FROM THEORY TO PRACTICE: A TOTAL ERGONOMICS MODEL OF A MANUFACTURING SYSTEM

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Abstract The objective of this paper is three fold. First, a general framework for development of total ergonomics model is introduced. Second, it is described how total ergonomics model may be applied in practice to intensify the productivity and working conditions of manufacturing systems. Third, it is shown whether the total ergonomics model is superior to the conventional ergonomics approach. This study is among the first to examine total ergonomics components in a manufacturing system. Total ergonomics model considers conventional ergonomics factors as well as management and organizational factors. The total factors are defined as teamwork, information flow, information exchange, training (accident prevention and mitigation and safety in addition to conventional training), management skills and organizational procedures. Control room operation and maintenance department of a large thermal power plant is chosen as the case of our study. To achieve the above objectives, an integrated approach based on total ergonomics factors is developed. Second, it is applied to the power plant and the advantages of total ergonomics approach are discussed. Third, the impact of total ergonomics factors on local factors is examined through non-parametric statistical analysis. Moreover, the importance and impacts of total ergonomics factors are shown through Cramer's Phi coefficient and Kruskal-Wallis test. It is shown that total ergonomics model is much more beneficial than conventional approach. It should be noted that the traditional ergonomics methodology is not capable of locating the findings of total ergonomics model. The distinguished aspect of this study is the employment of a total system approach based on integration of the conventional ergonomics factors with management and organizational factors.

Key Words Ergonomics, Manufacturing, Management, Organization, Safety, Total System, Teamwork, Information Flow, Training, Information Exchange

چکیده این مقاله سه هدف دارد: اول، یک چهار چوب کلی برای توسعه مدل فراگیر ارگونومی ارائه می دهد: دوم، کاربرد مدل فراگیر ارگونومی را به منظور ارتقای شرایط کاری و بهره وری سیستمهای تولیدی نشان می‌دهد و سوم، به این سؤال پاسخ می دهد که آیا مدل فراگیر ارگونومی نسبت به رویکرد متداول ارگونومی اویویت دارد یا خیر. این بررسی از اولین در نوع خود برای آزمون اجزاء مدل فراگیر ارگونومی است. مدل فراگیر ارگونومی علاوه بر فاکتورهای متداول، فاکتورهای مدیریت و سازمان را نیز در نظر می‌گیرد. فاکتورهای فراگیر عبارتند از کار گروهی، جریان اطلاعات، تبادل اطلاعات، آموزش (ایمنی و جلوگیری از حوادث)، مهارتهای مدیریت و ضوابط سازمانی. برای نمونه، اتاقهای فرمان و بخش نگهداری و تعمیرات یک نیروگاه بزرگ حرارتی در نظر گرفته شده است. به منظور نایل شدن به اهداف تحقیق، یک رویکرد یکپارچه براساس فاکتورهای فراگیر ارگونومی توسعه داده شده و فوائد آن بحث شده است. ثانیا، میزان اثر بخشی فاکتورهای فراگیر بر فاکتورهای متداول ارگونومی بوسیله روشهای ناپارامتری آماری آزمایش شده است. مضاقا اینکه میزان اثر بخشی و اهمیت فاکتورهای فراگیر ارگونومی بوسیله ضریب فای کرامر و آزمون کروسال والیس نشان داده شده است. در این مطالعه نشان داده شده است که مدل فراگیر ارگونومی به مراتب از رویکرد متداول سودمندتر است. بایستی متذکر شد که رویکرد متداول ارگونومی قابلیت شناسایی نتایج مدل فراگیر ارگونومی را ندارد. بنابراین از نکات متمایز این مطالعه بکارگیری یک رویکرد فراگیر سیستمی بر اساس یکپارچه سازی فاکتورهای متداول ارگونومی با فاکتورهای مدیریت و سازمان است.

