Original Article *J Res Health Sci, Vol. 8, No. 1, pp. 33-38, 2008*

The Application of Human Factors Engineering for Evaluation of Overall Performance

Mohammad Fam I. PhD

Dept. of Occupational Health, Faculty of Health, University of Hamadan Medical Science, Hamadan, Iran

(Received 2 Jul 2007; accepted 19 Dec 2007)

Abstract

Background: Total system design (TSD) factors are design factors, which have impact on overall performance of the power plants in context of total human engineering or macroergonomic. The evaluation of the impact of TSD factors was the main goal of this study. The main objective was human factors engineering on human performance in a power plant.

Methods: The systems being studied are the control rooms and maintenance departments of a 2000 MW thermal power plant in IRAN. By non-parametric correlation analysis and Kruskal-Wallis test of means, we can achieve between TSD factors and human performance.

Results: The selected TSD factors are related to procedures, work assessment, teamwork, self-organization, information exchange and communication. In a way we can say that various factors influence on human performance in the power plant is TSD factors such as organizational and safety procedures, teamwork, self-organization, job design and information exchange.

Conclusion: The best way to increase human performance is TSD factors must be considered, designed and tested concurrently with the engineering factors at the design phase of the system developmental cycle.

Key words: *Ergonomic, Human, Performance Power plants, Safety*

Introduction

Total system design (TSD) is an integrated developmental process, based on a series of well-defined phases. Frequently in the past, designers used other approaches without giving much attention to human performance. TSD requires equal consideration to all major components of the system such as human, hardware, software and organizational structures. Indeed, it is quite important to pay serious attention to human and organizational aspects of the TSD process from early design phase.

TSD factors in context of human performance are referred to as socio-technical factors in context of system design. It should be noted that the engineering design process is often perceived as mainly technical activity, yet within engineering design organization it really only coheres as a social activity. This paper introduces the socio-technical factors as essential and vital part of the design process in power plants and because they are related to overall management and organization structures, they are referred to as TSD factors in context of human performance (1-3).

TSD factors in context of human performance define the macroergonomics features of the system design and human performance engineering, whereas, the conventional system design factors in context of human performance define the ergonomics features of the system design and human performance engineering. Macroergonomic and the concept of total human factors were developed

***Correspondence:** Iraj Mohammadfam, Fax : +98 8118255301, E-mail: Fam@engmail.ut.ac.ir

by Hendrick and Meshkati and elaborated by other researchers (4-10).

Ergonomic attempts to optimize the interaction between human operator and machine. It considers those factors of machine, design and work posture that affect the user interface and working conditions related to the job or task deign. In a macroergonomics study, the ergonomics factors are considered in parallel to organizational and managerial aspects of working conditions in context of a total system design. Moreover, it attempts to create equilibrium between, organization, operators and machines. It focuses on total "people-technology" systems and is concerned with the impacts of technological systems on organizational, managerial and personnel subsystems (11-13).

Macroergonomic adopts a more holistic approach to human factors' problems of manufacturing systems. It considers the whole and avoids the trap of dealing with specialties with which we feel comfortable. A macroergonomics program optimizes interface between operators, machines and organization by using teamwork, on-the-job training, well-defined procedures and total management.

Materials and Methods

TSD factors in context of human performance are defined as factors influencing total system's performance such as rules and procedures and information exchange between personnel/departments. To measure the impacts of TSD factors on human performance, a questionnaire was designed and handed out to all control room and maintenance operators. It was designed based on total system design aspects of human performance in power plants. Moreover, key macroergonomics factors were included to evaluate human performance. The selected TSD factors are related to procedures, work assessment, teamwork, self-organization, information exchange and communication. They were inputted to the questionnaire and their statistical relationships to the human performance were examined through two non-parametric statistical (namely, Cramer's Phi and Kruskal-Wallis) approach. The selected TSD factors in context of human performance were tested in the following format:

1. Degree of familiarity with rules and procedures
2. Supervisors' monitoring and assessment at work
3. Reward for teamwork by supervisors
4. Ease of contact with supervisors
5. Problems with co-workers due to inter-organizational relationship
6. Quality of perceived information from supervisors
7. Quality of perceived information from co-workers
8. Usefulness of informal information exchange
9. Freedom for self-organized and individual decision-making

As mentioned, a set of non-parametric test of hypothesis is conducted to foresee if human performance is independent of the selected TSD factors. Furthermore, job pressure is selected as the factor representing human performance since it is identified as one of the most important human shaping factors. The sources of job pressure in the power plants are classified as 1) workload 2) stress and 3) time considerations. Because workload is identified as the most influential source of job pressure, it is selected as the measure of human performance in this study. It is tested whether job pressure due to workload is influenced by the TSD factors. In addition, the difference between mean ratings of operators in respect to selected TSD factors are examined through Kruskal-Wallis test. For example, the operators who can easily communicate with supervisors are compared with the ones who cannot easily communicate with supervisors in respect to the level of job pressure.

