# “Determination of ergonomics dimension of production enterprises by principal component analysis”


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# Determination of ergonomics dimension of production enterprises by principal component analysis

## Abstract

Ergonomics aims to increase productivity, work enthusiasm and performance by harmonization of products, duties and environment with employees. Ergonomics which takes an important place in order to maintain the security and effectiveness of the employees, also tries to increase the production and to protect employees' health in addition to balancing workload and working power in the best way. In this study, the factors, which can be used to determine the ergonomics of work places in the firms, have been obtained by the help of principal component analysis. Results have been evaluated following the surveys in two different production firms. 32 different variables have been discussed in the principal component analysis. Then, these variables have been collected in 9 factors in an automotive firm and in 10 factors in a textile firm. The two most effective aspects among automotive firms are "work environment, cleanliness and health" and "noise and temperature". In terms of textile firms the two most effective aspects are "machinery and work environment" and "team work and security".

**Keywords:** ergonomics, principal component analysis, multivariate analysis.
**JEL Classification:** C40, M10, J81.

## Introduction

Industrialization, which started from infancy at the end of the 17th century, reached the phase of automation through technological developments that gained speed in the 18th and 19th centuries. Health, security and productivity problems of human that took part in each phase of industrialization as a productive, constructive, creative and controlling factor for the established systems could only be handled in the first half of the 20th century (Oral, 1998).

The word, ergonomics, is composed of "Ergon" which means work in Greek and "Nomic" which means law in Greek and it means the science of work. Ergonomics is defined as a multidisciplinary research and development field, which aims to put forward basic laws of system productivity and Human-Machine-Environment harmonization against organic and psychological stresses arising out of the effect of all factors in the industrial work environment by taking into account anatomic features, anthropometric characteristics, physiological capacities and tolerances of people (Erkan, 1996: 16; Demir and Gümüşoğlu, 2003: 393-403).

Recently, definition of ergonomics made by International Ergonomics Association (IEA) is as follows: "Ergonomics or Human Factors Engineering is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance" (Hendrick, 2000: 22).

It is necessary to examine workplaces in terms of environmental elements such as lighting, noise, dust, smoke, heat, ventilation, vibration, high or low pressure, humidity and anthropometric data and organizational elements such as heavy and light physical work and to arrange the workplaces in line with the structural, dimensional and psychological characteristics of employees in order to ensure that employees work in a secure, healthy and productive manner. Ergonomics may be defined as arrangement of work according to the characteristics of people (Demir and Gümüşoğlu, 2003: 393-403).

For long years, ergonomics has attracted attention in developed countries as a discipline, however, the interest in the discipline of ergonomics has increased day by day in other countries. For example, in Latin America and especially in Brazil, ergonomic activities, which are performed in terms of education and training, are striking. Today, it is necessary to use human force in industrial life in a good way and to maximize the human productivity as much as possible within the current facilities. Ergonomics may be defined as application of science in human performance and elements in terms of machinery supervision and equipment design. Ergonomics deals with anatomy, physiology, industrial hygiene, dentistry and other disciplines. The science of ergonomics, through its expanding and enriching content against changing life and work forms, has turned into a form which is based on total ergonomics approach by taking into account the environment in order to increase quality of life (Soares, 2006: 555; Demir and Gümüşoğlu, 2003: 387).

In this study, working conditions of employees in two enterprises, which perform activities in auto-

motive and textile sectors, have been examined in terms of ergonomics and this study aims to determine the ergonomic aspects of these enterprises.

**Development process of ergonomics.** The first studies in the field of ergonomics were performed on the concept of work order and more productive and regular work by employees by F. W. Taylor in the second half of the 18th century. The first researcher, who proposed "the fee approach in terms of work enthusiasm" in social psychology and ergonomics, was Taylor (Erkan N., 1996: 17).

There are two new methodology attempts, which guide the ergonomics approaches in 1910s. The first methodology is "Work and Time Study" developed by the engineer, Gilberth, and his psychologist wife; the second methodology is "Consumption of Oxygen" developed by Douglas in order to measure the energy exerted at work (http://www.ergonomi. itu.edu.tr/ ergonomi.html).

