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Kruskal-Wallis, Friedman and Mood nonparametric tests applied to business decision making

Pruebas no paramétricas de Kruskal-Wallis, Friedman y Mood aplicadas a la toma de decisiones empresariales

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Abstract

The post COVID-19 crisis scenario demands continuous improvement in the quality of the products and services offered, supported by administrative and statistical tools that optimize business decision-making. In this research, three non-parametric statistical tests -Kruskal-Wallis, Friedman and Mood's median- are applied to three case studies in order to test the hypotheses posed, respectively: whether the distributions of the populations of the units sold by a distribution company are equal for three types of inputs, whether the stress levels differ or not for three types of work modalities in an automobile commercialization company and whether the medians of production yields in an agricultural company are equal or not for four varieties of fruit. The solution is sought using standard procedures for each of the nonparametric tests.

Keyword: Business, Statistics, Statistical analysis.

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Resumen

El escenario post crisis del COVID-19 exige el mejoramiento continuo de la calidad de los productos y servicios ofertados sustentado en herramientas administrativas y estadísticas que optimicen la toma de decisiones empresariales. En tal virtud, en la presente investigación se aplican tres pruebas estadísticas no paramétricas -Kruskal-Wallis, Friedman y mediana de Mood- a tres estudios de caso con el objetivo de probar las hipótesis planteadas, respectivamente: si las distribuciones de las poblaciones de las unidades vendidas por una empresa distribuidora son iguales para tres tipos de insumos, si los niveles de estrés difieren o no para tres tipos de modalidades de trabajo en una comercializadora automotriz y si las medianas de rendimiento de producción en una empresa agrícola son iguales o no para cuatro variedades de frutas. La solución se busca mediante procedimientos estándar para cada una de las pruebas no paramétricas.

Palabras clave: Empresa, Estadística, Análisis estadístico

Introduction

The scenarios surrounding industries in the globalized world of the 21st century, where technological and scientific advances are constantly evolving, make the demand for quality of products and services increasingly higher. Nowadays, one of the key factors for the success of an industry is to make use of all its knowledge and learning capacity, as well as its experience. Statistical inference through hypothesis testing in the business sector is one of the elements that can contribute the most to learning and improvement of products and processes; in this sense, the application of statistics is presented as an effective tool to understand and optimize the supply of goods and services in the business sector . (Koontz et al., 2017).

The statistics used for the verification of business hypotheses can be of parametric and nonparametric type; the first ones start from the assumption in which the samples come from populations with normal distribution, the second ones, are useful if the distribution from which the sample comes from is not specified or it has been proven that they do not meet the assumption of normality (Anderson et al., 2016; Flores-Ruiz et al., 2017).

In this research we proceed with the study of three cases referred to companies in the province of Tungurahua-Ecuador, in which the application of non-parametric methods using the Kruskal-Wallis, Friedman and Mood's median test is required. In the first case, the administration of the company D&D Distribuciones (2021)In the first case, the management of the company, dedicated to the commercialization of gifts in the province of Tungurahua-Ecuador, is interested in determining whether or not there are differences in sales between the three types of imported bases or supports used for the decoration of these gifts - cardboard boxes, wooden bases and glass bases - in order to forecast the volume of orders needed from suppliers in the international market. The

Kruskal-Wallis test is applied because we are dealing with independent samples, without necessarily assuming that the data have normal distributions.

In the second case study, the human talent management of the company, whose line of business is the commercialization of spare parts and accessories for vehicles, needs to verify Comercial Automotriz Romero (2021)whose line of business is the commercialization of spare parts and accessories for vehicles, needs to verify, through Friedman's test, whether three types of work modalities implemented during the first six months of 2021 -5 days teleworking, 5 days on-site and 5 days of mixed workday: 3 teleworking and 2 days on-site-, in the context of the health crisis Covid-19, differ or not in the stress levels of employees.

