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INFLUENCE OF WORKING PLACE ERGONOMIC SUITABILITY ON OPERATOR'S RELIABILITY

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Abstract. *The assessment of operator-dispatcher's reliability in the centre for control and management of Serbia Electric power generating industry has been carried out in this paper. Working place ergonomic suitability has been dealt with in detail and recommendations for its improvement have been suggested. The effect of the realization of the above-mentioned recommendations on the operator-dispatcher's reliability in two characteristic functional states-monotony and stress has been analyzed.*

Key words: *operator-dispatcher, reliability, working place ergonomic suitability*

1. INTRODUCTION

The actualization of system safety and risk problem has extremely intensified the study of human reliability in the sense of creating a uniform methodology for identification, quantification and reduction its errors. The study was immediately prompted by the great catastrophes caused by human error (Three Mile Island, Bhopal, Chernobyl, Challenger), which have resulted not only in a large number of human victims and enormous material losses but also in unforeseeable and immeasurable geneticall and ecological consequences [4].

The analysis of production system failures data points to the fact that man is the dominant factor of failure initiation. Figure 1 shows participation of certain factors in production system failure [1].

Human errors are not only a consequences of his psychophysiological characteristics (sensitivity, adaptability and selectivity of senses, as well as the characteristics of operation movements) but also a result of the interaction with the technical part of the system (perceptive, informative and operation inadequacy, complex activity algorithm, human presence in dangerous zones, poor quality of work organization) and with the working environment (discomfort of working environment, external disturbances).

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Therefore, human reliability assessment, which is emerging as an independent scientific discipline, is based on the achievements and methodologies of reliability theory, statistics, psychophysiology, ergonomics, sciences dealing with working environment quality etc.

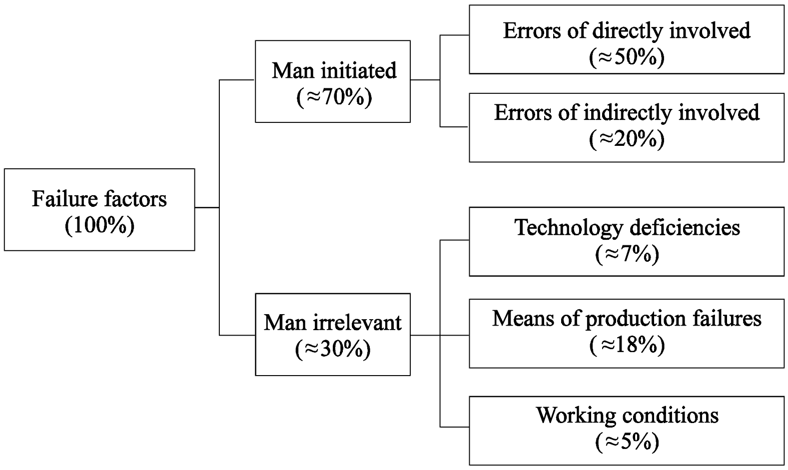


Fig. 1. Participation of certain factors in production system failures

Using the classification and quantification of human reliability factors and the definition of the complex index of reliability dealt with in papers [5,6,8] as a starting point, this paper assesses the reliability of operator-dispatcher in the centre for control and management of Serbia Electric power generating industry.

2. Ranking of operator-dispatcher's reliability factors

Assessment of operator-dispatcher's reliability requires ranking of reliability factors. It is fulfilled using paired comparison expert method. In the process of the comparison of factors $x_j \in x$, $j \in [1,m]$ each expert assesses all $0.5m(m+1)$ pairs of factors (x_j, x_k) applying the following rule:

$$e_{jk}^{i} = \begin{cases} 1, & \text{if} \quad x_j \succ x_k \\ 0.5, & \text{if} \quad x_j \sim x_k \\ 0, & \text{if} \quad x_j \prec x_k \end{cases}$$

where e_{jk}^{i} are the elements of the matrix E^{i} of paired comparisons of all the experts. There are the bases for the formation of the resulting matrix E^{r}, the elements of which are:

$$e_{jk}^{r} = \frac{1}{n}\sum_{i=1}^{n} e_{jk}^{i} \ ,$$

where $e_{jk}^{r} + e_{kj}^{r} = 1$.

The weight coefficients are determined by the application of the following algorithm:

1. The number of iterations $t_k(t_k = 3 \div 5)$, for calculating α_j, $j = [1,m]$ is given.
2. It is assumed that $t = 0$ and $\alpha_j = 1/m$.
3. It is assumed $t = t + 1$.
4. The calculation $\alpha_j^{(t)} = \frac{\sum_{i=1}^{n} e_{ij}^r \alpha_i^{(t-1)}}{\sum_{i=1}^{m}\sum_{j=1}^{m} e_{ij}^r \alpha_i^{(t-1)}}$ is carried out.
5. The condition $t \geq t_k$ is checked. If it is fulfilled, the algorithm ends; if not, the procedure continues by returning to the step 3.

