Año 28 No. Especial 10
JULIO-DICIEMBRE 2023

Año 28 No. Especial 10

JULIO-DICIEMBRE 2023

Revista Venezolana de Gerencia

UNIVERSIDAD DEL ZULIA (LUZ)
Facultad de Ciencias Económicas y Sociales
Centro de Estudios de la Empresa

ISSN 1315-9984

Como citar: Castillo Salazar, R. N. (2023). Suppliers selection in a public institution: A sustainable and hierarchical approach. *Revista Venezolana De Gerencia*, *28*(Edición Especial 10), 1541-1559. https://doi.org/10.52080/rvgluz.28.e10.41

Universidad del Zulia (LUZ)
Revista Venezolana de Gerencia (RVG)
Año 28 No. Especial 10, 2023, 1541-1559
julio-diciembre
ISSN 1315-9984 / e-ISSN 2477-9423

Suppliers selection in a public institution: A sustainable and hierarchical approach

Castillo Salazar, Regner Nicolás*

Abstract

This research analyzes the procurement supply chain management of a Peruvian public institution, using the AHP approach and sustainable supplier selection criteria. The sample included 7,833 employees of the purchasing department, including managers, administrators, assistants and collaborators. The analysis revealed 5 subgroups, the largest representing 28.04% and standing out for its emphasis on the environmental factor with an average of 62.85%. The subfactors of economic sustainability, product useful life and maintenance cost did not show significant differences in weighting, with a high average impact, 11.69% and 11.76% respectively. Therefore, companies seeking to supply these municipalities must focus on offering solutions with low maintenance costs and long useful lives to ensure economic sustainability. These results support the effectiveness of the AHP method in identifying critical factors in decision making.

Keywords: Supply chain; environmental sustainability; environmental sustainability; economic sustainability; AHP approach.

Recibido: 30.06.23 **Aceptado**: 14.10.23

* Doctor en Gestión Pública y Gobernabilidad, Maestro en Gestión Pública, Universidad César Vallejo, Perú, Licenciado en Administración de la Universidad Nacional de la Selva, Docente investigador RENACYT, Facultad de Ciencias Empresariales, Escuela Profesional de Administración, Universidad César Vallejo, Programa SUBE, Facultad de Economía, Escuela Profesional de Economía de la Universidad Nacional del Callao, correo electrónico rcastillos@ucv.edu.pe ORCID: https://orcid.org/0000-0001-8956-2402

Selección de proveedores en una institución pública: Un enfoque sostenible y jerárquico

Resumen

Esta investigación analiza la gestión de la cadena de suministro de compras de una institución pública peruana, utilizando el enfoque AHP y criterios de selección de proveedores sostenibles. La muestra incluyó 7.833 empleados del departamento de compras, entre gerentes, administradores, asistentes y colaboradores. El análisis reveló 5 subgrupos, el mayor de los cuales representa el 28,04% y destaca por su énfasis en el factor ambiental con una media del 62,85%. Los subfactores de sostenibilidad económica, vida útil del producto y coste de mantenimiento no mostraron diferencias significativas de ponderación, con un impacto medio elevado, 11,69% y 11,76% respectivamente. Por tanto, las empresas que pretendan abastecer a estos municipios deben centrarse en ofrecer soluciones con bajos costes de mantenimiento y larga vida útil para garantizar la sostenibilidad económica. Estos resultados respaldan la eficacia del método AHP para identificar los factores críticos en la toma de decisiones

Palabras clave: Cadena de suministro; sostenibilidad medioambiental; sostenibilidad económica; enfoque AHP.

1. Introduction

The intensificat on of commercial rivalry worldwide and the impact of globalization have prompted companies to be more effective and efficient in meeting the requirements and in adopting the necessary mechanisms to survive in scenarios full of uncertainty and change. As a result, more than 60% of companies in various countries have recognized the importance of optimizing supply logistics, assigning it a strategic role in productivity and seeking to create lasting competitive benefits (Amindoust et al, 2012). Among the key elements to achieve a successful supply chain are the adequate insertion of human resources, the implementation of effective organizational strategies, the efficient management of information and the use of related technologies (Silva, 2017; Bustillos & Carballo, 2018). These factors play a fundamental role in achieving optimization in supply logistics and contributing to the overall success of the company in a competitive environment.