In the third case illustrated in the present research, the agricultural-commercial company Bolhi Market (2021) verifies whether or not the yields of four varieties of fruit measured in Kg/Ha, differ from each other; for which it uses Mood's median test because it has a categorical variable and a continuous response variable, it is not known with certainty whether the data of all the groups have similar distributions and the observations are independent of each other. In the three cases studied, the solution is sought both by conventional procedures for each of the non-parametric tests contemplated in this research and by means of Minitab software.

Nonparametric methods are statistics used to test hypotheses in which the population distribution does not follow the normal curve or other specific shape, which is why they are also known as free distribution tests. Among the main nonparametric methods for the analysis of ordered data and Spearman's rank correlation coefficient are the sign test, Wilcoxon, Mann-Whitney, Kruskal-Wallis, Mood's Median and Friedman; while among the goodness-of-fit tests are the Kolmogorov-Smirnov and chi-square tests, mainly (Levin et al., 2014).

In nonparametric methods, the data generally respond to nominal and ordinal variables, rather than interval or ratio variables, or there are few data. In addition, it usually happens that the data do not meet the requirements of normality, level of measurement and homogeneity required for the application of parametric tests -Z, t student, F or ANOVA-, consequently, nonparametric methods are appropriate as alternatives to parametric tests. However, their main disadvantage is the loss of sharpness in the estimation of intervals in exchange for the possibility of using less information and much faster and less laborious calculations. (Sailema, 2019).

In addition, if the distributions of the groups include outliers and there is one categorical variable and one continuous response variable, Mood's median is used; if there is only one categorical factor and non-normal data from three or more populations and it does not include outliers, Kruskal-Wallis is used; and if there is a randomized block design to test medians, Friedman's test is applied, this test being a non-parametric alternative to the block design of experiments model and to an ANOVA with two factors. (Flores-Tapia & Flores-Cevallos, 2021; Lind et al., 2021).

The present research prioritizes the study in three business cases by applying the Kruskal-Wallis test, the Friedman median test and the Mood median test.

Kruskal-Wallis test

It is a nonparametric test for ordinal sample data from three or more independent populations classified by ranks. It does not require assumptions regarding the shape of the populations and is also called Kruskal-Wallis one-way analysis of variance by ranks. This test determines whether the medians of two or more groups differ, for which the data must contain a categorical variable, a continuous response variable and distributions with a similar shape in all groups. It can be considered a generalization of the Wilcoxon, U and Mann-Whitney rank sum tests and the Kruskal-Wallis test is analogous to the parametric one-way ANOVA test. Also, the ordering of information by ranks rather than plus and minus signs wastes less data than the sign test. (González et al., 2021; Triola, 2018).

Independent samples are randomly selected from k populations that differ only by location and are not necessarily assumed to come from normal distributions. It is important that each sample has at least five observations that are ranked from lowest to highest as if they were a single group (Flores-Tapia & Flores-Cevallos, 2017b). The Kruskal-Wallis statistic with k-1 degrees of freedom is denoted by the letter H and is given by equation 1, as follows:

$$H = \frac{12}{n\,(n+1)}\left[\frac{(R_1)^2}{n_1} + \frac{(R_2)^2}{n_2} + \cdots + \frac{(R_k)^2}{nk_1}\right] - 3(n+1) \quad (1)$$

Where:

∑R1, ∑R2, ..., ∑Rk: sums of the ranks of samples 1, 2, ..., k, respectively.

n1, n2, ..., nk: sample sizes 1,2, ..., k, respectively.

n: combined number of observations of all samples.

The Kruskal-Wallis test is right-tailed and seeks to test the following hypotheses:

H0: the samples come from populations with the same distribution.

H1: the samples come from populations with different distributions.

Friedman test

The Friedman test is the nonparametric alternative to the one-way ANOVA test with two factors when samples are dependent and also to a block design of experiments model. It is an extension of the Wilcoxon signed-rank test for more than two groups, based on sum of ranks. Assuming certain simplifications, it can be considered as a comparison between the medians of several groups, being appropriate when the data have a natural order, that is, when they have to be ordered and also paired to make sense of them. The concept is similar to the Wilcoxon rank sum for two groups, but this time assigning the ranks within each row, since there are more than two measures for each individual and then applying the rank sum for each column. (Freund et al., 2010).