Development of ergonomics has accelerated following the World War II. Studies were performed especially on military planes; anthropometry and biomechanics gained importance. In USA, England and Germany, studies on human factors / ergonomics were made in order to make research and perform practices so as to increase human performance in military weapon systems. These countries were interested in how to optimize weapon vision designs in order to ensure that people use weapons in a more effective way; they carried out studies in this field. A research was made in USA in relation to reasons for military plane accidents; it was realized that the reason, which was considered to be pilot's error, was indeed an error with regard to engineering design. It was observed that control tools, indicators, work area regulations in planes were not coherent with human abilities, physiology, limits and other characteristics. Thus, studies were conducted on human factors related to design of the human-machine intersection. Following the World War II, Europe and Japan faced with the tasks of reconstructing their factories. Therefore, interest developed in studies on human work nature, in other words, ergonomics and the information in this field was applied to design of workplaces. Today, studies, in which official organizations and unions take part, are carried out in order to ensure worker-machine-environment harmonization in the entire world (Hendrick, 2000: 28).

Rate of office employees has increased day by day in the world. For example, during the 20th century, in USA, rate of office employees increased from 17 % of the total labor force to more than 50%; the remaining employees work in agriculture, industrial production, sales and transportation sectors. Through popularity of information technologies, it is expected that the rate of office employees will continue to increase (Margaritis and Marmaras, 2007: 781; Boff, 2006: 391). Various studies were performed on proper design of various components in the work system in order to solve the problems encountered by office employees with regard to their work through ergonomics. For detailed information on this subject, see Çakır et al. (1980), Grandjean (1987), Helander (1988), Sauter et al. (1990), Kroemer and Kroemer (2001).

It is necessary to examine office conditions and to solve problems by applying the principles of ergonomics. Through small changes in relation to tools and equipment used in the workplace, great changes may be ensured with regard to production, performance, health and security (Vinck and Eijk, 2007: 568; Wells et al., 2007: 741).

## 1. Material and methodology

In this section, firstly, two production enterprises, in which the study has been performed, variables and multi-variate statistical methods will be described in brief in the context of the scope and limits of the study.

**1.1. Scope of the study.** The test of sphericity is applied in order to understand whether there are relations among variables or not and, if any, to determine significance of this relation (Saraçlı et al., 2004: 24).

For the test of sphericity:

$H_0$: $R = I$ (There is no difference between relation matrix and unit matrix. The relation among variables is not significant).

$H_1$: $R \neq I$ (There is a difference between relation matrix and unit matrix. The relation among variables is significant).

In order to determine the ergonomic aspects of two enterprises, a survey, which is composed of 32 questions, has been applied on 139 employees in the automotive enterprise and 30 employees in the textile enterprise. The data obtained from the survey has been evaluated through the principal component analysis.

Survey questions have been developed on Tanyaş (2000: 111-115) by some additions and revisions. 32 variables, which are used for determination of ergonomic aspects of the enterprises in the context of the study, are shown in Table 1.

Table 1. Variables used in the study

| | |
|---|---|
| D1 | My working hours (shift) positively affect my performance |
| D2 | The shift system in my workplace is regular enough to affect my working productivity in a positive way |
| D3 | Work tempo in my workplace positively affects my working productivity |
| D4 | Social facilities allocated for employees (canteen, club etc.) are sufficient |
| D5 | Temperature level in my work environment positively affects my work |
| D6 | Necessary measures (ventilation etc.) are taken against temperature |
| D7 | Noise level in my work environment positively affects my work |
| D8 | Noise in the work environment mostly results from the machinery |
| D9 | Noise in the work environment mostly results from people |
| D10 | Noise in the work environment mostly results from conveyor systems |
| D11 | Measures (ear plug, insulation etc.) are taken against noise |
| D12 | People, who work in the noisy environment, use protective equipment (ear plug etc.) |
| D13 | Lighting level in my work environment positively affects my work |
| D14 | Security measures are taken with regard to electricity equipment in the enterprise |
| D15 | Working conditions of the enterprise are suitable for women |
| D16 | Cleanliness (hygiene) is properly taken into account in my work environment in the workplace |
| D17 | Employees periodically go through health checks |
| D18 | Permanent health personnel in the enterprise is sufficient |
| D19 | The number of employees in my workplace is sufficient when compared to the workload |
| D20 | Recesses/breaks are sufficient in my workplace |
| D21 | Wage I earn in my workplace is sufficient when compared to the work I perform |
| D22 | Workplace order in my workplace positively affects my working productivity |
| D23 | The space I use for working in my workplace is sufficient |
| D24 | Machinery and equipment I use in my workplace are new and handy |
| D25 | Periodical maintenance of the machinery is performed in a proper way |
| D26 | There is personal protective equipment I need to use because of the work I perform (helmet, gloves, overall etc.) |
| D27 | Occupational accidents, which happen in my workplace, are very few |
| D28 | Personnel buses are sufficient in terms of transportation to the enterprise |
| D29 | Personnel buses are secure |
| D30 | Team work is allowed in the enterprise, in which I work |
| D31 | Social relations are good in my workplace |
| D32 | Measures are taken in relation to the environmentally hazardous waste materials (dust, smoke and material wastes etc.) from the enterprise |