The weight coefficients fulfill the condition $\sum_{i=1}^{m} \alpha_j = 1$. The resulting ranking is carried out as follows:

$$\alpha_1 \geq \alpha_2 \geq ... \geq \alpha_m \Leftrightarrow r_1 \leq r_2 \leq ... \leq r_m$$

Eight experts have ranked reliability factors of operator-dispatcher's working place. The resulting matrix is shown in Table 1 [7].

Table 1. Resulting matrix of paired comparison

Reliability factors	Psycho-phys. characteristics	Functional condition	Working place factors	Task complexity	Working environ. factors
Psycho-phys. characteristics	0	0.75	0.9375	0.9375	1
Functional condition	0.25	0	0.3125	0.625	0.8125
Working place factors	0.0625	0.6875	0	0.625	1
Task complexity	0.0625	0.375	0.375	0	1
Working environ. factors	0	0.1875	0	0	0

By the application of the paired comparison procedure the following coefficients have been determined:

$$\alpha_1 = 0.0006; \alpha_2 = 0.1023; \alpha_3 = 0.0548; \alpha_4 = 0.1341; \alpha_5 = 0.7087$$

and the ranking of the reliability factors has been carried out:

$$\alpha_5 > \alpha_4 > \alpha_2 > \alpha_3 > \alpha_1 \Leftrightarrow r_5 < r_4 < r_2 < r_3 < r_1 .$$

The result of ranking is shown in Table 2 [7].

Table 2. Ranking of reliability factors

Reliability factors	Working environ. factors	Task complexity	Functional condition	Working place factors	Psycho-phys. characteristics
Rank (R_i)	1	2	3	4	5

3. POSITIONS OF OPERATOR-DISPATCHER'S RELIABILITY FACTORS

Reliability factors position have been determined on the basis of the concrete values of reliability factors indices for the observed working place of operator-dispatcher.

The range of values of the indices of all factors is divided into five intervals. A mark-number (ranking from 1 to 5) defining the degree of its influence on the operator's reliability is attributed to each interval. The mark also determines the position of the reliability factors.

The state of reliability factors in the centre for control and management of Serbia Electric power generating industry is as follows [2,5,6]:

1. Psychophysiological characteristics of operator-dispatcher are very good at the working place observed (position 4)
2. Functional states typical for this working place are monotony (position 4) and stress (position 1).
3. The task complexity is minor, the task are carried out according to a defined and easy algorithm (position 5) except in the case of accidents, when the operator chooses the most suitable solution in the unfamiliar environment conditions (position 3).
4. According to the measured values of indices (light, noise, temperature) working environment factors are within the permitted value limits, defined by the standards (position 5).
5. Working place factors are positioned according to the values of working place ergonomic mark. In order to determine the ergonomic mark the following factors have been analyzed[3]:
   – the organization of control and management centre,
   – the location and dimensions of control panels,
   – the location and dimensions of indicators and operator's executive means,
   – the location and dimensions of the seats,
   – the location and dimensions of the situation panels,
   – the operator's hand reach,
   – the distribution of postures and body movements,
   – the visual fatigue signs,
   – the operators working hours

The factors are evaluated by marks ranging from 1 to 6. Table 3 represents the results of the evaluation of the existing condition of working place ergonomic suitability factors, as well as the required state of these factors for the observed working place.

Deviations of the existing form the required condition working place ergonomic suitability factors can be noticed in Table 3. Recommendations for working place change are given on the basis of the mark difference of the existing and the required conditions:

$R_0 = 1 \Rightarrow$ adaptation

$R_0 = 2 \vee R_0 = 3 \Rightarrow$ reconstruction

$R_0 = 4 \vee R_0 = 5 \Rightarrow$ new construction

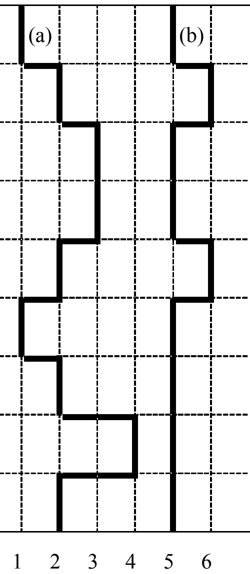
Ergonomic mark of the working place is arrived at by means of the following expression:

$$E = \frac{1}{n}\sum_{i=1}^{n} e_i$$

where n is the number of working place ergonomic suitability factors, e_i is the mark of the i-th factor.

Table 3. Ergonomic marks of working place factors and recommendations

Working place ergonomic suitability factors 0	Marks of existing (a) and required (b) factor states	Marks difer-ences	Recomendations
Organization of control and management centre		4	New construction
Location and dimensions of control panels		4	New construction
Location and dimensions of indicators and operator's executive means		2	Reconstruction
Location and dimensions of the seats		2	Reconstruction
Location and dimensions of the situation panels		4	New construction
Operator's hand reach		4	New construction
Distribution of postures and body movements		3	Reconstruction
Visual fatigue signs		1	Adaptation
Operator's working hours		3	Reconstruction



The positions of working place factors are determined according to the ergonomic mark of the working place, as shown in Table 4.