The Friedman test allows determining whether the median of the treatment effect differs or not in a randomized block design, for which it is required that the response factor be continuous or ordinal, the treatment of categorical type and to have a categorical block variable, the blocks being a group of experimental runs in constant conditions. Put another way, this test is designed to verify that the probability distributions of k treatments are identical or that at least two of the distributions differ in location (Guzman & Monteoliva, 1984; Minitab, 2021).

The test statistic is given according to Equation 2, as follows:

$$FF_r = \frac{12}{bk(k+1)} \sum_{i=1}^{k} R_i^2 - 3b(k+1) \quad (2)$$

Where:
b: blocks used in the experiment.
k: treatments.
(Ri)2: sum of the ranks of the observations corresponding to the squared treatment.
Also, as considered with the Kruskal-Wallis statistic, the null distribution of the Friedman statistic is calculated with a **λ**2 distribution with k-1 degrees of freedom, provided that the number of blocks used is large, noting also that the approximation is adequate if the number of treatments or the number of blocks is greater than 5 (Levin et al., 2014).
The hypotheses for the Friedman test are as follows:
H0: all treatment effects are zero.
H1: not all treatment effects are zero.

Mood median test

Mood's median test determines the dispersion of the populations with respect to the mean of the ranges of the two populations as if they were a single group, that is, it calculates whether the medians of two or more groups are different and the range of values that are likely to contain the difference between the medians of the populations. It is applied when a categorical variable and a continuous type response variable are available and it is not known with certainty whether the data from all groups have similarly shaped distributions. In addition, it is taken into account that the sample size has to be smaller than 15 or 20 observations and the observations must be independent of each other and the data are measured at least on an ordinal scale. (Guatemal, 2019).

Mood's median test is less sensitive to outliers than the Kruskal-Wallis test; however, the power is lower when the data come from distributions such as normal and can be considered as a special case of Ji-squared (Ramos et al., 2019).
The median Mood statistic is shown in Equation 3.

$$M = \left(r_i - \frac{N+1}{2}\right)^2 \quad (3)$$

Where:
N: n + m; where n is the size of sample 1 which is equal to or smaller than sample 2 or m.
ri: is the rank of the i-th observation x in the ordering of the combined x and y values.

(N+1) /2: average of the ranges assigned to the x and y values combined and ordered from highest to lowest.

$\left(r_i - \frac{N+1}{2}\right)^2$: deviation of each of the observations with respect to the mean range.

The above value in parentheses is similar to ∑ (Xi - X̄)2 in the calculation of the standard deviation; such that if the values of y are further apart than those of x (σ 1 <σ 2) the M statistic tends to be small, whereas if those of x are much more dispersed than those of y (σ 1 >σ 2) the statistic tends to a larger value (Guzman & Monteoliva, 1984).. Therefore, the objective of Mood's median test is to locate M that is sufficiently large or small to reject H0. The hypotheses posed for Mood's test are as follows:

H0: the medians of the population are all equal.

H1: population medians are not all the same.

On the other hand, for hypothesis testing of the Kruskal-Wallis, Friedman and Mood Median tests, software tools are available to help analysts in the implementation of computer models, such as Minitab, SPSS, R, Excel, Stata and Gretel software, mainly (Gujarati & Porter, 2009; IBM, 2021; Microsoft, 2021; Minitab, 2021)..

Materials and methods

The study contemplated the application of non-parametric techniques -a hypothesis test that does not require the population distribution to follow a normal distribution- such as the Kruskal-Wallis, Friedman and Mood's Median tests that fit the statistical methodology, particularly the hypothesis testing (Flores-Tapia et al., 2017; Hernández-Sampieri et al., 2014; Levin et al., 2014; Triola, 2018).The six stages or phases that were followed were foreseen:

- Definition of the problem of interest and collection of relevant data.
- Formulation of a mathematical model that represents the problem.
- Development of a computer-based procedure to derive a solution to the problem from the model.
- Model testing and improvement according to needs.
- Preparation for the application of the model prescribed by the administration.
- Implementation.