1. INTRODUCTION

Conventional ergonomics approach is concerned with improving the interface design between human operator and machine. However, in complex manufacturing systems, without its upward integration with job of operators and organizational design of such systems, at best, it leads only to sub-optimization and, therefore, results in an inherent error- and failure-prone total system. Such a system, eventually, when faced with concatenation of certain events, would suffer from this `resident pathogen' (Reason [1], Perrow [2] and Meshkati [3]). In fact, operators' error should be seen as the result of human variability, which is an integral element in human learning and adaptation (Rasmussen [4], Rasmussen and Batstone [5], Rasmussen, [6], Meshkati [7] and Clegg et al. [8]). Thus, human error occurrences are defined by the behavior of total human-task-organizational system.

Finding the mechanisms that optimize the teamwork between operator and machine is one of the great technological challenges of the twenty first century (Browning [9]). The technological challenge is to create an intellectual interface between human operators, machine and organizational structures. In fact, organizational errors are often the root causes of human errors and man-machine failures (Pate-Cornell [10], Perrow [11] and Kawowski [12]). Therefore, the interface systems must be matched with operators' capabilities. In addition, there is a need for an integrated design between operators, machines, management and organization.

As mentioned, agronomy strives 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 total ergonomics 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 (Hendrick [13] and [14], Azadeh [15] and Hendrick [16]).

A total ergonomics program requires teamwork between operators and managers at all levels. Work group or teamwork ideas have been shown to enhance productivity and reliability of manufacturing systems. Several studies show how teamwork could eliminate the potential for confusion and enhance the productivity (Sundstorm et al. [17], Turner [18] and Hart et al. [19]). The operators and supervisors should give each other necessary feedbacks. In fact, feedback is seen as a contingency leading to effective and cognitive outcomes, including level of attraction to the group, pride in the group, defensive feelings, and acceptance of the group problems (Brehmer [20], Raudsepp [21] and Harmon and Rahrbaugh [22]). The supervisors should allow operators' opinion or questions. This can be developed during simulator or training exercises. This means that the supervisors must always participate with the operators in team skill training and feedback sessions following simulator or training exercises.

We need to adopt a more holistic approach to human factors problems of manufacturing systems. We must consider the whole and avoid the trap of dealing with specialties with which we feel comfortable. The total ergonomics approach optimizes interface between operators, machines and organization by using teamwork, on-the-job training, reliable safety programs, well-defined procedures and effective management. One of the first practical studies to examine total ergonomics components in a manufacturing system is presented in this study. In the next sections, the structure of the total ergonomics model is discussed. In summary, a total ergonomics model considers all of the conventional ergonomics design features and thus insures optimal ergonomics compatibility of the system components with the system's overall structure. In socio-technical terms, this approach enables joint optimization of the technical and personnel sub-systems and results in higher productivity and safety.

The objective of this paper is three fold. First, a general framework for development of the total ergonomics model is introduced. Second, it is described how total ergonomics model may be applied in practice to intensify the productivity and working conditions of manufacturing systems. Third, it is shown whether the total ergonomics model is superior to the conventional ergonomics approach. This study is among the first to examine the total ergonomics and conventional ergonomics factors in a manufacturing system. A 2000 MW thermal power plant was chosen as the case of our study. By a non-parametric statistical methodology the correlation of total ergonomics factors are examined against conventional (local) ergonomics factors. Also, the difference between mean rating

