evaluate the occupational risk and to classify the criteria that establish the acceptable occupational risk.

Until now, there have appeared two trends regarding the efforts to establish the acceptability of the occupational risk:

- a - Taking into consideration the cost of human life;
- b - By comparisons to other occupational risks that have already been accepted or which cannot be avoided.

Things get more complicated if the factors that influence the level of acceptance (costs, level of influence, safety level, usefulness etc.) are taken into consideration, because these factors have a strong subjective character.

Practice hasn't imposed unanimously recognized models regarding the establishment of the acceptable occupational risk. This operation remains the responsibility of the factor that takes the management decision.

Estimation, evaluation and control of the occupational risk represent prerequisites for grounding and for a continual support of the decision that has been previously taken on occupational safety in a working system; envisaging unwanted events is being determined by the occupational risk and is expressed by the ratio between the possible occurrence of occupational diseases and accidents (which displays a random character) and the total amount of available resources with the view to providing a suitable occupational safety.

### 3. Results and discussion

#### 3.1. Graphical presentation of the risk for occupational accidents and diseases

For the case of a working system (Desroches, 1995; Matei et al., 1996), the acceptable risk is an indicator used to evaluate the level of occupational safety; it represents the results of a decision implemented objectively, by comparing to the known and agreed risks of occupational accidents and diseases. Several domains use the notion of admissible risk or limit risk.

Establishing the acceptable risk means a compromise between the issues agreed by the responsible body from an economic point of view when this one takes a priori in consideration the occurrence of occupational accidents and diseases risk (together with the occupational safety measures that should be implemented) and the expenses that shall have to be recovered a posteriori whether the occupational risk has been ignored, considering the following elements (Drăghici, 2007).

- The cost related to the removal of human and material damages;
- The cost involved by the unavailability of the system;
- The impact in the mass - media.

- By taking into consideration the fact that overall costs involved by the occupational safety cover the following elements:
- The costs of the risk studies and of the safety devices (a priori cost).

The costs related to the consequences of occupational diseases and accidents (a priori cost), it is possible to determine an „economically”, reasonable value, with the consideration of the residual occupational levels of unsafeness that have previously evaluated and of the investment costs and the costs related to the efforts made to rehabilitate the working system after the accident.

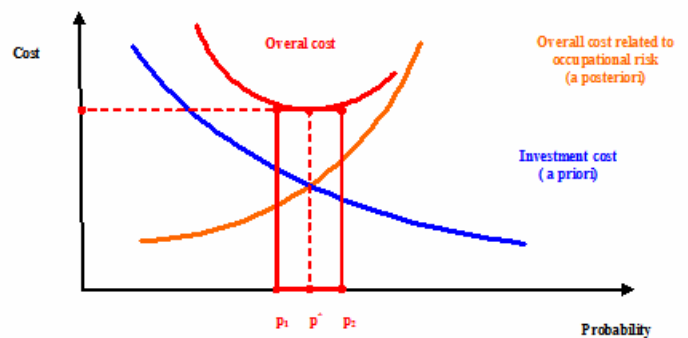


Fig. 2. Principle presentation of the acceptable ( $C_0$  – minimum cost;  $p^*$  – optimal probability;  $[p_1 p_2]$ – acceptable occupational risk level)

Fig. 2 shows the principle for the presentation of the jeans used to establish the economic optimum, by comparing the probability for the occurrence of unwanted events (such as the case of occupational accidents and diseases) to the accepted level of occupational unsafeness.

#### 3.2. Establishing the acceptable level of occupational risk, starting from the criterion of the cost price

It shall be formally analyzed the function related to the cost price which is being established in relation to the probable occurrence of occupational accidents and diseases; this represents the manner used to establish this function for the condition of minimum (Drăghici, 2007).

The overall cost price  $C$  (shown in Fig. 3) is made of the a priori cost related to investment cost  $C_1$  and the a posteriori cost related to the (occupational and technologic) risk, so that:

$$C = C_1 + C_2 \tag{2}$$

$$C_1 = C_{1const} + C(p) = C_{1const} + C_1/p \tag{3}$$

$$C_2 = C_{2const} + C_2 p \tag{4}$$

$$C = C_{1const} + C_{2const} + C_1/p + C_2 p \tag{5}$$

$$C = C_3 + C_1/p + C_2 p \tag{6}$$

where  $C_1$ ,  $C_2$  and  $C_3$  are constant values.

Establishing the acceptable occupational risk level in relation to the economic optimum, means to provide a balance between the increment of the risk related expenses concomitant to the diminution of the

investment costs, so that the cost price should not increase a lot above the minimum price.