The scope of the study contemplated the application of the three nonparametric tests contemplated, one to each of the three case studies proposed in the research following three phases, namely: definition of the problem, application of the mathematical models and development of the computer-based procedure, and presentation of results (Flores-Tapia & Flores-Cevallos, 2017a; Lind et al., 2021).. That is, once the problem was defined, a five-step hypothesis test was used to solve the question posed by management, that is:

Step 1: Formulation of the null and alternative hypotheses.

Step 2: selection of the significance level.

Step 3: decision on the test statistician
Step 4: Formulation of the decision rule
Step 5: calculation of the statistic and making the decision regarding the null hypothesis - not to reject the null hypothesis or to reject the null hypothesis and accept the alternative. The procedure for calculating each of the statistics considered in this research is detailed below.

Kruskal-Wallis test

In the case of the Kruskal-Wallis test, all samples were combined into a single sample, sorted in ascending order and a rank was assigned to each sample value -if there was a tie in the rank, the average of the ranks involved was assigned to each observation. Then, for each sample, the sum of the ranks and the sample size were determined. Subsequently, the hypothesis testing steps were followed, that is, the null and alternative hypotheses were formulated, the significance level was set, the Kruskal-Wallis statistic was identified by verifying compliance with the positions for this test, the critical value was established by consulting the Chi-square table with k-1 degrees of freedom, and the decision rule was formulated. Finally, the Kruskal-Wallis statistic was calculated and a decision was made regarding the null hypothesis, applying the decision rule, that is, if the calculated Kruskal-Wallis value -H- is less than the critical value, the null hypothesis is not rejected, otherwise, the null hypothesis is rejected and the alternative hypothesis is accepted.

Friedman test

Since it is a statistic equivalent in ranks to the sum of squares for treatments -SST- for the randomized block design, once the data of a randomized block design were obtained, within each block the observed values of the responses of each of the k treatments were classified from 1 to k blocks, from the smallest to the largest, and each of the ranks was summed. In case of a tie between the ranks involved, the average was assigned to each one, as long as the ties occurred within the same block. Subsequently, the null and alternative hypotheses were determined, the significance level was established, the Friedman test was selected, verifying compliance with the assumptions for its application, the decision rule was formulated indicating that the region of rejection of the null hypothesis is given by $Fr > \boldsymbol{\lambda}2\boldsymbol{\alpha}$ with (k-1) degrees of freedom. The critical value, as in the Kruskal-Wallis test, was consulted in the table corresponding to the chi-squared distribution. Finally, the Friedman statistic was calculated and the decision rule was applied with respect to the null hypothesis.

Mood median test

Once the data for each of the samples had been sorted, the median and the size of each sample and of all the samples were calculated. Then the null and alternative hypotheses were formulated, the level of significance and the critical values of Mood's median test were determined by consulting the values in the corresponding chi-square table, after verifying compliance with the assumptions that allow its application. Subsequently, the sample medians were transformed into a **λ**2 value, obtaining the test statistic, for which a table was constructed with the observed frequencies, the observations in each sample above and below or equal to the overall median of all samples were counted, and the Mood median statistic was calculated with Equation 4.

$$\lambda_c^2 = \sum \frac{(F_o - F_e)^2}{F_e} \quad (4)$$

Where:

∑: summation

Fo: observed frequency

Fe: expected frequency

The final step consisted of comparing the critical value with the calculated value of the Mood median and a decision was made whether or not to reject the null hypothesis by applying the decision rule.

Results

Following the methodology indicated above, the application is developed and the results of the Kruskal-Wallis, Friedman and Mood Median tests considered for the case studies, which are the object of this research, are shown.

Kruskal-Wallis test

Before proceeding with the application of the Kruskal-Wallis test and the presentation of the results, the statement of the case study and the conditions of the study are established as follows:

The company D&D Distribuciones located in Ambato-Ecuador is dedicated to the production of gifts for special occasions. The management is interested in knowing what type of bases - pedestals or supports - customers prefer for gifts - cardboard boxes, wooden bases and glass bases - because this type of material is imported and it is necessary to place the order with enough time in advance and in the quantities that best suit the company. Specifically, we want to test whether or not there is a difference in sales depending on the three types of bases or supports used for gifts and thus make the best decisions regarding the import order.