**1.2. Principal component analysis.** The principal component analysis, which is used in the study, generally eliminates the structure of interdependence among the variables and decreases the size of an inter-related, multi-variate data set. This decrease means transformation to a new set of variables, which is called "principal component". The principal component analysis is used in order to explain and interpret variance-covariance structure of the set of variables through linear combinations of these variables and a lower number of variables (Johnson and Wichern, 1988: 340; Çakmak and Şenyiğit, 2006: 7). The principal component analysis, which was first introduced by Karl Pearson (1901) and developed by H. Hotelling (Srivastava, 1983: 274), is a data reduction method; one of the most important aims of this analysis is to study the source of interdependence among variables. In these analyses, relations among all variables are studied. Based on these relations, data is presented in a more significant and condensed way and ease of interpretation is ensured (Balcı, 2004: 242; Turgut and Baykul, 1992-1: 173).

In a system, where it is observed that there are $p$ number of variables (characteristics) with regard to $n$ number of units, variability is defined as $k$ number of new variables ($k < p$). These new variables can define the variability in a $p$-sized system without resulting in a considerable loss of information. If the researcher uses raw data matrix, the researcher determines the number of principal components based on the variance-covariance matrix while the researcher uses the correlation matrix in case of standardized data matrix. If the variances in relation to the data are close to each other and the units of measurement are the same, the covariance matrix is used; otherwise, the correlation matrix is used (Tatlıdil, 1992: 122; Çakmak and Keçek, 2007: 1012). The resulting $Y_1$, $Y_2$, $Y_3$, …, $Y_p$ principal components are independent, in other words, the correlation among these components is zero. $Y_1$ is the most important component, which has the greatest contribution to the total variance. Subsequently, significance of the consequent principal components gradually decreases. As for the number of significant principal components, Kaiser (1960) states that the principal components, whose Eigen value $(\lambda_i)$ is lower than 1, should not be included in the analysis as they contain limited information. Another criterion, which is used for determination of the number of significant principal components, is $k$ value that meets the condition of $\left(\sum_{i=1}^{k}\lambda_i\right)/p \geq \frac{2}{3}$ or the number of the principal components which define at least 70% of the total variance (Stevens, 1986: 341). Varimax vertical rotation method, which was proposed by Kaiser and which enables the analyst to interpret in a better way, is applied on the resulting principal components. According to this method, some of the correlations between the variables and the significant principal components (factors) are approximated towards 1 while the other part is approximated towards 0 (Tatlıdil, 1992: 150). It is ensured that the variables, which are highly correlated with the factors, are concentrated in the related factors. The resulting matrix with pxk size is called "rotated factor matrix". By taking into account the characteristics of variables, which are concentrated on each factor, each factor is given a name. The number of factors, which will represent the data in the most appropriate way, is determined through the total variance percentage defined by each factor. The number of

factors to be taken into account is equal to the number of factors, whose Eigen value is higher than 1 (Ünsal, 1996: 141-142).

## 2. Findings of the study

In the study, primarily, a principal component analysis has been performed through 32 variables, which are used for determination of ergonomic aspect with SPSS 14.0 package program. Separate analyses have been made for two enterprises.

In this study, through the analysis, which is performed with SPSS 14.0 package program, $H_0$ hypothesis has been rejected. According to this analysis, it is observed that the relation among the variables is significant in a significance level of 0.005. Therefore, it is necessary to apply the principal component analysis. The most common criterion for determination of suitability of the data for the principal component analysis is the criterion of Kaiser-Meyer-Olkin (KMO), which gives an idea on homogeneity of the variables. Criteria of KMO are given in Table 2 (Sharma, 1996: 116).

Table 2. Criteria of KMO

| Criterion of KMO | Proposed value |
|---|---|
| ≥ 0.9 | Extraordinary |
| 0.80-0.89 | Good |
| 0.70-0.79 | Medium |
| 0.60-0.69 | Bad |
| 0.50-0.59 | Very bad |
| 0-0.59 | Unacceptable |

The fact that the value, which is obtained as the criterion of KMO, is higher than 0.6 indicates that it is appropriate to perform the principal component analysis (Büyüköztürk, 2005: 126).