It is important to highlight that the appropriate formulation of the supply chain is essential to establish a base of suppliers that meet the competitive priorities of production, supply network tactics, unification and business performance (Kushwaha, 2010; Mohammady, 2006; Hou et al, 2017; Zimmer, Fröhling & Schultmann, 2016).

The choice of suppliers has a significant impact on the efficiency and profitability of organizations (Mendoza, Santiago & Ravi, 2008; Christopher, 2016; Kuse, Endo & Iwao 2010). In another context, Silvestre (2014) pointed out that Green Supply Chain Management (GSCM) has acquired outstanding relevance as a research area both in the business field and in the political field, being considered an extension of the conventional supply chain and generating a new closed-loop approach within said chain.

In this sense, several researchers have focused their efforts on the design, administration and evaluation of GSCM practices, where the environmental component is positioned as the most significant in the entire chain (Seuring & Müller, 2008; Carter et al, 2020; Ahí & Searcy, 2013; Ghayebloo et al, 2015; Govindan et al, 2015; Ali et al, 2017; Ilbahar, Kahraman y Cebi 2022; Sarache, Costa & Martínez, 2019; Alzate, Calle & Muriel, 2020).

The Analytical Hierarchical Process (AHP) tool is a tool used to develop measures in physical or social settings when no physical or statistical measures are available. In the social realm, the AHP model provides a way to convert subjective evaluations into relative values. Within the AHP framework, three fundamental principles apply: first, break down the problem to identify the important factors; then, comparative judgments are made for the broken elements of the problem; and finall , measures of relative importance are estimated using pairwise comparison matrices, which are then combined to obtain a general assessment of the available options (Olson, 1996).

The AHP process is an adaptable tool that allows individuals and companies to develop concepts, identify problems, make assumptions, and derive the desired solution from them. In addition, it provides the ability to examine the ability to change or not change the solution or the resulting effect against modifications of the available data (Forman, 2001).

At the United Nations summit held in Rio de Janeiro in 1992, the global challenge of sustainable development was raised, which led to the promulgation of the General Environmental Law No. 28611 in Peru, where the concept of sustainability was introduced. in public purchases. Article 37 of said law mentions the possibility of granting special scores to environmentally responsible suppliers in public tenders (Ley General del Ambiente No. 28611).

However, in the Regulation of the State Procurement Law (RLCE), established by Supreme Decree No. 184-2008-EF, the applicability of the term sustainability in public procurement is not clarified, although Law No. 1017 of State Procurement, in its article 4, numeral m, mentions the need to apply the parameters to ensure environmental sustainability and minimize the adverse consequences expressed in the standard (Ley Nº 1017, 2012).

In line with the policies established by the Ministry of Environment and Sustainable Development (2019) in relation to eco-efficiency in the public sector, guidelines have been established through Supreme Decree No. 009-2009-MINAM. Finally, Supreme Decree No. 350-2015-EF, approved within the framework of the State Procurement Law (LCE) No. 30225 and modified by Supreme Decree No. 056-2017-EF, refers to the methods of selection (Kuczynski and Thorne, 2017). Guidelines have been established through Supreme Decree No. 009-2009-MINAM. Finally, Supreme Decree No. 350-2015-

EF, approved within the framework of the State Procurement Law (LCE) No. 30225 and modified by Supreme Decree No. 056-2017-EF, refers to the methods of selection (Kuczynski and Thorne, 2017). Guidelines have been established through Supreme Decree No. 009-2009-MINAM. Finally, Supreme Decree No. 350-2015-EF, approved within the framework of the State Procurement Law (LCE) No. 30225 and modified by Supreme Decree No. 056-2017-EF, refers to the methods of selection (Kuczynski and Thorne, 2017).

The AHP model has applications in the selection of alternatives or options in various situations and human projects. Poveda (2023) showed that human capital has played a relevant role in coordinating and supporting the achievement of social well-being, economic progress and protection of the environment. It presents resources to identify and select criteria and indicators, as well as structure options and a scientific basis that allow the efficient participation of the parties involved to evaluate the role of people in sustainable development.