Following the methodology proposed in this research and considering for this test a significance level of 5% and taking into account the units sold during the months of February to June 2021, the null and alternative hypotheses are stated as follows:

Ho: the distributions of the populations of units sold are equal for the three types of gift bases.
H1: Not all population distributions are equal.

We proceed with the classification in ranges of each sample value with the respective sum for each of the groups or types of gift bases (Table 1), establishing the decision rule for the significance level of 0.05; that is, if the calculated value of H is less than the critical value, the null hypothesis is not rejected. Then, the critical value is located in the Chi-square table for 2 degrees of freedom (k-1), being the value 5.991 and, once the assumptions for the application of the Kruskal-Wallis statistic are verified, we proceed with the calculation of H, obtaining a value of 8.06 and as the calculated value H is greater than the critical value, the null hypothesis is rejected and the alternative is accepted. That is, there is sufficient evidence to conclude that there is a difference between sales in the three types of gift bases or supports, which implies that the managers of the company D&D Distribuciones need to place the import order with different quantities for each of the three types of gift bases.

Table 1. *Ranking and summation of ranks for each of the gift base types* -D&D Distributions

Months 2021	R3 Ranges	Cardboard Boxes (Units)	R2 Ranges	Wooden bases (Units)	R1 Ranks	Glass bases (Units)
February		230				
March						
April		110			5	
May						
June					1	
Summation						

Source: Own elaboration based on D&D Distribuciones company data.

However, if the calculations are made using Minitab software with the Kruskal-Wallis non-parametric statistics option, the results are as follows:

Descriptive statistics

Type of base or support	N	Median	Classification of averages	Z-value
Glass Base	5		3.4	-2.82
Wooden Base	5		9.8	1.10
Cardboard Boxes	5		10.8	1.71
General			8.0	

Test

Null hypothesis	H_0: All medians are equal.
Alternative hypothesis	H_1: At least one median is different.

GL	H-value	p-value
	8.06	0.018

The sample median estimates for the three groups are 50,150 and 200 and since the p-value 0.018 is less than the significance level determined for this test of 0.05; consequently, the null hypothesis is rejected.

Friedman test

Before proceeding with the application of the Friedman test and the presentation of the results, the statement of the case study and the conditions of the same are established, in the following terms:

The human talent management of the company Comercial Automotriz Romero compares the stress level of three work modalities during the first six months of the year 2021 in the context of the Covid-19 health crisis: 5 days teleworking, 5 days face-to-face and mixed workday - 3 days teleworking and 2 days face-to-face. The management wants to observe whether stress levels differ or are the same for the three types of work modalities and, consequently, conducts a randomized block experiment for 6 collaborators, recording the response on a scale of 1 to 3.
Once the data were obtained, the observed values were classified into ranges in each of the treatments and the sum was calculated (Table 2).

Table 2. *Classification and summation of ranks for each of the work modalities -Comercial Automotriz Romero-.*

Collaborators	R3 Ranges	Telework	R2 Ranges	On-site	R1 Ranks	Mixed day
1	1.0	1.21	3.0	1.56	2.0	1.48
	1.5	1.63	3.0	2.01	1.5	1.63
	1.0	1.42	2.0	1.70	3.0	2.06
	1.0	1.16	2.5	1.27	2.5	1.27

5	2.0	2.43	3.0	2.64	1.0	1.98
	1.0	1.94	3.0	2.81	2.0	2.44

Source: Own elaboration based on data from Comercial Automotriz Romero.

Then the standard statistical procedure is followed to test the null and alternative hypotheses with a chosen significance level of 5%. As the number of blocks exceeds 5 (six in this case) the Friedman test is used, considering as a decision rule: if the calculated value a of F_r is less than the critical value, the null hypothesis is not rejected. The null and alternative hypotheses are stated as follows:

Ho: all treatment effects are zero. That is, stress levels do not differ for the three types of work modalities, they are the same.