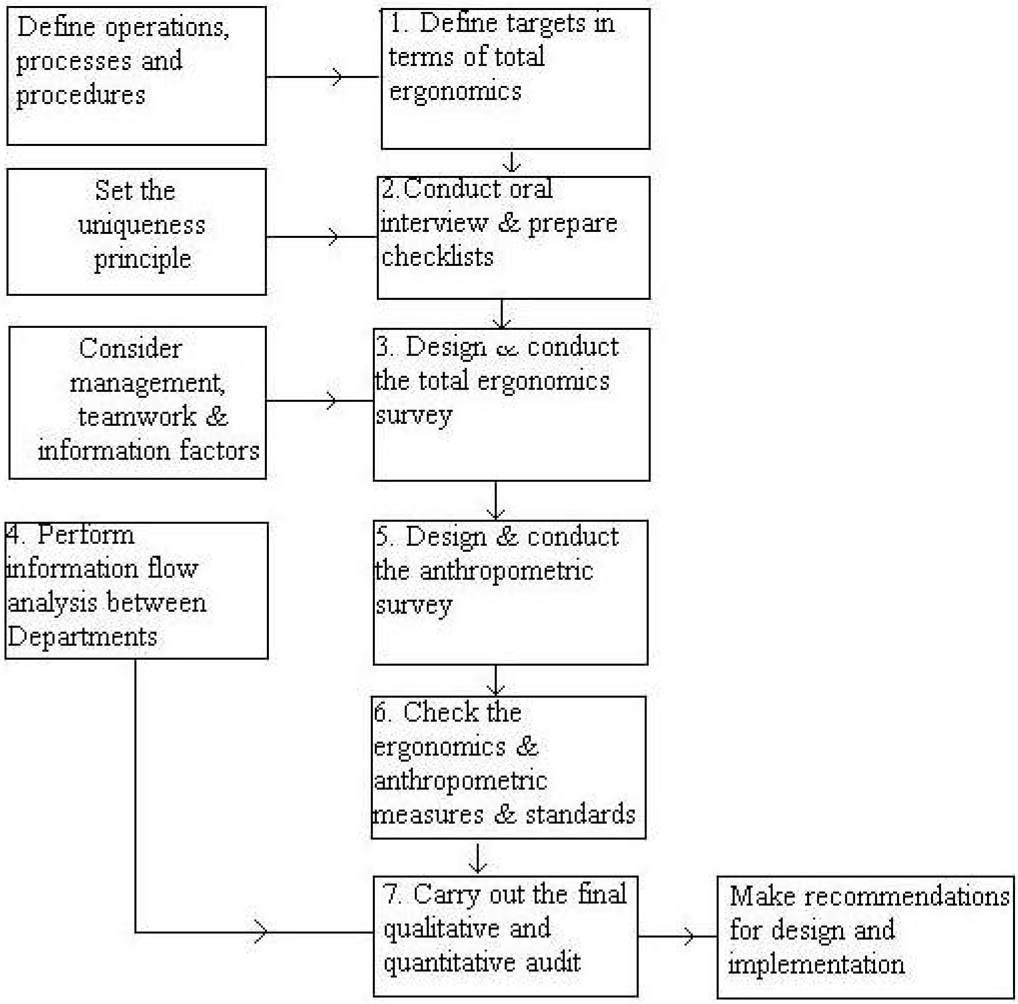

Figure 1. The general steps required to achieve a total ergonomics model.

of operators in respect to particular total factors are examined through non-parametric analysis. Furthermore, the influence or impacts of total ergonomics factors on local factors are examined through non-parametric Cramer's Phi coefficient and Kruskal-Wallis tests.

2. TOTAL ERGONOMICS MODEL

Total ergonomics model is the integration of conventional ergonomics factors and management and organizational factors. Furthermore, the total model requires the assessment of management factors, information flow (between departments, personnel and management) in addition to conventional ergonomics analysis. The general procedure of the total ergonomics model is shown in Figure 1. The two distinct features of the total model are shown in outboxes number 3 and 4. Other activities (boxes 1, 2, 5 and 6) are performed by a conventional approach.

As seen and like conventional approach, all procedures, processes and operations of the system under study must be defined. Second, managers and operators are interviewed to exhibit their opinion about the working conditions and ergonomics considerations. Third, a detailed questionnaire containing valuable information related to human factors, safety, management, teamwork and training are developed and presented to operators and managers to reveal the drawbacks and to identify the cause-and-effect relationships. Fourth, an integrated information flow analysis between departments (in our study between maintenance and control room departments) is performed to identify weaknesses and strengths about information flow. Fifth, a detailed ergonomics questionnaire concerning working postures, body movements and environmental issues is designed and conducted.

Also, in each station anthropometric and ergonomics measures such as height, weight, seating position, etc. was checked against standards. Finally, a final audit and a complete qualitative and quantitative (if applicable) analysis are performed to uncover hidden points (Eastman Kodak, [23] and [24]; Bailey, [25]). This approach would develop a total rather than local ergonomics modeling. It must be noted that the total ergonomics model must be cautiously tailored and applied to the system under study. The two distinct features of the total ergonomics model are discusses in the next sections.

