Selection of Techniques of Multivariate Data Analysis that Apply to the Impact Study of Thermal Discomfort on the Workers Productivity in Textiles Sector in Bogotá D.C.

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Abstract

Workers’ productivity in the textiles sector in Bogotá can be affected by the thermal discomfort associated with variables such as air temperature, air humidity, air velocity, type of dress, work activity, metabolic consumption, among other issues that can be divided into those related to the thermal environment, the individual, and work. Given that in this study of impact of thermal discomfort on workers’ productivity in the textiles sector in Bogotá involves more than two variables, it is necessary to implement the techniques of multivariate data analysis among which are the multiple regression, correlation canonical, logistic regression, cluster analysis, among others. For the selection of the methods is relevant the classification of the variables involved in dependent and independent, as well as quantitative and qualitative, in order to choose appropriate techniques to data and facilitate their management and analysis, leading to making optimal decisions.

Keywords: Thermal discomfort, Multivariate analysis, Productivity
1 Introduction

Textile and clothing Industry in Colombia constitute more than 5% of the total exports of the country, 3% corresponds to the national GDP (Gross Domestic Product) and 7.5% corresponds to the manufacturing GDP, additionally in clothing industry, sales grew by 9.9% annually over the last decade and the jobs generated by this sector in 2014 were close to 94,506 (PROCOLOMBIA, 2015) [18].

Bogotá has 38% of manufacturing establishments throughout the country, highlighting the activities related to woolen yarn, clothing, artificial and synthetic fibers, among others, which has positioned this city as the epicenter of textile and clothing sector in Colombia. (Bogotá Chamber of Commerce, 2015) [2].

According to the importance of the fabrics sector in Colombia and specifically in Bogotá, it is equally important that the workers’ productivity in this sector is the best possible; this productivity is often affected by the quality of the internal environment which influences the work performance of people, making an optimal working environment and comfortable conditions are requirements that the worker must have to perform properly (Lan, Wargocki, & Lian, 2011) [14].

It must be taken into consider that not only the internal environment influences the workers’ productivity, also the activities developed in textile companies, the individual metabolic consumption, the type of clothing used by workers, among other aspects generate thermal discomfort which produces bad work performance. According to ISO 7730, thermal comfort is "the mind condition in which satisfaction with the thermal environment is expressed", As thermal neutrality is a comfort condition (Godoy Muñoz, 2012) [10], workers exposed to heat or cold, they can suffer different consequences, for example, exposure to heat can lead workers to perform unsafe acts or be distracted when carrying out their activities as a result of the effects it brings, such as absenteeism, irritation, nonconformity and other emotional conditions (Revueitas Agüero, Betancourt Bethencourt, Ramirez, & Martinez Garcia, 2015) [19]; on the other hand, the cold can affect the workers’ performance in their work activities as a result of the problems it generates, among which are increased physical effort, deterioration of physical capacity due to body cooling, thermal discomfort, manual performance and mobility affectation, among others (Duque Vera & Morales Chacón, 2012) [6].
Taking into account that in the impact of thermal discomfort study on the workers’ productivity in the fabric sector in Bogotá, there are more than two variables involved, some of which are related to the work environment, the worker and the activities he performs, it is necessary to apply the multivariate data analysis for its control. This opens the way to the question: ¿What techniques or methods of multivariate data analysis are more convenient for the case of the thesis in question?

2 Theoretical framework- Multivariate data analysis

Multivariate analysis can be defined as a set of methods and analysis statistical techniques that study, analyze, represent and interpret the resulting data from a large number of variables in a sample of individuals (three or more variables that are treated simultaneously) (López Roldán & Fachelli, 2015) [15] (Cuadras, 2014) [4].

Due to the complexity of most phenomena, it is necessary to collect information from a large number of variables (Castaño V., 2010) [3], for which the multivariate data analysis is adequate, which facilitates the study of a large amount of complex information, and due to this last characteristic it requires the use of a computer to carry out the corresponding calculations (UNAD, 2013) [21] (Pérez López, 2004) [17].

Variable in multivariate analysis techniques refers “some magnitude that represents the characteristic of the elements under investigation that are being measured” (Jiménez Marqués, 2004) [12]. Variables can be classified as dependent and independent, the first are also referred to as criteria or response variables, and its behavior is explained by one or more independent variables, on the contrary, the last are also referred to as explanatory variables, and these are the ones that explain the phenomenon studied. The variables are also classified in metrics and non-metrics, the metrics or quantitative are the quantification of a certain characteristic (examples of these are height, income, age, among others), non-metric or qualitative are those related to characteristics that are qualities (examples of this are social class, sex, nationality, among others). (Jiménez Marqués, 2004) [12].

There are different methods (Figure 1) provided by the multivariate data analysis that allows analyzing this kind of information, these can be classified into three groups: dependence, interdependence and structural methods. The important criteria for such classification are: the objective of study, dependence or not between variables and scales of measurement (Álvarez Suárez, Caballero, & Pérez Lechuga, 2006) [1].
The purpose of dependency methods is to determine if and how the independent variables affect the dependent ones; the structural methods focus on determining the relationship between the variables of both groups, and how the independent ones affect the dependent ones; finally, the objective of interdependence methods is to identify the variables that are related and in what way (Salvador Figueras, 2000) [20].