H1: not all treatment effects are zero. That is, stress levels differ for the three types of work modalities.

Subsequently, the critical value is located in the chi-squared table for 2 degrees of freedom and **α** = 0.05, determining this value to be 5.991. Finally, the calculated value F_r = 6.75 is compared with the critical value, proceeding to reject the null hypothesis and accept the alternative; that is, the stress levels of at least two of the three modalities have probability distributions that differ in location.
The same result is also obtained using Minitab software with the Friedman test option.

Descriptive statistics

Work modality	N	Median	Sum of classifications
Mixed		1.68167	12.0
On-site		1.87333	16.5
Telework		1.52500	7.5
General		1.69333	

Test

Null hypothesis	H_0: All treatment effects are zero.
Alternative hypothesis	H_1: Not all treatment effects are zero.

Method	GL	Chi-square	p-value
Not adjusted for ties		6.75	0.034
Tight for ties		7.36	0.025

The p-value for the stress level data is less than the significance level of 0.05, therefore, human talent management rejects the null hypothesis and accepts the alternative.

Mood median test

Before proceeding with the application of the Mood median test and the presentation of the results, the statement of the case study and the conditions of the same are established in the following terms:

The agricultural-commercial company Bolhi Market is conducting an experiment with four fruit varieties to determine if there are significant differences in yield. The four varieties were randomly assigned to 28 experimental plots located in the same locality. The yield in Kg/Ha was recorded for each of the 28 plots, obtaining the following results from Table 3.

Table 3. *Yield by type of fruit variety - Bolhi Market commercial agricultural company-.*

Variety	Yield in Kg/Ha			
F1			45	N1= 8
F2		99		N2= 7
F3		42		N3= 6
F4			45	N4= 7
				N=28

Source: Own elaboration based on data from Bolhi Market, a commercial agricultural company.

The next step consists of ordering the data of each sample and after calculating the median, whose result is 34, the hypotheses are formulated as follows:
Ho: M1=M2=M3=M4: the median yields Kg/Ha are equal among the four varieties.

H1: at least one pair of medians is different among the four varieties.
With a significance level of 5% the critical value for 2 degrees of freedom (k-1) consulting the chi-squared table is 7.815. Then, the assumptions for the Mood median statistic are verified and Table x is constructed, obtaining a value of 2.15 corresponding to the Mood statistic.

Table 4. *Calculation of the median statistic of Mood -commercial agricultural company Bolhi Market-.*

fo	faith	fo - fe	(fo-fe) ^2	((fo-fe) ^2) /fe
	3.71	-1.71	2.94	0.79
	4.29	1.71	2.94	0.69
	3.25	0.75	0.56	0.17
	3.75	-0.75	0.56	0.15
	2.79	0.21	0.05	0.02
	3.21	-0.21	0.05	0.01
	3.25	0.75	0.56	0.17
	3.75	-0.75	0.56	0.15
λ				2.15

Source: Own elaboration

Finally, the critical value is compared with the calculated value of the median Mood, in this case as the calculated value is lower than the critical value, Ho is not rejected, the median yield Kg/Ha is equal in all fruit varieties.

Using Minitab software, with the non-parametric option, Mood's median test, the same result is obtained as with the previous procedure, as follows:

Descriptive statistics

C	Median	Overall median of N <=	Overall median of N >	Q3 - Q1	95% median CI
F1				21.25	(14.8069, 38.4505)
f2	45			55.25	(21.9356, 79.3515)
f3	42			35.00	(18, 65)
f4				37.00	(15.6667, 57.4667)
General					

Test

Null hypothesis	H_0: Population medians are all the same.
Alternative hypothesis	H_1: Population medians are not all the same.

GL	Chi-square	p-value
	2.21	0.530

The p-value of 0.530 is greater than the significance level of 0.05; consequently, the null hypothesis is not rejected. Therefore, the median yield Kg/Ha is the same for all fruit varieties. The Ji-square value is 2.21, practically the same (2.15) obtained by the previous statistical procedure without software support - the slight decimal variation is due to rounding of figures.