Akhrouf & Derghoum (2023) propose to base themselves on the AHP tool to choose or select multiple options in the health sector, using expert software that allows government entities and stakeholders to prioritize and select projects efficientl . Jurı´k et al, (2022) developed an application based on AHP to evaluate production projects according to sustainable development criteria. A study on project selection using multi-criteria decision support methods indicated that AHP, ANP and TOPSIS were the most popular methods (Bruno et al, 2009; Sadi-Nezhad, 2017). Khan and Ali (2020) concluded that the AHP method is widely preferred by researchers in various fields and applications. However, there is little research using the AHP approach or its variants in the selection of health infrastructure projects. Therefore, it is important to consider the environmental criteria as a key factor when applying the AHP approach in the choice of suppliers.

Given the above and in favor of promoting compliance with environmental regulations, the use of the Analytic Hierarchy Process (AHP) tool, developed by Saaty (1977), is proposed to carry out a multicriteria analysis in the selection of suppliers seeking to contribute to the development sustainable. The main purpose of this work is to analyze the management of the supply chain using the AHP approach and supplier selection criteria in the purchasing area of a Peruvian public institution, based on the hypothesis that all the factors of the AHP approach have the same effect same impact on the selection of suppliers with sustainable criteria.

2. Methodological considerations

In principle, it must be ruled out that the approach used was quantitative and correlational, by collecting field information that involves numerical measurements and statistical estimates to test and support the hypotheses. According to Hernández et al, (2014), this approach aims to measure variables and study their relationships or contrasts to obtain values that support the hypotheses. Likewise, a non-experimental-cross-correlational design was used, without manipulation of variables, collecting the information at a specific moment and studying the relationships between the variables to understand their behavior (Sánchez &

Reyes, 2015). The population under study was made up of 8638 employees, which included managers, administrative staff, assistants and collaborators in the logistics area of a Peruvian public institution nationwide. The sample was selected probabilistically using a random selection method, following the formula proposed by Aguilar (2005). As a result, a sample of 7833 workers of said institution was obtained.

An AHP approach or hierarchical analytical process was used to evaluate the management of the supply chain in the selection of suppliers in the purchasing area of a public institution of the government of Peru (Kabir et al, 2022; Huang and Keskar, 2007; Zanghelini, Cherubini & Soares, 2018; Zhu et al, 2022). During this stage, an orderly sequence of problems was established to define the goals, criteria and alternatives to be implemented. Likewise, the alternatives through which the criteria to be evaluated were established were identified. These criteria had to be relevant to the problem and had to identify attributes that would help make informed decisions (Jamal et al, 2020).

In the study, the variable "AHP approach" was established based on the research and statistical requirements. This variable consisted of three operational dimensions: in criteria of environmental sustainability, social sustainability and economic sustainability. Table 1 presents these dimensions of the AHP approach variable, its indicators, and the number of items per indicator.

Table 1
Dimensions, indicators and items of the instrument applied for the AHP approach

Dimensions	Indicators (Operational Definition)	items
Environmental sustainability criteria.	**indicator 1**: Energy efficienc .	2
	indicator 2: Waste management.	2
	indicator 3: Minimization of emissions.	2
	Indicator 4: Technological development.	2
	Indicator 5: Optimization of resources.	3
Social sustainability criteria.	**indicator 1**: Social innovation.	1
	indicator 2: Eradication of child labor.	1
	indicator 3: Recruitment of personnel with disparity.	1
	Indicator 4: Occupational Health & Safety.	2
Economic sustainability criteria.	**indicator 1**: Manufacturer's guarantee	1
	Indicator 2: Product shelf life.	1
	Indicator 3: Maintenance cost.	1
	Indicator 4: Reason for the disbursement of the acquisition and the annual budget.	1

Source: Own elaboration based on Kuczynski and Thorne, (2017).