2.1 Total Ergonomics Survey An effective and practical total ergonomics model should be designed for the real people in the loop, namely, operators and supervisors. Therefore before designing and implementing the total ergonomics survey, managers and operators of the system being studied are required to be interviewed to exhibit their opinion about the working conditions and ergonomics considerations. The results of interviewing method should enable us develop total ergonomics and anthropometric questionnaires with reference to existing standards in the field. Interview techniques should cover the issues related to:

- Safety and hygiene factors
- Teamwork
- Anthropometric measures
- Management and organizational factors
- Training
- Job satisfactions

After the interviewing process, a detailed questionnaire must be designed by referring to the findings of the interview method and use of ergonomics, safety and organizational standards (Hendrick [13] and [14] and Azadeh, [15]). The inquisition process must contain valuable and practical information related to human, safety, management and organizational factors. In addition, several questions concerning teamwork and training must be developed. The results of survey may be analyzed by statistical techniques such as pie chart, bar chart, non-parametric tests and correlation analysis. The findings of this study must stress weak and strong points regarding the above factors.

2.2 Information Flow Analysis This part of study examines the flow of information between departments. Also, interpersonal communication problem between operators and operators and supervisors must be studied. This requires organizational and information structures including existing software, hardware, information systems, level of hierarchy, procedures and documentation be examined. The objective is to use all the formal means to uncover deficiencies in the flow of information within and between departments. To achieve the above objective, it is suggested that data flow diagrams (DFD) representing the information flow between and within departments be prepared. Second, documentation relating to work requests, work permits and quality of communications are studied and analyzed. The results of this technique together with findings of the total ergonomics survey (containing questions regarding information flow between co-workers and between co-workers and supervisors, information systems, etc.) should enable us locate major deficiencies in regard to the flow of information between and within departments.

After all the seven steps are carried out, a final audit is conducted to uncover hidden points in relation to safety and ergonomics issues. This phase acts as a final check against total ergonomics factors discussed in the previous sections. First, all previous findings are reviewed to expose hidden total ergonomics issues such as managerial or training problems. Second, the system being studied must be carefully visited (station by station) to unveil hidden ergonomics and anthropometric issues. The results of the conventional approach together with the two features discussed in the last two sections should highlight major deficiencies and enable us to carry out a total ergonomics model in a manufacturing system.

3. A CASE STUDY

A 2000 MW thermal power plant composed of large control rooms and maintenance department was considered as the case of our study. The power plant is composed of four units and one control room controls each two units. Maintenance department is composed of several machine shops, technicians and engineers. The objectives of the total ergonomics model were defined as:

• Improvement of working conditions

• Reduction of lost workdays as the result of injuries

• Use of proper operating procedures for operators

• Identifying organizational deficiencies, which degrade human performance

• Enhancing the availability of the power plant through design of total ergonomics model

Note that the last two objectives (4 and 5) are strictly related to total ergonomics approach and could not be achieved through the conventional approach. All operators and supervisors of the control rooms and maintenance department were involved in our study. The total approach discussed in this paper was applied to the power plant. For the accomplishment of total ergonomics program, the rules and procedures, operations and processes of the shop was carefully studied. To help the ease of comprehension, a detailed flowchart and a schematic diagram were prepared. The most important findings of the interview methods with operators and managers are as follows:

• Moderate to high workload level in several workstations

• Safety procedures are violated

• Protective and safety equipment are not used

• Operators complaining of back pains

• High level of stress in the control rooms

• Lack of teamwork between operators and supervisors in both maintenance and operation departments

A total ergonomics survey was developed and presented to operators and supervisors. Some questions are presented in Table 1, which suggest workstation and organizational design issues. In fact, question number 5, 6 and 8 are related to the total ergonomics approach discussed in this paper. They are not considered in a conventional ergonomics approach. In addition, certain pressures that push operators override safety precautions are summarized