The systems being studied are the control rooms and maintenance departments of Sh. Rajaeil power plant in Ghazvin- Iran. The plant was provided with dry cooling system (Heller), the power evacuated from the 400kV switchyard, and all the units are in operation. The number of company's staff was 472.

Results

The Cramer's Phi statistic tests the null hypothesis (H_0) of no correlation between the two variables against alternative hypothesis (H_1) of correlation between the two variables. The test of hypothesis is in the following general format:

H_0: The TSD factors are not correlated with job pressure due to workload

H_1: Otherwise

As shown in Table 1 there is strong evidence that the nine TSD factors are correlated with the job pressure at work. Furthermore, the job pressure at work is influenced by familiarity with organizational rules and procedures and information flows between co-workers, co-workers, and supervisors. In addition, job pressure is positively correlated with teamwork. Operators who are rewarded for teamwork report lower level of job pressure and consequently produce higher performance. The freedom for self-organization is positively correlated with human performance. In summary, these findings suggest the positive impacts of TSD factors on human performance (Table 1).

Table 1: Test of correlation between human performances (job pressure) and the selected TSD factors

TSD factor	Cramer's Phi	*P*- Value (α)
1. Degree of familiarity with rules and procedures	.63	.00070
2. Supervisors' monitoring and assessment at work	.44	.00010
3. Reward for teamwork by supervisors	.51	.00310
4. Ease of contact with supervisors	.48	.00002
5. Problems with co-workers due to inter-organizational issues	.57	.00040
6. Suitability of perceived information from supervisors	.49	.00110
7. Suitability of perceived information from co-workers	.41	.00040
8. Usefulness of informal information exchange	.53	.00010
9. Freedom for self-organized and individual decision-making	.44	.00030

To further investigation, series of comparative studies are performed between various groups of operators in the next section. It is examined if TSD factors influence the human performance in particular and the system in general. To achieve this objective, two groups of operators are examined on the selected response variables. The selected response variables are the quality of information perceived from supervisors and co-workers and job pressure. The Kruskal -Wallis test performs an analysis that is very similar to an analysis of variance (ANOVA) on the ranks. The test is conducted when the assumptions for the parametric ANOVA cannot be made (14). Furthermore, it assumes independence between subjects in conditions. This test also acts as verification and validation process of the previous test and almost the same types of results are reported in different format. The general format for the test is as follows:

Ho: The two groups of operators have the same performance with respect to the response variable, where the response variables are the quality of perceived information from supervisors and co-workers and job pressure.

H_1: Otherwise

In job pressure, two major types of operators exist in which those operators who cannot easily communicate with supervisors report higher level of job pressure. Operators who can easily communicate with supervisors report higher quality of perceived information from supervisors. Operators who believe that there could be a better job design reported higher level of job pressure.

The last column in Table 2 and 3 define the relative advantage of group 1 over group 2 in relation to the quality of information perceived from supervisors and co-workers, respectively. Furthermore, the relative statistical advantage of group 1 over group 2 is tabulated by the percent increase in quality of information perceived from supervisors and co-workers, respectively. The last column in Table 3 defines the relative advantage of group 1 over group 2 in relation to the job pressure. The significant difference between the groups of operators who are utilizing the TSD factors and the groups who are not with respect to the response variables reveal that TSD factors extensively influence the human performance in particular and the system in general.

Table 2: The significant level of test of comparison on the quality of information perceived from supervisors

Difference in mean ranking		***P*- Value (α)**	**Relative advantage (%)**
Group 1	**Group 2**		
With on-the–job training	Without on-the-job training	0.0516	30
No problem with organizational procedures	Having problems with organizational procedures	0.0020	60
Rewarded for teamwork	Not rewarded for teamwork	0.0031	40
With individual decision-making capability	Without individual decision-making capability	0.0154	30
Can easily communicate with supervisors	Cant easily communicate with supervisors	0.0113	40
No problem with co-workers due to inter-organizational issues	Having problems with co-workers due to inter-organizational issues	0.0131	32

Table 3: The significant level of test of comparison on the job pressure

Difference in mean ranking		**Significant level (α)**	**Relative disadvantage (%)**
Group 1	Group 2		
Can easily communicate with supervisors	Cant easily communicate with supervisors	0.0053	58
Believing a better job design is required	Believing current system is ok	0.0021	300

The Kruskal-Wallis test of comparison between the two groups verifies and validates the previous results obtained from the test of correlation between TSD factors and job pressure.