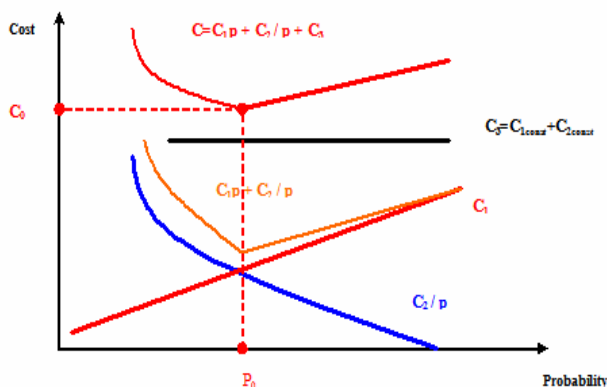


Fig. 3. Graphic presentation of the structure of the overall cost price C

Establishing the acceptable occupational risk level in relation to the economic optimum and the optimal probability regarding the occurrence of an unwanted event (such as occupational accidents and diseases) is performed by deriving the cost function C from the evaluation variable p:

$$dC/dp=0 \Rightarrow C_2-C_1/p_2=0 \quad (7)$$

$$p_0=(C_2/C_1)^{1/2} \quad (8)$$

Equation (8) is introduced in equation (5), by taking into consideration only the costs that depend on probability. Consequently, the following equations are obtained:

$$C_0=C_2p_0+C_1/p_0 \quad (9)$$

$$C_0=2(C_1 C_2)^{1/2} \quad (10)$$

Whether  $\Delta$  deviation of the cost price against the minimum price is considered then it is possible to establish the range inside which the variation of probabilities (with the related risk levels) don't influence with more than  $\Delta$  the minimum calculated cost price ( $C_0$ ).

An analytical equation of the aspects mentioned above shall take the following form:

$$C_0(1+\Delta)=C_1/p+C_2p \quad (11)$$

By replacing the value of  $C_0$  from (10) in (11), the equation obtained is:

$$2(1+\Delta)(C_1 C_2)^{1/2}=C_1/p+C_2p \quad (12)$$

If the terms of the equation are arranged in accordance with p, the result is:

$$p^2-2p(1+\Delta)(C_1 C_2)^{1/2}+C_1/C_2=0 \quad (13)$$

The equation has the following results:

$$p_1=(1+\Delta)p_0-[(2+\Delta)\Delta]^{1/2}p_0 \quad (14)$$

$$p_2=(1+\Delta)p_0+[(2+\Delta)\Delta]^{1/2}p_0 \quad (15)$$

Subsequently, it is possible to determine the values of  $p_1$  and  $p_2$ , based on the results gained above, as well the range between these roots which corresponds to the acceptable risk level, when the variations of the probabilities regarding the occurrence of unwanted events don't influence the minimum cost price with more than  $\Delta$ .

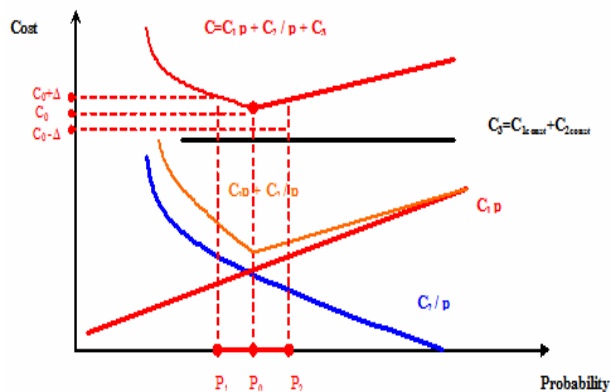


Fig. 4. Graphical presentation of the acceptable occupational risk level

For example, if a deviation of 5 % from the minimum cost price is admitted ( $\Delta = 0,05$ ) the values of  $p_1$  and  $p_2$  shall be the following ones:

$$p_1=(1+0,05)p_0-(0,1025)^{1/2}p_0 = 0,7p_0 \quad (16)$$

$$p_2=(1+0,05)p_0+(0,1025)^{1/2}p_0 = 1,4p_0 \quad (17)$$

It has to be underlined the fact that a variation of 5 % of the cost price against the minimum value gives a rather large range for the optimum domain of the occupational risk level. This allows a comprehensive consideration of the main and secondary occupational accidents and diseases risk factors so as to carrying on the activity in optimum economic conditions, with an acceptable level of occupational safety.

Establishing the acceptable risk level is a compromise between the aspects to which the responsible entity (organization, body, legal entities) agrees to take risk from an economic point of view, whether this entity has considered, a priori, the possible occurrence of risks (together with the safety measures that should be applied) and the expenses that should be recovered a posteriori whether risk has been ignored, by taking into consideration the following elements:

- costs involved with the removing of material and human damages;
- costs generated by the unavailability of the system;
- impact in the media.

#### 4. Conclusions

Evaluating the occupational safety means to determine (measure) the extent to which the working systems deviate from the ideal state when there is no possibility for the occurrence of occupational accidents and diseases.

Evaluation of occupational accidents and diseases represents an indirect means to assess the occupational safety by assigning values to the indicator called "risk level for occupational accidents and diseases".

The general management of any activity requires an analysis and evaluation of the

occupational risk since working process always involves the occupational safety policy.

Establishing the acceptable occupational risk level against an economic optimum value requires a balance between the augmentation of expenses related to occupational accidents and diseases risks at the same time with the diminution of expenses for investments so that the cost prices should reach a reasonable amount.

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