STUDY ON THE DYSFUNCTIONS OF THE HUMAN COMPONENT IN THE SOCIO-TECHNICAL SYSTEMS

Puiu GRĂDINARU[1], Doruleţ GRĂDINARU [2]

[1]University of Pitești, gradinarupuiu@yahoo.ro

[2]University of Pitești, gradinaru_dorulet@yahoo.ro

Abstract: *Socio-technical systems are systems that ensure self-regulation and self-organization in relation to the objectives set and its connections with the environment. The dysfunctions in the socio-technical systems may be of a technical or socio-human nature with various consequences. The reliability of these systems depends not only on the reliability of the technical subsystem but also on the reliability of the human subsystem. Human reliability has as an indicator the error, as failure is the main indicator of technical reliability. The study considers only the human factor both in terms of its activity and the obtained results. In this regard, the study uses stochastic simulation to predict operator errors, as well as Markov chains, as a predictive tool for the stability of the company personnel.*

Keywords: Socio-technical system, Human reliability, Monte Carlo method, MARKOV chains.

JEL Classification Codes: L21, M10.

1. INTRODUCTION

The socio-technical systems are complex consisting of more people and more machines, in which there are two subsystems that are interconditioned and differ in nature, namely the technical and socio-human subsystem in which social, interpersonal relations predominate (Josif and Moldovan-Scholz, 1996).

These systems have well known characteristics: structure, purpose, inputs, outputs, interactions between components, system functionsand its components, as well as properties: stability, adaptability and reliability.

The two components of the socio-technical systems interact through an informational circuit within a physical and social environment (figure 1).

The operator receives information from the machine, from the environment, from other persons and responds by actions, entering information in the machine and in the environment.

Through feedback loops, the system ensures self-regulation in relation to the objectives set and the connections between it and the external environment formed by other cyber systems and subsystems.