Discussion

The conventional design approach in power plants considers the engineering design parameters and ergonomics factors (in some cases). However, the TSD approach of this study in context of human performance considers the engineering design parameters and macroergonomics factors. The impacts of TSD factors on human performance showed in Table 1. This table shows through design and evaluation of a detailed survey containing information about TSD factors and human performance. It had been showed that a total system design approach in context of human performance is much more efficient than a conventional design approach. This is shown through introduction of the TSD model, applying the model in a power plant and showing its advantage through statistical analysis.

Non-parametric statistical analyses were used to show positive correlation between human performance and TSD factors and to highlight the impact of TSD factors on human performance. Furthermore, it is noted that by designing and implementing a TSD approach, the system and its human element are totally rather than locally optimized in context of human performance.

It should be noted that the conventional design approach in context of human factors is only capable of identifying local or stationary human performance issues. This study showed that the employment of a TSD approach is superior to conventional design approach.

The findings of this study have several design implications. Rules and procedures, information exchange between personnel (operators and supervisors) teamwork and self-organization may be designed and accommodated through standardization of the documentation process and automated tracking systems. This may be achieved through:

1. Implementation of ISO 9000 series of standards to promote standardization of documentation (rules, procedures, guidelines and communications) process.
2. Implementation of ISO 14000 series of standards to promote standardization of documentation process for environmental management systems.
3. Implementation of OHSAS 18000 to develop standardization of documentation process for safety management and occupational hygiene systems.
4. Design and implementation of automated information exchange in context of information technology. This would facilitate and enhance the existing information structure.

Design and implementation of the re-engineering concept may enhance organizational relationships and surveillance. Re-engineering is the collection of activities and mechanisms required changing from hierarchical to horizontal, flat and cross-functional structures based on teamwork within an organization. The main goal in such program is customer's satisfaction. More elaboration on the scientific tools for implementation of TSD factors in context of human performance is left for a full research paper in the future

Acknowledgements

We gratefully acknowledge MAPNA groups for supporting this research financially.

References

1. Kogi K. Work improvement and occupational safety and health management systems: common features and re-

search needs. *Ind Health*. 2002; **40(3):** 121-33.
2. Clegg CW. Socio technical principles for system design. *Applied Ergonomics*. 2000; **31(1):**463-77.
3. Czaja, SJ, Sharit J. Technology-based jobs, stress and older workers. *Review of Public Personnel Administration*. 2000; **15(2):**46–61.
4. Hendrick HW. Future directions in macroergonomics. *Ergonomics*. 1995; **38(6)**:1617-24.
5. Kossiakoff A, Sweet W. Systems engineering principles and practice. Wiley, USA, 2003: PP.124-43.
6. Carayon P. Job design and job stress in office workers. *Ergonomics*. 1993; **36(5):**463-77.
7. Buede DM. The engineering design of systems: models and methods. Wiley, USA, 2000: PP. 241-259.
8. Kleiner BM. Macroergonomic Analysis of formalization in a dynamic work system. *Applied Ergonomics*. 1998; **29 (1):** 255-59.
9. Kleiner BM, Drury CG. Large-scale regional economic development: Macroergonomics in theory and practice. *Human Factors and Ergonomics in Manufacturing*. 1999; **9:**151-63.
10. Rabbitt P, Lowe C. Patterns of cognitive ageing. *Psychological Research*. 2000; **63(2):**308-16.
11. Fredericks T, Abudayyeh O, Palmquist M, Tores H. Mechanical contracting safety issues. *J Construct Eng. Manage*. 2002; **128(4):**86-93.
12. Blanchard BS. System engineering management. 3rd ed. Wiley, USA, 2004: PP.67-84.
13. Hess J, Hecker S. Stretching at work for injury prevention: issues, evidence and recommendations. *Appl Occup Environ Hygiene*. 2003; **18:**331-38.
14. Kossiakoff A, Sweet W. Systems engineering principles and practice. Wiley, USA, 2003. PP.312-41.