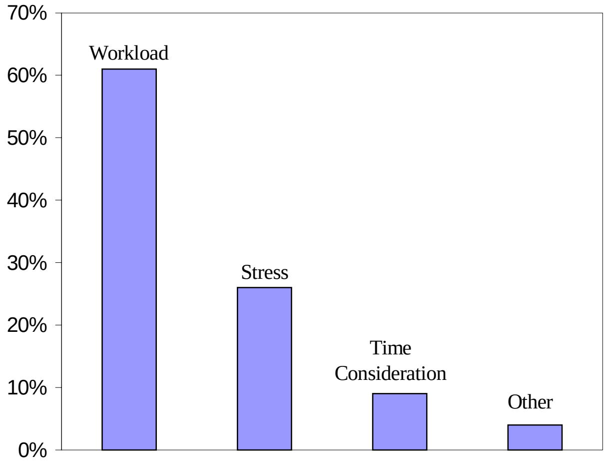

Figure 2. Certain job pressures during emergencies in the control rooms.

in Figure 2 that suggests poor job design and imbalance of operators' workload level during emergencies. Furthermore, a high workload level is due management and organizational issues not considered in a typical conventional approach.

A complete ergonomics and anthropometric study was conducted throughout the control rooms and maintenance department. The results of this study shows:

• Poor workstations design

• Improper utilization of equipment and instruments

• Inappropriate labeling and coding procedures

Anthropometric and ergonomics measures were checked and measured against acceptable standards. Some of the most important findings of this study are as follows:

• There needs to be a balance between maintenance department's temperature and humidity

• Incompatibility between panel dimensions and operators' natural dimension in the control rooms

• Noise level in control rooms needs to be reduced to the standard level.

• There is insufficient lighting in the maintenance workshops

Information flow between control rooms and maintenance departments is analyzed through historical data, order forms and other forms exchanged between the two departments. Also, certain complementary questions are included in

TABLE 1. Selected Questions From Total Ergonomics Survey.

Question:	Percent Responded		
	Yes	No	Uncertain
1. Is there formal on-the-job training at work?	76.8	23.2	0
2. Is there training about safety procedures and precautions?	91.9	8.1	0
3. Do you need to memorize rules and procedures?	83.7	9.3	7
4. Are you able to figure out what causes an accident?	93	2.3	4.7
5. Are you familiar with organizational rules and procedures?	33.7	10.5	54
6. Is there any financial reward for as a team?	44.2	24.4	31.4
7. Do you have difficulty with procedures during emergency or increased demand?	27.9	40.7	31.4
8. Are there pressures that could push you override safety precautions?	57	30.2	12.8
9. Should there be a better workstation design?	73.3	3.5	23.2

the total ergonomics survey, which together with information flow assessment revealed certain shortcomings with the flow of information between the two departments. Finally, a final audit was conducted as a complementary technique to unveil forgotten and unseen issues in the control rooms and maintenance workshops. The results show several problems concerning local and total ergonomics factors. For instance, proper protective equipment was not worn (local) and safety procedures was violated by operators of a welding workstation (total factor).

The most important findings of the total ergonomics approach are listed as follows:

1. Spread teamwork and group think
2. Re-design of information flow between maintenance and control rooms
3. Prepare sufficient organizational support for control room operators
4. Develop a set of well-defined procedures for control room operations
5. Optimize workload level of operators
6. Some workstations of the maintenance department must be redesigned
7. Utilization of safe and conventional protective equipment.
8. Modifications of coding and labeling in control rooms

It should be noted that a conventional ergonomics approach could only locate the local issues addressed in the last four bullets (and probably some portion of bullet number 4). This is why designing and implementing the conventional ergonomics approach would result in local rather than total optimization of human performance. The company is at stage of carrying out the findings of our study and consequently improving productivity and reliability of control rooms and maintenance operations of the power plant.

4. TEST OF HYPOTHESIS

In this section a set of test of hypothesis is conducted to foresee if local factors are independent of total ergonomics factors. Also, the difference between mean rating of operators in respect to particular total factors are examined through Kruskal-Wallis test. For example, the operators who can easily communicate with supervisors are compared with the ones who can't easily communicate with supervisors in respect to the level of job pressures. Local factors are defined as factors affecting ergonomics conditions stationery such as job pressures or evaluation techniques. Total factors are defined as factors influencing total system's performance such as rules and procedures, information exchange between personnel/departments. To show if the total ergonomics approach is superior to conventional ergonomics approach, we need to show the total factors are influencing conventional (local) factors. The most important traditional (local) factor is job pressure due to time and production demands, which we code it as number 1. A set of total factors is identified from one of the questionnaire and their statistical relationships to the local factors are examined through a non-parametric (namely, Cramer's Phi) approach. The total factors chosen are as follows:

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

4.1 Cramer's Phi Coefficient This coefficient is a correlation index for K by L matrices and its maximum value does not depend on the number of levels of variables (K and L). It is the extended version of Phi coefficient. The range of this coefficient regardless of the values of L and K is always between 0 and 1 (Hooman [26]). If K and L are defined such that L<= K, the Cramer's Phi Coefficient is defined as follows:

$$\phi' = \sqrt{\frac{\chi^2}{n(L-1)}}$$

Where the numerator value of chi-square is found from appropriate table with 2 degrees of freedom at the chosen level of significance. n is the total number of subjects and L is the number of the levels of the first variable. The above statistic would test the null hypothesis (H_o) of no correlation between the two variables against alternative hypothesis (H_1) of correlation between the two variables. The results of the non-parametric Cramer's Phi Coefficient between the local ergonomics variable and the nine total ergonomics variables are presented in the Table 3.

TABLE 3. The Cramer's Phi between Local and Total Factors in the Maintenance Department.

Local Variable	Total Variable	Cramer's Phi	Significant Level (alpha)
1	2	.67	.00000
1	3	.40	.00900
1	4	.55	.00002
1	5	.50	.00002
1	6	.61	.00000
1	7	.56	.00000
1	8	.45	.00008
1	9	.43	.00017
1	10	.50	.00002

It should be noted that the number 1 in the first column refers to the job pressures (local variable). As shown there is strong evidence that the nine total factors are correlated with the job pressures at work. Furthermore the job pressures at work is influenced by familiarity with organizational rules and procedures and information flows between co-workers and co-workers and supervisors. Also, job pressures are positively correlated with teamwork (work relationship with supervisors). In summary, these findings show the positive impacts of local on total ergonomics factors and to further our investigation, series of comparative studies are performed between various groups of operators in the next section. It is examined if total ergonomics factors influence the human performance in particular and the system in general.

4.2 Kruskal-Wallis Test The Kruskasl-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 (Hinton, [27]). Furthermore, it assumes independence between subjects in conditions. The test statistic is calculated using the following formula, which allows for different numbers of subjects in each of the two conditions:

$$H = \frac{12}{N(N+1)} \sum \frac{T_i^2}{n_i} - 3(N+1)$$

N is the total number of subjects, n_i is the number of scores in each of the two condition, and T_i is the total of the rank in each of the two condition. The calculated value of H is then compared with the table value of chi-square with 1 degree of freedom at the chosen level of significance to reject the null hypothesis.

The first test examines the differences between operators who receive on-the-job training and the ones who receive no on-the-job training in respect to the level of job pressures. From the results of Kruskal-Wallis through SPSS, it is concluded that there is significant difference between the two groups (at alpha = .05) and the operators who receive no on-the-job training report higher level of job pressure (time and production pressures) by about 30 percent. The next test examines the previous two groups in respect to the quality of perceived information from supervisors. It is concluded that there is significant difference (at alpha = .10) between the operators who receive on-the-job training and the ones who receive no on-the-job training in lieu of the quality of information they receive from the supervisors. Furthermore, the quality of perceived information from supervisors is higher for the operators who receive on-the-job training by about 30 percent. Also, the operators who received training related to accident mitigation and prevention and safety issues are compared with the ones who don't receive such training in regard to job pressures by the Kruskal-Wallis. The null hypothesis is rejected at alpha = 0.01 and it is concluded that there is significant difference (at alpha = .05) between the two groups in respect to job pressures (production and time pressures). In fact, the operators who don't receive safety training report higher level of job pressure (by about 40 percent).