In this study, this value has been obtained as 0.806 and it has been determined that the data is suitable for the principal component analysis.

**2.1. Findings obtained for the automotive enterprise.** This enterprise, which performs activities in the automotive sector, manufactures fuel and oil hoses, cooling and heating system hoses for the automotive sector, industrial hoses and mounted fuel systems and the entire production is exported to foreign countries.

Given the results of the principal component analysis on determination of ergonomic aspects in this enterprise, according to the results of the total defined variances, 9 principal components (factors), whose Eigen value is higher than 1, have been obtained. These factors define 66.338% of the total variance.

In order to ensure ease of interpretation with regard to the principal components, VARIMAX method, which is effectively used among the vertical rotation methods, has been applied for rotation of the factors. The resulting factors, the factor loads per each factor, shares of the factors in the total variance and their Eigen values are given in Table 3.

Table 3. Results of the principal component analysis on the automotive enterprise

| **Factors** | | **Factor loads** | **Defined variance** | **Eigen value** |
|---|---|---|---|---|
| **Factor 1: Work environment, cleanliness and health** | | | 26,305 | 8,417 |
| (D16) | Cleanliness (hygiene) is properly taken into account in my work environment in the workplace | ,707 | | |
| (D19) | The number of employees in my workplace is sufficient when compared to the workload | ,653 | | |
| (D25) | Periodical maintenance of the machinery is performed in a proper way | ,623 | | |
| (D17) | Employees periodically go through health checks | ,597 | | |
| (D23) | The space I use for working in my workplace is sufficient | ,597 | | |
| (D18) | Permanent health personnel in the enterprise is sufficient | ,592 | | |
| (D22) | Work order in my workplace positively affects my working productivity | ,544 | | |
| (D24) | Machinery and equipment I use in my workplace are new and handy | ,513 | | |
| **Factor 2: Human-source noise** | | | 8,667 | 2,773 |
| (D9) | Noise in the work environment mostly results from people | ,796 | | |
| (D12) | People, who work in the noisy environment, use protective equipment (ear plug etc.) | ,785 | | |
| (D11) | Measures (ear plug, insulation etc.) are taken against noise | ,772 | | |
| (D6) | Necessary measures (ventilation etc.) are taken against temperature | ,660 | | |
| (D4) | Social facilities allocated for employees (canteen, club etc.) are sufficient | ,594 | | |
| (D5) | Temperature level in my work environment positively affects my work | ,566 | | |
| (D29) | Personnel buses are secure | ,405 | | |
| **Factor 3: Noise level and hazardous wastes** | | | 6,972 | 2,231 |
| (D7) | Noise level in my work environment positively affects my work | ,746 | | |
| (D32) | Measures are taken in relation to the environmentally hazardous waste materials (dust, smoke and material wastes etc.) from the enterprise | ,710 | | |

Table 3 (cont.). Results of the principal component analysis on the automotive enterprise

| Factors | | Factor loads | Defined variance | Eigen value |
|---|---|---|---|---|
| **Factor 4: Motivation** | | | 5,569 | 1,782 |
| (D21) | Wage I earn in my workplace is sufficient when compared to the work I perform | ,745 | | |
| (D20) | Recesses/breaks are sufficient in my workplace | ,559 | | |
| **Factor 5: Shift system and productivity** | | | 4,874 | 1,560 |
| (D1) | My working hours (shift) positively affect my performance | ,753 | | |
| (D13) | Lighting level in my work environment positively affects my work | ,701 | | |
| (D3) | Work tempo in my workplace positively affects my working productivity | ,459 | | |
| (D2) | The shift system in my workplace is regular enough to affect my working productivity in a positive way | ,416 | | |
| **Factor 6: Measures against occupational accident and transportation** | | | 3,969 | 1,270 |
| (D28) | Personnel buses are sufficient in terms of transportation to the enterprise | ,732 | | |
| (D27) | Occupational accidents, which happen in my workplace, are very few | ,653 | | |
| (D26) | There is personal protective equipment I need to use because of the work I perform (helmet, gloves, overall etc.) | ,494 | | |
| **Factor 7: Machine-source noise** | | | 3,456 | 1,106 |
| (D8) | Noise in the work environment mostly results from the machinery | ,715 | | |
| (D14) | Security measures are taken with regard to electricity equipment in the enterprise | ,528 | | |
| (D10) | Noise in the work environment mostly results from conveyor systems | - ,474 | | |
| **Factor 8: Team work and social relations** | | | 3,358 | 1,075 |
| (D30) | Team work is allowed in the enterprise, in which I work | ,833 | | |
| (D31) | Social relations are good in my workplace | ,550 | | |
| **Factor 9: Working conditions for women** | | | 3,169 | 1,014 |
| (D15) | Working conditions of the enterprise are suitable for women | ,817 | | |