The results obtained for the first case study, D&D Distribuciones, show that not all the distributions of the population are equal; that is, there is a difference in sales depending on the three types of bases or supports used for gifts, establishing that with this information the company's management is in a position to make the best decisions regarding the management of the import order of bases for gifts. In the second case study, it is concluded that at least one of the three types of work modality implemented by the company Comercial Automotriz Romero in times of the Covid-19 health crisis, during the first six

months of the year 2021, has a different effect. In the third case study, the results of the experiment conducted by the agricultural-commercial company Bolhi Market determine that the differences between the median yields Kg/Ha of the four fruit varieties are not statistically significant.

Now, after reviewing some studies related to the application of the three parametric tests contemplated in this study, the following stands out Obando et al. (2017)who use the Friedman test to demonstrate the existence of significant favorable differences of the physical activity program in the intervention group in the incidence of stress, determining the decrease of stress in the administrative staff once compared the average ranges of the initial and final test performed. Also, Acha (2018)The Kruskal-Wallis test is applied to a set of yam production data to prove that five plots in which the crop is distributed have identical distributions, previously the fulfillment of the assumptions to proceed with this test was verified.

For their part, Flores Tapia et al. (2017) investigate the effect of stem size, the most important cultivable rose varieties and bud condition on the total sales volume in the floricultural company "High Connection Flowers" in Latacunga canton. They use tools of quantitative methods for decision making, that is, the design of experiments by means of complete factorial models, requiring for their application, first, the testing of the hypothesis of equality of variances and the Anderson-Darling normality test. Another author, Benavides et al. (2020) evaluated the feeding behavior of seven Holstein dairy cows in agro-ecosystems with alder and pasture, acacia and pasture and only pasture. The test lasts six months and takes into account the time of pasture consumption, rumination and rest. It is shown that there is a higher pasture consumption in combination with alder than in the other cases. While, Mandicak et al. (2021). the Kruskal-Wallis test was used to analyze whether information and communication technology has an impact on sustainable chain and cost management in various construction projects in Slovakia, and the hypothesis was positively confirmed. The research samples consist mainly of foreign companies operating in Slovakia.

However, the studies referred to above do not use a methodological procedure applying the three types of non-parametric tests prioritized in this research - Kruskal-Wallis, Friedman and Mood Median- in two business cases in the same article and referring to the search for answers to business concerns, as is done in the present research; The usefulness of parametric tests for obtaining information for business decision-making when the distribution of the data from which the sample comes from is not specified or it has been proven that they do not comply with the normality assumption, leaving the way open for future

business research in which this type of alternative tests to parametric tests such as Z, ANOVA or t student, which are applied when the data are based on the assumption that the samples come from populations with normal distribution, are applied.

On the other hand, the results of the study are consistent with the theory explained by. Flores-Tapia & Flores-Cevallos (2017b); Levin et al. (2014); Lind (2012); Triola (2018)., among others.

Conclusions

The article verifies that non-parametric tests such as Kruskal-Wallis, Friedman and Mood's median can be used to obtain hypothesis testing results that allow companies to make the best decisions. In this sense, throughout the article, the objectives of this case study research have been achieved, that is, each of the concerns of the management of the companies under study have been answered based on the data and results obtained in each case, that is: it has been determined that there is no difference in sales between the three types of gift bases marketed by the company D&D Distribuciones, it has been observed that the stress levels of at least two of the three work modalities implemented by the company Comercial Automotriz Romero have probability distributions that differ in their effect and it has been verified that the yields of four varieties of fruit grown by the company Bolhi Market, measured in Kg/Ha, do not differ from each other.

On the other hand, it should be noted that the application of the goodness-of-fit tests considered in this study using conventional statistical procedures and with the support of computer tools, such as Minitab and other specialized programs, speed up processing times and save significant costs for organizations that need timely information for technical decision-making, confirming their usefulness, especially if internal conditions and the business environment become increasingly complex, as in the case of the crisis generated by COVID-19.

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