After understanding the various alternatives and defining the criteria, ranking and weighting of each criterion is carried out when selecting the alternatives. This is done in order to estimate the importance assigned by decision makers to each option i, and compare it with each criterion or alternative j. In order to evaluate the relative preference of the elements, a scale from 1 to 9 was used according to Robles-Algarín et al. (2018). In this way, a matrix of paired comparisons is constructed that results in a square matrix Anxn = [aij], where 1 ≤ i, j ≤ n. on the other hand, some axioms must be considered:

The one for reciprocity states that, if A is a pairwise comparison matrix, it holds that if aij = x, then aji = 1/x, where x is in the range from 1/9 to 9. Only n (n-1)/2 comparisons to satisfy the reciprocity property.

The axiom of homogeneity applies when the components being contrasted are of the same order of magnitude and hierarchy. On the other hand, the axiom of independence is used when the decision maker executes the comparisons assuming that the parameters do not depend on the different alternatives. By complying with these axioms, the corresponding comparison matrix can be determined (Table 2).

Table 2
Decision matrix for various instrument options

	attribute 1	attribute 2	…	…	attribute no.
Provider1	X11	X12	…	…	x1n
Provider 2	X21	x22	…	…	x2n
…	…	…	…	…	…
…	…	…	…	…	…
provider m	xm1	xm2	…	…	x2mn

Source: Hwang and Yoon, (1981).

After making the comparisons between the paired matrices, the priorities are calculated. These priorities are represented by a vector or several vectors, depending on whether it is an A(nxn) matrix. As in pairwise comparisons, the eigenvalues or eigenvectors of A (λ1, λ2,..., λn) are obtained by solving the equation: det (A- λI) = 0. The principal eigenvalue (λmax) of the matrix is define as the maximum value obtained by applying the aforementioned formula (Moustakas et al, 2020).

The principal eigenvalue of {A} and {a} represents the associated eigenvector. The eigenvectors associated with the priority values are the weighting vectors to be used to achieve these priorities (Zhou, 2012).

The generated eigenvector represents that of the criteria matrix, designated as Vc, which reflects the relative relevance of each selected criterion in the joint evaluation of the analyzed alternatives (Kim et al, 2019). On the other hand, when the eigenvector obtained corresponds to the eigenvector of the surrogate matrix for a specific parameter, called Vai (column vector), the relative importance of each surrogate matrix of criterion i is represented, and standard eigenvectors are obtained (Kim et al, 2019; Yang et al, 2022).

During the pairwise matrix comparison process, the subjectivity of the decisions is considered, seeking to make them as realistic and objective as possible, since the different elements of a matrix are compared with another matrix (Moghadam and Lombardi, 2019). If the validity of the decisions made is accepted, the decision-making process can continue; however, if it is not acceptable, it is necessary to carry out a new analysis and review the judgments of comparison between pairs. To determine the consistency of the process, equation 1 (Strantzali and Aravossis, 2016) is used, which provides normalized scores for each alternative in each criterion. These scores are represented by the dimensionless value rij, which varies between 0 and 1.

The normalization matrix A is used for the choice of alternatives. This matrix is built from the original paired comparison matrix, where each element is divided by the sum of the components of its respective column. The purpose of the normalization matrix is to obtain a relative representation of the importance of each criterion or alternative in relation to the others.

$$Normalizado \frac{a_y}{\sum_{k-1}^{n} a_{ij}}$$

(Equation 1)

Equation 2 allows calculating the sum of the rows of the matrix, which is a fundamental step in choosing solution alternatives or improvement options. The sum of rows represents the relative importance of each criterion or alternative with respect to the others. It is a value that provides key information about the weighting of each item in the analysis and helps establish a hierarchy of importance in decision making.

$$\frac{a_{11}}{\sum_{n-1}^{n} a_{n1}} + \frac{a_{12}}{\sum_{n-1}^{n} a_{n2}} + \cdots + \frac{a_{1n}}{\sum_{n-1}^{n} a_{nn}} = b_1$$

$$\frac{a_{11}}{\sum_{n-1}^{n} a_{n1}} + \frac{a_{12}}{\sum_{n-1}^{n} a_{n2}} + \cdots + \frac{a_{1n}}{\sum_{n-1}^{n} a_{nn}} = b_2$$

$$\frac{a_{11}}{\sum_{n-1}^{n} a_{n1}} + \frac{a_{12}}{\sum_{n-1}^{n} a_{n2}} + \cdots + \frac{a_{1n}}{\sum_{n-1}^{n} a_{nn}} = b_n$$