Dependency methods are divided into two groups, depending on whether the dependent variable is metric or not. When the dependent variable is metric, multivariate analysis techniques are regression analysis, MANOVA, canonical correlation and survival analysis. In case the dependent variable is not metric, the techniques are discriminant analysis, logistic regression and conjoint analysis. (Salvador Figueras, 2000) [20].

The explanation of some of these techniques is shown below:

- Multiple regression analysis: this technique allows explaining the behavior of a dependent variable through the behavior of independent variables. (Fernández Nogales, 2004) [9]

- MANOVA (multivariate analysis of variance): this technique allows analyzing the relationships between two or more dependent metric variables and different categories of independent variables. (Estévez García & María Jesús, 2007) [7]

- Canonical correlation, this technique allows correlating several independent variables and several dependent variables simultaneously. (Mercado Hernández) [16]

- Conjoint analysis (also known as experiment design), this technique analyzes the effect these have on the metric or non-metric variables and the independent non-metric variables. (Salvador Figueras, 2000) [20]
Interdependence methods are divided into two groups, depending on whether the data are metric or not. When the data are metric, the appropriate techniques are factor analysis and principal component analysis. Otherwise, the techniques are correspondence analysis and log-linear models. Two other techniques used in both cases are multidimensional scales and cluster analysis. (Salvador Figueras, 2000) [20]

The explanation of some of these techniques is shown below:

- Multidimensional scales: it is the technique that allows investigating which are the underlying criteria or dimensions used by a group of individuals to express their perceptions about the proximity or preferences between various objects (Fernández Nogales, 2004) [9].
- Cluster or group analysis: a set of techniques that allow the classification into homogeneous groups, that means, that the individuals located in the same group are similar with respect to the variables that are analyzed. (Mercado Hernández) [16] (Fernández Nogales, 2004) [9]
3 Application

Taking into account the thesis, the variables involved are (Fernández García, 2008) [8] (National Institute of Safety and Hygiene at Work):

- Regarding Thermal environment: Air temperature, air humidity, air velocity, walls and objects temperature.
- Regarding Individual: Metabolic consumption, body temperature, productivity.
- Regarding work: Type of activity, type of dress.

As the previous variables are necessary for the analysis, it is important to separate them in independent and dependent (Chart 1), for this case the productivity was taken as dependent and the other variables independent to determine their influence in it. It is also important to classify them according to the type of scale (Chart 2) in non-metric or qualitative and metric or quantitative variables (National University of Colombia), in order to determine the appropriate technique for data management.

**Chart 1. Classification of dependent or independent variables**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dependent</th>
<th>Independent</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Productivity</td>
<td>-</td>
<td>- Air temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Air humidity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Air velocity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Walls and objects temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Type of activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Type of dress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Metabolic consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Body temperature</td>
</tr>
</tbody>
</table>

**Chart 2. Classification of qualitative or quantitative variables**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Qualitative</th>
<th>Quantitative</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Tipo de vestido.</td>
<td>-</td>
<td>- Air temperature</td>
<td></td>
</tr>
<tr>
<td>- Type of activity</td>
<td>-</td>
<td>- Air humidity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>- Air velocity</td>
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</tr>
<tr>
<td></td>
<td>-</td>
<td>- Walls and objects temperature</td>
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<tr>
<td></td>
<td>-</td>
<td>- Metabolic consumption</td>
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<td></td>
<td>-</td>
<td>- Body temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>- Productivity</td>
<td></td>
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</tbody>
</table>
It is determined that if the analysis implies that there is only one dependent variable, which is also metric, the appropriate technique for handling the data is the multiple regression analysis (National University of Colombia).

Multiple regression is the technique that has as main objective to predict the variations that occur in dependent variable, as a consequence of independent variables changes present in the model. This is implemented to analyze the data, since there is a metric dependent variable, related to one or more independent variables that can be metric or non-metric. (Estévez García & María Jesús, 2007) [7]

In this case, the technique has as main objective to predict the worker productivity in the Fabric sector in Bogotá based on the type of activity he performs, the type of clothing he uses when working, speed, temperature and humidity of the air, metabolic consumption and body temperature. Other applicable techniques to the thesis are the structural methods, which, as previously mentioned, these focus on analyzing the relationship between dependent and independent variables, and the way in which the last ones affect the first ones. In this case, we would analyze the relationship between the variables mentioned above and the workers’ productivity.

4 Conclusions

- The techniques of multivariate analysis promote the handling of large amounts of information, which makes their results more accurate and reliable as well as more real for the management and study of complex phenomena.

- The multivariate data analysis can facilitate optimal decision making to reduce the impact of thermal discomfort on the workers’ productivity in the fabric sector in Bogotá, through the application of appropriate techniques for the management of data related to the subject.

- Multiple regression and structural methods are the appropriate techniques for the management of information related to the impact of thermal discomfort on workers’ productivity, taking into account the classification of variables in dependent and independent and in metric and non-metric.
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**Received: April 17, 2018; Published: May 14, 2018**