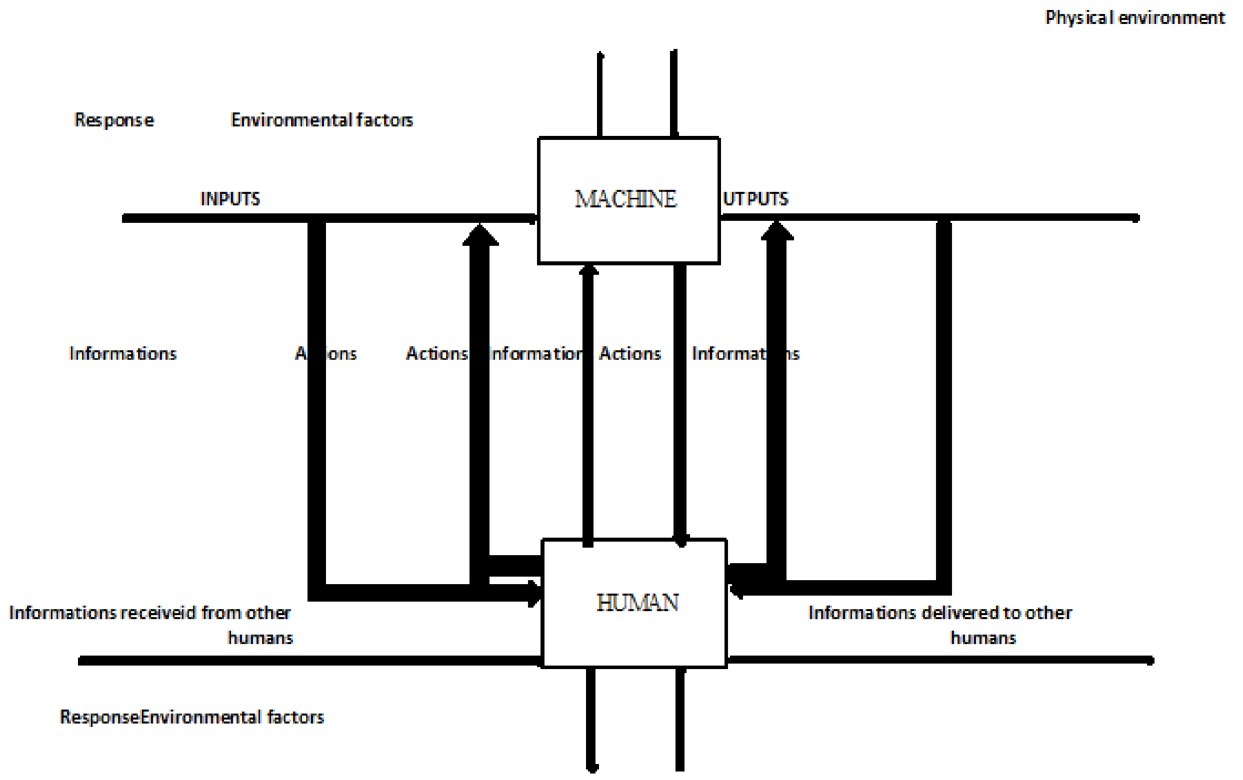

Figure 1 ***The socio-technical system in relation to the environment***

Source: Iosif, Gh., Moldovan – Scholz, M., Labor Psychology, Didactic and Pedagogical Publishing House, RA., Bucharest, 1996, pp. 82-83.

The system retains its degree of organization as it accumulates and uses information from the environment, informational syntropia having a tendency to increase and information entropy to decrease.

2. THEORETICAL ASPECTS

The reliability of the socio-technical systems is conditioned by the reliability of each component, as well as their organization. Human reliability is defined as the probability of an individual, a team or an organization to perform a mission under certain conditions and over a certain period of time (Nicolet and Celier, 1985). Human reliability depends mainly on the human's competences-the characteristics of the work required couple, as well as the environment (external conditions) in which he carries out his activity. Human reliability includes a set of knowledge on predicting, analyzing and reducing human errors, focusing on the role of the human in the operations of design, maintenance and exploitation of the system (Neboit et al., 1990). It is safe to say that human reliability, as a discipline, is connected to other disciplines such as: ergonomics (in terms of optimizing the relationship between man and his work); the quality (especially management quality) and work safety (Iosif and Moldovan-Scholz, 1996).

The human reliability indicator is the error that covers all cases where mental or physical activities do not reach the desired goals and when failures cannot be attributed to chance (Reason, J., 1990). It can be said that errors occur only in goal-oriented actions, implies the failure in achieving a goal, and third, errors can be preventable (Zapf et al., 1992).

The multitude of classification criteria highlights the following categories of errors (Iosif and Moldovan-Scholz, 1996): knowledge errors, processing errors, errors due to lack of attention, errors of omission, incorrect application of correct rules, errors of recognition, errors of thought, errors of judgment and so on.

This study aims to predict the error rate using The Random Number Method (Monte Carlo technique), which involves the following stages of work (Rusu, 2001):

a) Establishing the probability distribution for the random variables and the calculation of cumulative probabilities;
b) Establish a range of random numbers for each of the random variables;
c) Random number generation (as many simulated uploads are done);
d) Calculation of the probability distribution characteristics of the investigated random variable: the mean, the standard deviation, the coefficient of variation.

Another efficient method of predicting natural phenomena is Markov's Chains Method, that take into account chains of interconnected events, where the subsequent evolution depends on the current state as well as the previous states of the systems. In other words, to be considered a Markov chain a system must have a set of distinct states with identifiable transitions between them. The result is repeatedly multiplied (the vector) with the same transition matrix until the result multiplying with the matrix gives the same result, so that the chain reaches a state of equilibrium. The last vector (result) represents the prediction for the future.

The study also aims to forecast the stability of the personnel of the companies with the help of Markov Chains, considered as a stochastic model.

3. THE STUDY OF HUMAN RELIABILITY AND STABILITY OF HUMAN RESOURCES IN COMPANIES

3.1 The use of stochastic simulation in predicting the error rate of operators in an industrial company (Monte Carlo Method)

Suppose that the error rate due to the operators' lack of attention during the last 12 months within a company it is presented in table 1.

Table1 ***The evolution of the error rate over the last 300 days***

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Error rate (%)	1.7	4.4	2.8	3.3	4.8	3	5.5	3.8	8	5.2	1.5	2.4
Absolute frequency (days)	25	24	27	23	25	25	27	27	25	26	26	20

The solution of a and b steps is presented in the table 2.

Table2 ***The probability distribution***

Error rate	Probability distribution	Cumulative probability	Random number range
1.7	0.08	0.08	(01,02,03,…,08)
4.4	0.08	0.16	(09,10,11,12,…,16)
2.8	0.09	0.25	(17,18,19,…,25)

3.3	0.08	0.33	(26,27,28,…,33)
4.8	0.08	0.41	(34,35,36,…,41)
3	0.08	0.49	(42,43,44,…,49)
5.5	0.09	0.58	(50,51,52,…,58)
3.8	0.09	0.67	(59,61,61,…67)
8	0.08	0.75	(68,69,70,…,75)
5.2	0.09	0.84	(76,77,78,…,84)
1.5	0.09	0.93	(85,86,87,…,93)
2.4	0.07	1.00	(94,95,96,…,100)

In table 3 only six simulation attempts were made, generating random numbers (step c), over the next 12 months.