Factors have been named in this table by taking into account characteristics of the variables for each factor and the level of contribution to the factor (factor loads).

**Factor 1:** The first factor, which is obtained as a result of the Principal component analysis applied on the data obtained from the automotive enterprise, defines 26.305% of the total variance. D16 variable, which is defined as "Paying attention to cleanliness (hygiene) in the work environment", provides the highest contribution to this factor with a value of 0,707. D19, D25, D17, D23, D18, D22 and D24, which are defined as "Sufficiency of the number of employees in terms of the workload, proper periodical maintenance of the machinery, periodical health checks of the employees, sufficiency of the space used for working, sufficiency of the permanent health personnel in the enterprise, positive effect of the workplace order on the working productivity, the fact that the used machinery and equipment are new and handy" are the other variables collected under this factor. This factor may be called "Work environment, cleanliness and health".

**Factor 2:** This factor defines 8.667% of the total variance. D9 variable, which is defined as "The fact that the noise in the work environment mostly results from people", provides the greatest contribution among seven variables that contribute to this factor. D12, D11, D6, D4, D5 and D29 variables, which are defined as "Use of protective equipment (ear plug etc.) by people, who work in the noisy environment, taking measures (ear plug, insulation etc.) against noise, taking necessary measures (ventilation etc.) against temperature, sufficiency of the social facilities (canteen, club etc.) allocated for employees, positive effect of the temperature level in the work environment on the work, security of personnel buses, are collected under this factor. Given the variables, which significantly contribute to this factor, this factor may be called "Human-source noise".

**Factor 3:** This factor defines 6.972% of the total variance. D7 variable, which is defined as "Positive effect of the noise level in the work environment on the work", provides the greatest contribution to the factor with a value of 0,746. Then, D32 variable, which is defined as "Taking measures against environmentally hazardous waste materials (dust, smoke and material wastes etc.) from the enterprise", is collected under this factor. This factor may be called "Noise level and hazardous wastes".

**Factor 4:** D21 variable, which is defined as "Sufficiency of the wage earned in the workplace in terms of the work performed", provides the highest contribution to this factor; its factor load is 0,745. The other variable in this factor is "sufficiency of recesses/breaks" (D20). This factor, which defines 5.569% of the total variance, may be called "Motivation".

**Factor 5:** This factor defines 4.874% of the total variance. The factor is composed of four variables. D1 variable is defined as "Positive effect of the working hours (shift) on the performance"; it is the most effec-

tive variable in the factor with a factor load of 0,753. D13, D3 and D2 variables, which are defined as "Positive effect of the lightning level in the work environment on the work, positive effect of the work tempo in the workplace on the working productivity, regularity of the shift system to have positive effect on the working productivity", are other variables that contribute to this factor. This factor may be called "Shift system and productivity".

**Factor 6:** This factor defines 3.969% of the total variance. D28 variable, which is defined as "Sufficiency of personnel buses in terms of transportation to work", provides the highest contribution to the factor with a value of 0,732. D27 and D26 variables, which are defined as "rarity of the occupational accidents that happen in the workplace, existence of protective equipment (helmet, gloves, overall etc.) to be used in line with the work performed", are other variables collected under this factor. This factor may be called "Measure against occupational accident and transportation".

**Factor 7:** In this factor, which defines 3.456% of the total variance, the most effective variable is D8 variable, which is defined as "The fact that the noise in the work environment mostly results from machinery" and whose factor load is 0,715. D14 variable, which is defined as "Taking security measures in relation to the electricity equipment", is the other variable that provides a positive contribution to this factor. D10 variable, which is defined as "The fact that the noise in the work environment mostly results from machinery", provides a negative contribution to the factor. This factor may be called "Machine-source noise".