(Equation 2)

The priority vector B is obtained through the application of Equation 3, which allows calculating the relative relevance of the parameters or alternatives. This priority vector B represents the weight of each element in relation to the others, and is used to determine the hierarchy of importance in decision making.

$$\left[\frac{b_1}{n}, \frac{b_2}{n}, \ldots, \frac{b_n}{n}\right]^T |$$

(Equation 3)

Equation 4 establishes that the product between the original matrix A and the priority vector B results in a column matrix C. The column matrix C represents the values resulting from multiplying each component of matrix A by its corresponding weight in vector B. This The multiplication process provides valuable information about the relative contribution of each element in decision making.

$$|A * B = C = [c_1, c_2, \ldots, c_n]^T$$

(Equation 4)

Then, we proceed to calculate the quotient between the column of matrix C and the priority vector B, which gives us another column vector called D, as established in equation 5.

$$\frac{C}{B} = D \quad \text{Equation 5}$$

By summing and averaging the components of the column vector D, the value of the consistency index (CI) can be generated using equation 6.

$$CI = \frac{\lambda max-n}{n-1} \quad \text{(Equation 6)}$$

Subsequently, the value of the consistency index (CI) obtained is compared with the random CI (Table 3). The random CI represents the consistency value that would have been obtained if the numerical judgments of the scale had been entered completely randomly in the comparison matrix (Saaty, 1980).

Table 3
Comparisons between the IQ obtained and the random IQ

Matrix dimensions	1	2	3	4	5	6	7	8	9	10
Random Consistency	0,000	0,000	0.520	0.890	1,110	1,250	1,350	1,400	1,450	1,490

Source: Yang et al, (2022).

Therefore, the CI is divided by the random consistency, thus obtaining the Inconsistency Ratio (IR), Equation 7:

$$IR = \frac{CI}{Consistencia\ Aleatoria} \quad \text{(Equation 7)}$$

Finally, we consider that a matrix is consistent when the values stipulated for the size of each matrix are not exceeded, Table 4. If a matrix exceeds the consistency index, the evaluations made are verified and changed

Table 4
Limits of coherence

Matrix Dimension (n)	Consistency ratio (%)
3	5.00
4	9.00
5 or more	10.0

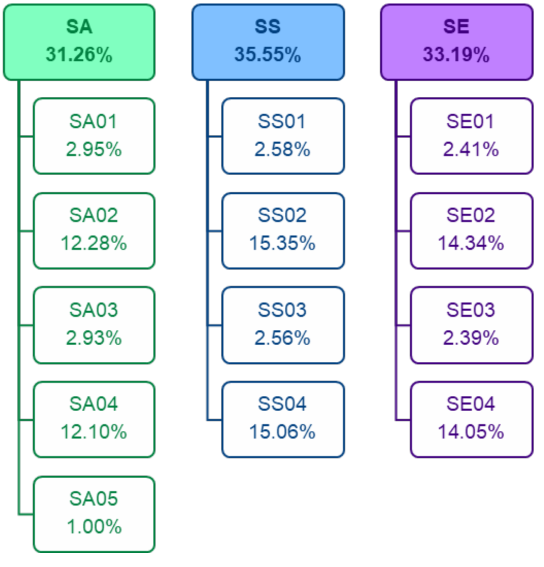
Source: Yang et al, (2022).

In the criteria and subcriteria selection stage, a group of qualitative parameters was defined that are used to compare different alternatives in terms of social sustainability (SS), economic sustainability (SE) and environmental sustainability (SA). The information collected was recorded. in the Microsoft Excel 2021 program and analyzed using the SPSS 29 statistical software. To evaluate the hypotheses, parametric analysis of variance tests were performed with a confidence level of 95%, α = 0.05, as well as a factorial analysis. of segmentation. The results were presented using segmentation and box-and-whisker plots, as well as tables showing the parameters estimated in the statistics.