Table3 ***The simulated rate and random rate***

Months	Random numbers	Simulated rate	Random numbers	Simulated rate	Random numbers	Simulated rate	Random numbers	Simulated rate	Random numbers	Simulated rate	Random numbers	Simulated rate
1	96	2.4	36	4.8	81	5.2	58	5.5	70	8	7	1.7
2	94	2.4	50	5.5	68	8	70	8	19	2.8	47	3
3	7	1.7	46	3	34	4.8	36	4.8	54	5.5	39	4.8
4	67	3.8	78	5.2	89	1.5	1	1.7	87	1.5	24	2.8
5	93	1.5	77	5.2	58	5.5	32	3.3	22	2.8	45	3
6	75	8	45	3	55	5.5	2	1.7	83	5.2	99	2.4
7	78	5.2	39	4.8	37	4.8	6	1.7	71	8	50	5.5
8	68	8	82	5.2	13	4.4	39	4.8	74	8	83	5.2
9	6	1.7	52	5.5	25	2.8	40	4.8	37	4.8	63	3.8
10	41	4.8	38	4.8	6	1.7	84	5.2	81	5.2	44	3
11	35	4.8	76	5.2	62	3.8	96	2.4	42	3	15	4.4
12	1	1.7	67	3.8	61	3.8	100	2.4	63	3.8	78	5.2
	-	46/12= 3.38	-	56/12 = 4.67	-	51.8/ 12= 4.32	-	46.3/12 = 3.86	-	58.6/ 12= 4.88	-	44.8/ 12= 3.73

Calculation of the probability distribution characteristics of the investigated random variable (step d) is presented below.

- **The mean**

$$\bar{x} = \frac{\sum_i^n xi}{n}$$

$$\bar{x} = \frac{3,83+4,67+4,32+3,86+4,88+3,73}{6} = \frac{25,29}{6} = 4.22$$

- **Standard deviation**

$$S = \sqrt{\frac{\sum_{i=1}^{n} (Xi - \bar{x})2}{n-1}}$$

$$S = \sqrt{\frac{(3.83-4,22)2+(4,67-4,22)2+(4,32-4,22)2+(3,86-4,22)2+(4,88-4,22)2+(3,73-4,22)2}{6-1}} =$$

$$= \sqrt{\frac{0,15+0,20+0,01+0,13+0,44+0,24}{5}} = \sqrt{\frac{1,17}{5}} = \sqrt{0,23} = 0.48$$

- **Variation Coefficient**

$$V = \frac{S}{\bar{x}} \text{ x } 100$$

$$V = \frac{0,48}{4,22} \text{ x } 100 = 11.38\%$$

It can be noted that the variation of the operator error rate for the following year is slight. In the situation in which the error rate variation had a higher value (≥25%), it is appreciated that it ascends different causes that must be identified by the manager, analyzed and found appropriate solutions to reduce them. To sum up, the calculated mean does not say much, the most eloquent feature being the coefficient of variation.

3.2 The application of Markov chains in predicting the stability of the company's personnel

The two states used are the two companies A and B, which are dependent variables. Suppose that this month the degree of stability at both companies is equal, which means 50%. For a previous period of 24 months, the possibility for an employee to remain faithful to company A is 0,8, and the probability that an employee migrates to company B is 0,2. In company B, the probability of an employee remaining is 0,9 and migrating to Company A, the probability of 0,1.

The matrix of probabilities will be: $\begin{pmatrix} 0,8 & 0,2 \\ 0,1 & 0,9 \end{pmatrix}$

The condition is that the sum of the values on each line of this matrix is equal to 1. In the first month, the degree of stability of the personnel will look like this:

$$(0{,}5 \quad 0{,}5) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}45 \quad 0{,}55)$$

The rule of multiplying a vector with a quadratic matrix is applied, meaning:

0.5 x 0.8 + 0.5 x 0.1 = 0.4 +0.05 = 0.45 (for company A)

0.5 X 0.2 + 0.5 x 0.9 = 0.1 + 0.45 = 0.55 (for company B)

Continue calculating until the chain reaches a state of equilibrium:

$$(0{,}45 \quad 0{,}55) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}42 \quad 0{,}58)$$

$$(0{,}42 \quad 0{,}58) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}39 \quad 0{,}61)$$

$$(0{,}39 \quad 0{,}61) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}37 \quad 0{,}63)$$

$$(0{,}37 \quad 0{,}63) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}36 \quad 0{,}64)$$

$$(0{,}36 \quad 0{,}64) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}35 \quad 0{,}65)$$

$$(0{,}35 \quad 0{,}65) \cdot \begin{pmatrix} 0{,}8 & 0{,}2 \\ 0{,}1 & 0{,}9 \end{pmatrix} = (0{,}35 \quad 0{,}35)$$

In the distant future, company B will have a personnel stability degree of 65% while company A will have a stability degree of only 35%.