**Factor 8:** This factor defines 3.358% of the total variance. The variable, which provides the highest contribution to this factor, is D30 variable with a value of 0,833; D30 variable is defined as "Providing opportunity of team work in the enterprise". The other variable in the factor is D31 variable, which is defined as "Good social relations in the workplace". This factor may be called "Team work and social relations".

**Factor 9:** This factor defines 3.169% of the total variance. D15 variable, which is defined as "Suitability of the working conditions in the enterprise for women", is the only variable under this factor. This factor may be called "Working conditions for women".

**2.2. Findings obtained for the textile enterprise.** This enterprise, which performs activities in the textile sector, manufactures raw clothing and fabric with dyed yarn by using cotton, polyester, linen, viscose, modal lycra and fibre-mixed yarns. Besides, overalls (for health personnel, security personnel, cleaning personnel, restaurant personnel) and promotional products are among the main products of the enterprise.

Given the results of the principal component analysis on determination of ergonomic aspects in this enterprise, according to the results of the total defined variances, 10 principal components (factors), whose Eigen value is higher than 1, have been obtained. These factors define 81.723% of the total variance. In order to ensure ease of interpretation with regard to the principal components, VARIMAX method has been used again. The resulting factors, the factor loads per each factor, shares of the factors in the total variance and their Eigen values are given in Table 4.

Table 4. Results of the principal component analysis on the textile enterprise

| Factors | | Factor loads | Defined variance | Eigen value |
|---|---|---|---|---|
| **Factor 1: Machinery and working environment** | | | 20,944 | 6,702 |
| (D24) | Machinery and equipment I use in my workplace are new and handy | ,900 | | |
| (D25) | Periodical maintenance of the machinery is performed in a proper way | ,863 | | |
| (D31) | Social relations are good in my workplace | ,745 | | |
| (D32) | Measures are taken in relation to the environmentally hazardous waste materials (dust, smoke and material wastes etc.) from the enterprise | ,601 | | |
| (D23) | The space I use for working in my workplace is sufficient | ,594 | | |
| (D20) | Recesses/breaks are sufficient in my workplace | ,460 | | |
| **Factor 2: Team work and security** | | | 11,516 | 3,685 |
| (D30) | Team work is allowed in the enterprise, in which I work | ,798 | | |
| (D4) | Social facilities allocated for employees (canteen, club etc.) are sufficient | ,767 | | |
| (D27) | Occupational accidents, which happen in my workplace, are very few | ,668 | | |
| (D14) | Security measures are taken with regard to electricity equipment in the enterprise | ,623 | | |
| (D29) | Personnel buses are secure | ,578 | | |
| **Factor 3: Noise, cleanliness and lightning** | | | 10,635 | 3,403 |
| (D11) | Measures (ear plug, insulation etc.) are taken against noise | ,822 | | |
| (D12) | People, who work in the noisy environment, use protective equipment (ear plug etc.) | ,814 | | |
| (D16) | Cleanliness (hygiene) is properly taken into account in my work environment in the workplace | ,649 | | |
| (D13) | Lighting level in my work environment positively affects my work | ,621 | | |

Table 4 (cont.). Results of the principal component analysis on the textile enterprise

| Factors | | Factor loads | Defined variance | Eigen value |
|---|---|---|---|---|
| **Factor 4: Health and work environment** | | | 9,536 | 3,051 |
| (D17) | Employees periodically go through health checks | ,787 | | |
| (D7) | Noise level in my work environment positively affects my work | ,691 | | |
| (D5) | Temperature level in my work environment positively affects my work | ,652 | | |
| (D18) | Permanent health personnel in the enterprise is sufficient | ,631 | | |
| **Factor 5: Workload and workplace order** | | | 7,391 | 2,365 |
| (D19) | The number of employees in my workplace is sufficient when compared to the workload | ,794 | | |
| (D22) | Workplace order in my workplace positively affects my working productivity | ,772 | | |
| (D21) | Wage I earn in my workplace is sufficient when compared to the work I perform | ,688 | | |
| **Factor 6: Transportation and temperature measures** | | | 5,870 | 1,878 |
| (D9) | Noise in the work environment mostly results from people | -,769 | | |
| (D28) | Personnel buses are sufficient in terms of transportation to the enterprise | ,642 | | |
| (D6) | Necessary measures (ventilation etc.) are taken against temperature | ,550 | | |
| **Factor 7: Shift and working conditions for women** | | | 4,621 | 1,479 |
| (D1) | My working hours (shift) positively affect my performance | ,826 | | |
| (D15) | Working conditions of the enterprise are suitable for women | ,604 | | |
| **Factor 8: Shift system and machinery-induced noise** | | | 4,030 | 1,289 |
| (D2) | The shift system in my workplace is regular enough to affect my working productivity in a positive way | ,833 | | |
| (D8) | Noise in the work environment mostly results from the machinery | ,559 | | |
| **Factor 9: Personal protective equipment** | | | 3,677 | 1,177 |
| (D26) | There is personal protective equipment I need to use because of the work I perform (helmet, gloves, overall etc.) | ,832 | | |
| **Factor 10: Noise induced by conveyor systems and work tempo** | | | 3,504 | 1,121 |
| (D10) | Noise in the work environment mostly results from conveyor systems | ,818 | | |
| (D3) | Work tempo in my workplace positively affects my working productivity | ,709 | | |