3. Procurement supply chain management of a Peruvian public institution: Results

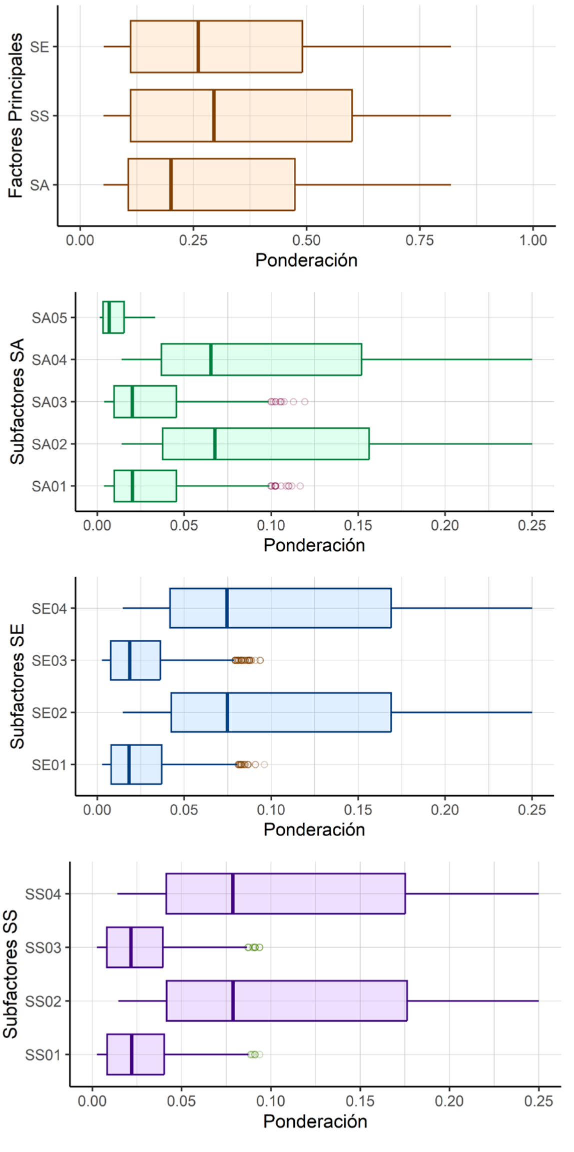
It is evident in the case of the main factors, that the Social Sustainability (SS) factor has the highest average impact, with a value of 35.55%, followed by the Economic Sustainability (SE) factor, with a value of 33.19%. On the other hand, the Environmental Sustainability factor shows the lowest average, with a value of 31.26%. When analyzing the subfactors related to Environmental Sustainability, it stands out that the waste management element (SA02) has the greatest impact or weighting, representing 12.28% of the total. In contrast, the optimization of resources (SA05) obtains the lowest score, with an average of 1.00%. Regarding the Social Sustainability (SS) subfactors, the scores vary from 2.56% (SS03 - Hiring of personnel with disparity) to 15.35% (SS02 - Eradication of Child Labor) (Diagram 1 and Illustration 1).

Diagram 1
AHP Model Results – Averages of Factors and Subfactors



Source: Yang et al, (2022).

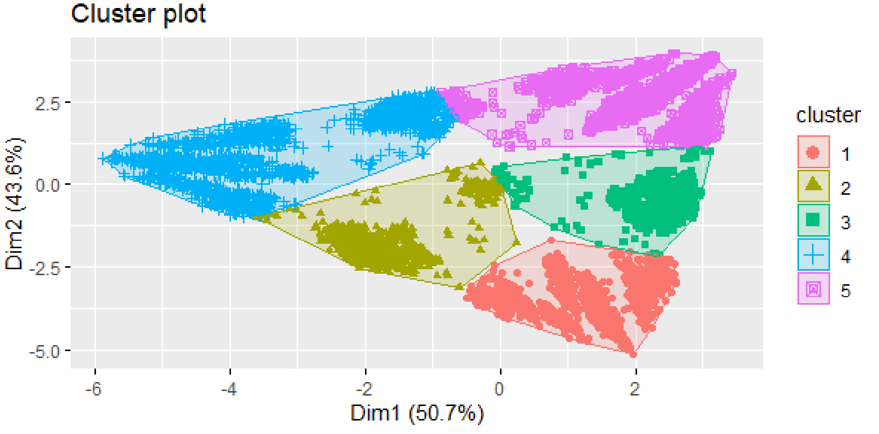
Illustration 1
AHP Model Results – Variability of Factors and Subfactors



Source: own elaboration based on data processing.