The difference between operators who are capable of locating non-routine (emergency) situation at work with the ones who don't have this capability in relation to the quality of information they perceive from co-workers is examined. It is concluded that there is significant difference between the two groups in lieu of the quality of information they perceive from co-workers at alpha = 0.10. Operators who are capable of locating emergency situations report higher quality of perceived information (about 45 percent) from co-workers. Also, the operators who have problems using organizational procedures during routine situations are compared with the group who do not report any problems in respect to the quality of information they perceive from co-workers. The null hypothesis is rejected and it is concluded that the two groups of operators differ significantly (at alpha = 0.10) in the quality of information they receive from co-workers. The operators who don't have any problem using organizational procedures report higher quality of perceived information from co-workers. Next, the same group of operators was compared in regard to the quality of information they perceive from supervisors. The null hypothesis was rejected at alpha = 0.01 and it was concluded that the ones who do not report any problem with organizational procedures also report higher quality of perceived information from supervisors by about 60 percent. The same two groups of operators are examined in lieu of job pressures. The null hypothesis is rejected at alpha = 0.01 and hence, it is concluded that the operators who do not report any problem with organizational procedures also report lower level of job pressures by about 50 percent. The operators who have problems with using procedures during emergency (non-routine) situation are compared with the ones who do not such problems in respect to the quality of information they perceive from co-workers. The null hypothesis is rejected and it is concluded that the two groups differ significantly (at alpha = 0.01). Moreover, the operators who report no problem with procedures during emergency situations also report higher quality of perceived information from co-workers by about 50 percent.

The operators who are rewarded by supervisors for teamwork are compared with the ones who are not rewarded for teamwork in respect to job pressures (production and time pressures). Interestingly enough, the null hypothesis is rejected at alpha = 0.01 and it is concluded that the two groups differ significantly in lieu of job pressures. Hence, the operators who are rewarded for teamwork report lower level of job pressures by about 70 percent. The same two groups were compared in respect to the quality of information they perceive from co-workers. The null hypothesis is rejected at alpha = 0.01 and it is concluded that the operators who are rewarded for teamwork report higher quality of perceived information from co-workers by about 40 percent.

The operators who violate the safety procedures due to job pressures are compared to the operators who don't violate the safety procedures due to job pressures in respect to the level of job pressures. The null hypothesis is rejected at alpha = 0.01 and the operators who violate safety procedures due to job pressures report higher level of job pressures during routine situations by about 45 percent. The same two groups are compared in lieu of the quality of information perceived from co-workers. The null hypothesis is rejected at alpha = 0.01 and it is concluded that the operators who don't violate safety procedures due to job pressures report higher quality of perceived information from co-workers by about 50 percent.

The operators who can easily communicate with supervisors are compared with the ones who can’t easily communicate with supervisors in respect to the level of job pressures. The null hypothesis is rejected at alpha = 0.01 and it is concluded that the two groups differ significantly in lieu of job pressures. Moreover, the operators who can’t easily communicate with supervisors report higher level of job pressures by about 58 percent. The preceding groups were compared in respect to the quality of information they perceive from supervisors. The null hypothesis is rejected at alpha = 0.01 and it is concluded that the operators who can easily communicate with supervisors report higher quality of perceived information from supervisors by about 40 percent.

The operators who report problems with co-workers due to inter-organizational issues are compared the ones who don't have such problems due to inter-organizational issues in respect to the level of job pressures. The null hypothesis is rejected and it is concluded that the two groups differ significantly at alpha = 0.01. Furthermore, the operators who do not report problems with co-workers due to inter-organizational issues report lower level of job pressures by about 45 percent. The preceding groups are compared in lieu of the quality of information perceived from supervisors. The null hypothesis is rejected at alpha = 0.01 and it is concluded that the operators who don't report problems with co-workers due to inter-organizational issues also report higher quality of perceived information from supervisors by about 32 percent.

The operators who feel they have freedom to make decisions without continuous contact with others (particularly supervisors) are compared with the ones who feel they don't have freedom to do so in respect to the quality of information perceived from supervisors. It is concluded that the two groups differ significantly in respect to the quality of information perceived from supervisors (at alpha = 0.05). Furthermore, the operators who report that they have freedom to make decisions without continuous contact with others also report higher quality of perceived information from supervisors by about 30 percent.

The operators who believe there could be a better job design are compared with the ones who do not believe there could be a better job design in respect to the level of job pressures. The null hypothesis is rejected and it is concluded that the two groups differ significantly at alpha = 0.01. Moreover, the operators who believed that there could be a better job design reported higher level of job pressures (production and time pressures) by about 300 percent.