**Factor 1:** The first factor, which is obtained as a result of the principal component analysis applied on the data obtained from this textile enterprise, defines 20.944% of the total variance. D24 variable, which is defined as "The fact that the used machinery and equipment are new and handy", provides the highest contribution to this factor with a value of 0,900. D25, D31, D32, D23 and D20 variables, which are defined as "Proper periodical maintenance of the machinery, good social relations in the workplace, taking measures against environmentally hazardous waste materials (dust, smoke and material wastes etc.) from the enterprise, sufficiency of the space used for working, sufficiency of recesses/breaks", are the other variables collected under this factor. This factor may be called "Machinery and work environment".

**Factor 2:** This factor defines 11.516% of the total variance. D30 variable, which is defined as "Providing opportunity of team work in the enterprise", provides the greatest contribution to this factor; its factor load is 0,798. D4, D27, D14 and D29 variables, which are defined as "Sufficiency of the social facilities (canteen, club etc.) allocated for employees, rarity of the occupational accidents that happen in the workplace, taking security precautions in relation to the electricity equipment, security of personnel buses", are also collected under this factor. This factor may be called "Team work and security".

**Factor 3:** In this factor, which defines 10.635% of the total variance, the most effective variable is D11 variable, which is defined as "Taking measures (ear plug, insulation etc.) against noise and whose value is 0,822". D12, D16 and D13, which are defined as "Use of protective equipment (ear plug etc.) by the people who work in the noisy environment, paying attention to cleanliness (hygiene) in the work environment, positive effect of the lighting level in the work environment on the work", are the other variables collected under this factor. This factor may be called "Noise, cleanliness and lighting".

**Factor 4:** D17 variable, which is defined as "Periodical health checks of the employees", provides the highest contribution to this factor with a value of 0,787. In this factor, which defines 9.536% of the total variance, the other variables are D7, D5 and D18 variables and these variables are defined as "positive effect of the noise level in the work environment on the work, positive effect of the temperature level in the work environment on the work, sufficiency of the permanent health personnel in the enterprise". This factor may be called "Health and work environment".

**Factor 5:** This factor defines 7.391% of the total variance. Sufficiency of the number of employees in terms of the workload (D19) is the most effective variable in this factor with a value of 0,794. D22 and D21 variables, which are defined as "Positive effect of the workplace order on the working productivity, sufficiency of the wage earned in terms of the work performed", are also collected under this factor. This factor may be called "Workload and Workplace order".

**Factor 6:** The 6th factor, which is obtained as a result of the factor analysis, defines 5.870% of the total variance. D28 variable, which is defined as "sufficiency of personnel buses in terms of transportation to the enterprise", provides the greatest positive contribution to this factor with a value of 0,642. While D6 variable, which is defined as "Taking necessary measures (ventilation etc.) against temperature, provides a positive contribution to this factor; D9 variable, which is defined as "The fact that the noise in the work environment mostly results from people", negatively contributes to this factor. This factor may be called "Transportation and Health measures".

**Factor 7:** In this factor, which defines 4.621% of the total variance, the most effective variable is D1 variable, which is defined as "Positive effect of the working hours (shift) on the performance and whose value is 0,826. The other variable in this factor is D15 variable, which is defined as "Suitability of the working conditions in the enterprise for women". This factor may be called "Shift and working conditions for women".

**Factor 8:** This factor defines 4.030% of the total variance. D2 variable, which is defined as "regularity of the shift system to have positive effect on the working productivity", provides the greatest contribution to this factor and its factor load is 0,833. The other variable in the factor is D8 variable, which is defined as "The fact that the noise in the work environment mostly results from machinery". This factor may be called "Shift system and machinery-induced noise".