To identify behavior patterns among decision makers, a segmentation analysis was carried out (Illustration 2). This technique revealed the existence of 5 clearly differentiated groups, as shown in Table 5.

Illustration 2
AHP Model Results – Segmentation



Source: own elaboration based on data processing.

Table 5
Segmentation Summary – Factors

Segment	Size	SA	H.H	HE
1	914	0.4402	0.1194	0.4403
2	2064	0.1593	0.6966	0.1441
3	1003	0.0945	0.4568	0.4487
4	2196	0.6285	0.2424	0.1291
5	1656	0.1464	0.1493	0.7043

Source: own elaboration based on data processing.

The segment with the largest number of individuals (n=2196, which represents 28.04% of the sample) is segment 4. This group is characterized for assigning a greater weight to the environmental factor, with an average of 62.85%. Secondly, they give importance to the social factor, with a 24.24% weighting, and finall , to the economic factor, with a 12.91% weighting. On the other hand, segment 1 is the smallest group, with 914 individuals (11.67% of the sample). In this segment, there is a tie for first place between environmental and economic factors, both with approximately 44% weighting.

In order to verify or refute the proposed hypotheses, variance analyzes were performed. The null hypothesis states that all the factors or subfactors examined have the same impact on supplier selection, while the alternative hypothesis suggests that there is a significant difference between the elements analyzed. The data obtained from the hypothesis tests show that, in all the cases analyzed, the value of the F statistic is greater than the corresponding critical value. This indicates that the between-group variation is greater than the average within-group variation. Consequently, the null hypothesis is rejected and the alternative hypothesis is accepted. In other words, with a 95% statistical confidence level, the existence of significant differences between the groups is corroborated (Table 6).

Table 6
Analysis of Variance Results

Hypothesis	Subject	F	F Critical
General	Main Factors	275.2567	2.9961
Specific 0	SA subfactors	87.6454	2.3722
Specific 0	SS subfactors	671.2861	2.6052
Specific 0	SE subfactors	858.5527	2.6052

Source: own elaboration based on data processing.

Likewise, a significant difference was found between the economic sustainability subfactors. To identify the elements that differ from each other, a mean difference test was performed (Table 7). It is observed that, of the 25 combinations analyzed, in 6 of them (SA01 vs SA03, SA02 vs SA04, SS01 vs SS03, SS02 vs SS04, SE01 vs SE03 and SE02 vs SE04), the value of the t statistic is within the interval 95% confidence. Therefore, it is concluded that, in these 6 cases, the means are the same and there are no significant differences between them. However, in the other 19 scenarios, the value of the t statistic is outside the confidence interval. This indicates that in these cases there are significant differences in the average impacts.

Table 7
Mean difference test result

Comparison	degrees freedom	Student's t-value	tcritical
SA vs SS	15630	-11.1085	1.9601
SA vs SE	15662	-5.0909	1.9601
SS vs SE	15645	6.0750	1.9601
SA01 vs. SA02	8743	-85.1456	1.9602
SA01 vs. SA03	**15663**	**0.5604**	**1.9601**
SA01 vs. SA04	8749	-83.7726	1.9602
SA01 vs. SA05	9576	71.8467	1.9602
SA02 vs. SA03	8731	85.3633	1.9602
SA02 vs. SA04	**15664**	**1.1750**	**1.9601**

Cont... Table 7

SA02 vs. SA05	7935	105.5606	1.9603
SA03 vs. SA04	8736	-83.9904	1.9602
SA03 vs. SA05	9600	71.5391	1.9602
SA04 vs. SA05	7936	104.2204	1.9603
SS01 vs SS02	8285	-101.2661	1.9603
SS01 vs SS03	**15664**	**0.8733**	**1.9601**
SS01 vs. SS04	8300	-100.5079	1.9602
SS02 vs SS03	8283	101.4803	1.9603
SS02 vs. SS04	**15660**	**1.6292**	**1.9601**
SS03 vs. SS04	8297	-100.7253	1.9602
SE01 vs. SE02	8280	-97.9121	1.9603
SE01 vs. SE03	**15664**	**0.8220**	**1.9601**
SE01 vs. SE04	8296	-97.1893	1.9602
SE02 vs. SE03	8280	98.1045	1.9603
SE02 vs. SE04	**15659**	**1.7323**	**1.9601**
SE03 vs. SE04	8297	-97.3851	1.9602

Source: own elaboration based on data processing.