One thing to know is that the dynamics of the workforce market often lead to the change of the values of the probability matrix. If these values remained constant, the degree of stability would be slightly predictable.

3. CONCLUSIONS

The human component in the socio-technical systems is decisive in their efficient operating. The efficiency of this component especially in the systems with high degree of automation must be extraordinary, perfect. Finding an error or delay in an operation makes very high costs occur, with negative economic consequences one after another. So in such cases the cost of human error can be enormous.

We appreciate that the ergonomic organization of the work can bring its substantial contribution in preventing the occurrence of the errors of the operators, regarding the following aspects (Burlain, 1990; Burlain, 1997):

a) mitigation of fatigue during the work program, so that the functional potential of the body can provide useful activities at the maximum level;
b) improving the relations between the human and the machine within the "human-requests" system, regarding both the measuring devices and the control units;
c) ergonomic organization of the work process in each workplace based on the principles of movement economy so that the work is done out with the least energy consumption;
d) the choice of working methods that are justified in terms of economic, technical and social criteria;
e) evaluating the pace of work, considering the mobilization of the latent part of the work capacity;
f) ensuring a good physiological state based on good thermal comfort;
g) analysis of the characteristics of the main factors that influence the durations of the isolated and combined movements made by the operators, included in the system of working time regulations on movements M.T.M.

Managers can act to avoid personnel fluctuation in the following directions:

a) use of human resources in relation to the professional training and skills of each employee;
b) creating opportunities for development and promotion;
c) elimination of stressful working environment, with direct impact on the balance between the personal and professional life of employees;
d) supporting new employees for quick integration and accommodation;
e) improve the wage system;
f) permanent appreciation of the work of the employees using the management through objectives;
g) tracking the increasing cohesion of the work teams;
h) ensuring the proper working conditions;
i) ensuring that the positions occupied by the company personnel are in line with their expectations in order to increase the job satisfaction;
j) the application by the manager in the relationship with the personnel he/she leads of the concept of empowerment, thus giving employees the opportunity to develop initiatives, identify new opportunities in their work, generate ideas and take responsibility for the results they achieve;
k) using methods to stimulate s creativity, especially brainstorming, discovery matrix and Zwicky's morphological method.

REFERENCES

1. Nicolet, J.L., Colier, J., La fiabilite humain dans l'enterprise, Masson, Paris, 19.
2. Neboit, M., Cuny, X., Fadier, E. and Ho, M.T., Fiabilite humaine: presentation du domaine in J. Leplat et G. De Terssac (eds.), Les facteurs humains de la fiabilite dans les systemes complexes,, Ed. Octares, Marseille, 2004.
3. Iosif, Gh., Moldovan-Scholz, M., The psychology of work, Didactic and pedagogical publishing house, Bucharest, 1996.
4. Reason, J., Human error, Cambridge, Cambridge University Press, 1990.
5. Zapf, D., Broadbeck, F.C., Frese, M. Peters, H. and Prumper, Z., Error in working with office computers: a first validation of taxonomy for observed errors in a field setting, International Journal of Human-Computer Interaction, 1992.
6. Rusu, E., Optimal management decisions through operational research methods. Problems and case studies, Economic publishing house, Bucharest, 2001.
7. Militaru, Gh., Services Management, C.H. Beck Publishing House, Bucharest, 2010.
8. Bărbulescu, C., Strategic Enterprise Systems, The economic Publishing House, Bucharest, 1999.
9. Scarlat, E., Chiriță, N., The Basics of Economic Cybernetics, The economic Publishing House, Bucharest, 1997.
10. Gagniuc, P. A., Markov chains: From theory to implementation and experimentation, John Wiley&Sons, 2017.
11. Burlain, P., Economics and ergonomic organization of work, Didactic and pedagogical publishing house, Bucharest, 1990.
12. Burlain, P., Human resources management. Global interdisciplinary treatment, Lumina Lex SRL Publishing House, Bucharest, 1997.