**Factor 9:** D26 variable, which is defined as "Existence of protective equipment (helmet, gloves, overall etc.) to be used in line with the work performed" is the only variable collected under this factor and its factor load is 0,832. This factor, which defines 3.667% of the total variance, may be called "Personal protective equipment".

**Factor 10:** This factor defines 3.504% of the total variance. D10 variable, which is defined as "The fact that the noise in the work environment mostly results from conveyor systems", provides the highest contribution with a value of 0,818. D3 variable, which is defined as "Positive effect of the work tempo in the workplace on the working productivity", is other variable in this factor. This factor may be called "Noise induced by conveyor systems and work tempo".

## Conclusion and evaluation

In this study, a survey on examination of the workplaces in terms of ergonomic aspects has been applied on the employees, who work in two enterprises in automotive and textile sectors. In this survey, 32 variables have been specified for determination of the ergonomic aspects; the principal component analysis (PCA), which is one of the multivariate analysis techniques, has been applied on these variables. As a result of the PCA performed through the data obtained from the automotive enterprise, 9 factors have been obtained; the most effective two aspects are "Work environment, cleanliness and health" and "Human-source noise", which define 34.971% of the total variance; factors, which are defined as "Noise level and hazardous wastes", "Motivation", "Shift system and productivity", "Measure against occupational accident and transportation", are also significant factors. As a result of the analysis performed through the data obtained from the textile enterprise, 10 factors have been obtained; the most effective two aspects are "Machinery and work environment" and "Team work and security", which define 32.460% of the total variance; "Noise, cleanliness and lighting", "Health and work environment" are prominent factors.

As a result of the analysis, as for the automotive enterprise, in the 1st factor, which is called "Work environment, cleanliness and health", "Paying attention to cleanliness (hygiene) in the work environment" and "Sufficiency of the number of employees in terms of the workload" variables attract attention as the most effective variables in this factor. As there is a very high workload in this enterprise, it could be recommended to increase the number of employees. Other effective variables in the first factor are "Proper periodical maintenance of the machinery" and "Periodical health checks of the employees", respectively.

As a result of the analysis performed on the textile enterprise, in the 1st factor, which is called "Machinery and work environment", "The fact that the machinery and equipment used in the workplace are new and handy" and "Proper periodical maintenance of the machinery" variables are the most effective variables in this factor. Other variables are "Good social relations in the workplace", "Taking measures against environmentally hazardous waste materials (dust, smoke and material wastes etc.)", respec-

tively. As the automotive sector needs to have a more sensitive production process against foreign body such as dust, dirt, hygiene is among the variables of the 1st factor for the automotive sector while the same variable takes place under the 3rd factor for the textile enterprise. In the 1st factors of the two separate enterprises, on which the same analyses are applied, "The space used for working in the workplace is sufficient", "Machinery and equipment used in the workplace are new and handy" and "Periodical maintenance of the machinery is performed in a proper way" variables are common variables. Although these two enterprises perform activities in different sectors, as the production is made on the basis of automation in both enterprises, these three variables are collected under the 1st factor, which is the most effective aspect. As for the enterprises, the fact that the machinery and equipment are new and handy and periodical maintenance of the machinery and equipment will prevent the risk of malfunction in the production process, the increase in costs arising out of malfunction and cessation of the production. Therefore, the fact that these common variables are collected under the 1st factor for both enterprises indicates that these variables are very significant for both enterprises. As a result of taking comprehensive measures against temperature in the textile enterprise, variables on temperature and measures taken against temperature are collected under the 4th and 6th factors while these variables are collected under the 2nd factor in the automotive enterprise in parallel with the magnitude of the temperature problem. It is necessary to take measures against negative effects of temperature in the automotive enterprise.

In both enterprises, which are taken into account in the study, it is observed that variables related to noise, cleanliness, health and machinery are of great importance in terms of ergonomics in the production environments, which are composed of a large number of machinery and employees. Today, as automation-based production gradually gains importance, the fact that the machinery and equipment used in the workplace are new and handy, periodical maintenance of this machinery and sufficiency of the working spaces, in which employees perform their activities, can be considered as the most prominent and significant issues in terms of ergonomic aspects.

When due precautions are taken and proper working conditions are ensured concerning the two enterprises in our study, health and security conditions brought in by working in an ergonomic environment will reduce occupational diseases, industrial accidents and fatigue of workers. Furthermore, level of productivity will be increased quality and quantity of production and performance of workers.

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