The results of the tests are summarized in Table 4. As seen we can conclude that total factors significantly influence human performance and therefore they must be considered and designed concurrently with the local factors in order to optimize human performance in particular and the system in general.

5. CONCLUSIONS

The importance of a total rather than a local ergonomics approach is shown in this paper. We

TABLE 4. The Results of Kruskal-Wallis Test on Difference on Ranks.

Difference in mean ranking of 2 groups of operators		Response variable	Significance level for rejection	% improvement in mean response ranking[1]
Group I	**Group II**			
Operators with on-the-job training	Operators with no on-the-job training	Job pressures	0.0924	30 (I)
Operators with on-the-job training	Operators with no on-the-job training	Quality of perceived information from supervisors	0.0856	30 (I)
Operators with safety and accident prevention training	Operators with no training	Job Pressures	0.0100	40 (I)
Operators capable of locating emergency situations	Operators not capable of locating emergency situations	Quality of perceived information from co-workers	0.0694	45 (I)
Operators having problems with organizational procedures	Operators having no problem with organizational procedures	Quality of perceived information from co-workers	0.0609	40 (I)
Operators having problems with organizational procedures	Operators having no problem with organizational procedures	Quality of perceived information from supervisors	0.0003	60 (II)
Operators having problems with organizational procedures	Operators having no problem with organizational procedures	Job Pressures	0.0009	50 (II)
Operators having problems using procedures during emergency	Operators having no problem using procedures during emergency	Quality of perceived information from supervisors	0.0011	50 (II)
Operators who are rewarded for teamwork	Operators who are not rewarded for teamwork	Job Pressures	0.0030	70 (I)
Operators who are rewarded for teamwork	Operators who are not rewarded for teamwork	Quality of perceived information from supervisors	0.0041	40 (I)
Operators who violate safety procedures	Operators who don't violate safety procedures	Job Pressures	0.0054	50 (I)
Operators who can easily communicate with supervisors	Operators who cant easily communicate with supervisors	Job Pressures	0.0073	58 (II)
Operators who can easily communicate with supervisors	Operators who cant easily communicate with supervisors	Quality of perceived information from supervisors	0.0164	40 (I)
Operators with problems with co-workers	Operators with no problem with co-workers	Job pressures	0.0139	45 (I)
Operators with problems with co-workers	Operators with no problem with co-workers	Quality of perceived information from supervisors	0.0123	32 (I)
Operators with individual decision making capability	Operators with no individual decision making capability	Quality of perceived information from supervisors	0.0454	30 (I)
Operators believing a better job design is required	Operators believing current system is OK	Job pressures	0.0010	300 (I)

1: The Latin number in the parentheses indicates the group number

showed that a total ergonomics approach is much more efficient than conventional approach. This is shown through introduction of the total ergonomics model, applying the model in a power plant and showing its advantage through statistical analysis. Non-parametric statistical analyses are used to show positive correlation between local and total factors and to highlight the impact of total factors on human performance. Furthermore, it is noted that by designing and implementing a total ergonomics approach, the system and its human performance are totally rather than locally optimized. It should be noted that the conventional ergonomics approach is capable of identifying local or stationary ergonomics issues. The distinguished aspect of this study is the employment of a total system approach based on integration of the conventional ergonomics and management factors. To conduct a total ergonomics study, we must consider the whole and avoid the trap of dealing with specialties with which we feel comfortable. A well-defined practical total ergonomics program requires teamwork between operators and supervisors at all levels. The total approach should be cautiously carried out to avoid local or short-term improvements. This requires a team of experts specializing in human factors, organizational design and statistics. Moreover, the experts should be familiarized with the idea of total ergonomics. It should be noted that each system is unique and the problem solving approach of each system must be based on systems uniqueness philosophy.

Peter Drucker [28] says the importance of a total rather than a local approach best. He states that the emerging theory of manufacturing will require that every manufacturing manager be responsible for integrating people, machines and time (Drucker, [28]). The manufacturing managers need to adopt a more systemic approach understanding the complex interrelationship in the system. Systemic understanding is difficult to achieve, but is necessary if we are to face with increasing uncertainties and competitions of manufacturing systems in the twenty first century.

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