Table 4. Positions of working place factors

Ergonomic mark	[1,2)	[2,3)	[3,4)	[4,5)	[5,6]
Position	1	2	3	4	5

The ergonomic mark of the working place observed is 2.22, which points to the fact that the ergonomic demands are minimally fulfilled (position 2).

The recommended reconstruction of the working place up to the required standard would increase the existing ergonomic value to 3.33 (position 3) and the recommended new construction to 4 (position 4).

The required ergonomic mark of the above mentioned working place is E=5.22 (position 5), which is in accordance with the needs and importance of the management of Serbia Electric power generating industry and with the high demands that this system should fulfil.

4. Operator-dispatcher's reliability assessment

Operator-dispatcher's reliability assessment is carried out on the basis of the position and the rank of reliability factors, the following matrix:

$$\begin{array}{c} \\ \\ M = \left\| m_{ij} \right\|_{i,j=1,5} = \end{array} \begin{array}{c} \text{P o s i t i o n } (j) \\ \begin{array}{ccccc} 1 & 2 & 3 & 4 & 5 \end{array} \\ \left\| \begin{array}{ccccc} 0.626 & 1.252 & 1.878 & 2.504 & 3.130 \\ 0.884 & 1.768 & 2.652 & 3.536 & 4.420 \\ 0.960 & 1.920 & 2.880 & 3.840 & 4.800 \\ 0.984 & 1.968 & 2.952 & 3.936 & 4.920 \\ 0.992 & 1.984 & 2.976 & 3.968 & 4.960 \end{array} \right\| \end{array} \begin{array}{cc} 1 & R \\ 2 & a \\ 3 & n \\ 4 & k \\ 5 & (i) \end{array},$$

the following formula for calculating the complex index of reliability:

$$k = \frac{\sum_{i,j=1}^{5} m_{ij}}{\sum_{i=1}^{5} m_{i5}}$$

and Table 5, which shows the relations between the complex index of reliability and the operator's reliability [7]:

Table 5. Relations between the complex index of reliability and the operator's reliability

Complexity index reliability	Operator's reliability
$0.2 \le k \le 0.36$	insufficient
$0.36 < k \le 0.52$	critical
$0.52 < k \le 0.68$	good
$0.68 < k \le 0.84$	very good
$0.84 < k \le 1$	optimum

The complex indices of reliability for the operator-dispatcher's characteristic functional conditions-monotony (K_m) and stress (K_s) are as follows:

$$K_m = \frac{m_{15} + m_{25} + m_{34} + m_{42} + m_{54}}{m_{15} + m_{25} + m_{35} + m_{45} + m_{55}} = \frac{17.326}{22.23} = 0.78$$

$$K_m = \frac{m_{15} + m_{23} + m_{31} + m_{42} + m_{54}}{m_{15} + m_{25} + m_{35} + m_{45} + m_{55}} = \frac{12.678}{22.23} = 0.57$$

Table 6. represents the values of these indices if the recommended working place changes were carried out.

Table 6. K_m and K_s values for the recommended working place changes.

K_m	K_s	Remarks
0.78	0.57	Existing working place condition
0.82	0.61	Recommended working place reconstructions done
0.87	0.66	Recommended new constructions done
0.91	0.70	All the recommended changes carried out

5. CONCLUSION

Operator-dispatcher in the centre for control and management of Serbia Electric power generating industry should have high reliability (very high or optimum). However, in the existing working place conditions the operator's reliability while acting in event of accidents is not satisfactory ($K_s = 0.57$). Therefore the recommended working place changes are necessary in order to increase both working place ergonomic suitability and operator's reliability. The required reliability in case of accidents cannot be provided either by the recommended reconstruction alone ($K_s = 0.61$) or by the recommended new construction alone ($K_s = 0.66$), but only by all the recommended working place changes ($K_s = 0.70$) The increase in reliability in normal working conditions is evident as well (increase in the value of the complex index of reliability from 0.78 to 0.91)

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UTICAJ ERGONOMSKE PODOBNOSTI RADNOG MESTA NA POUZDANOST OPERATORA

Suzana Savić, Miroljub Grozdanović

U radu je izložena procena pouzdanosti operatora-dispečera u centrima za kontrolu i upravljanje Elektroprivrede Srbije. Posebno je razmatrana ergonomska podobnost radnog mesta dispečera i date su preporuke za njeno poboljšanje. Analiziran je efekat realizacije datih preporuka na pouzdanost operatora-dispečera za dva karakteristična funkcionalna stanja: monotoniju i stres.

Ključne reči: *operator dispečer, ergonomska podobnost, pouzdanost*