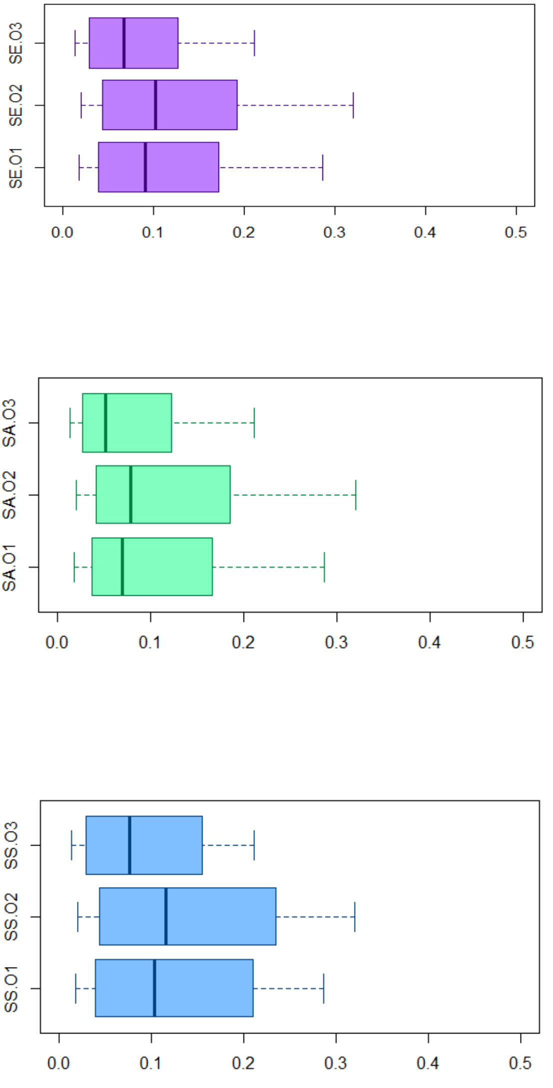
After having developed the model and analyzed the subgroups of the sample, we proceeded to evaluate three possible suppliers for the acquisition of desktop computers. According to the results, it was found that the environmental factor of Option 3 obtained the lowest value, with a value of 0.0807. On the other hand, the economic factor of Option 2 registered the highest value, with 0.1300. Regarding the final evaluation, it was determined that Option 2 obtained a total score of 39.17%, which places it in first place. Option 1, for its part, obtained a score of 35.02% and ranked second. Finally, Option 3 obtained the lowest score with 25.81% and was ranked last (Table 8 and Illustration 3).

Table 8
Results Evaluation Options - Averages

	SA	H.H	HE	Addition
Option 1	0.1095	0.1245	0.1162	0.3502
Option 2	0.1224	0.1393	0.1300	0.3917
Option 3	0.0807	0.0917	0.0857	0.2581
Addition	0.3126	0.3555	0.3319	1.0000

Source: own elaboration based on data processing.

Illustration 3
Results Evaluation Options - Variability



Source: own elaboration based on data processing.

4. Conclusions

The segmentation analysis in the study revealed a finding of great relevance regarding supplier selection and the supply chain. A dominant group was identified among the respondents who showed a strong inclination towards environmental aspects in their process of selecting sustainable suppliers. These individuals assign a significantly higher weight to the environmental factor compared to social and economic factors when choosing suppliers for their operations.

The significance of this result translates into a wake-up call for companies that seek to be considered sustainable suppliers by this group of consumers. To stay competitive and attract these customers, companies must focus on environmental sustainability throughout their supply chain. This involves not only the adoption of sustainable practices in the production and delivery of products and services, but also the selection of suppliers who share these environmental values. Additionally, it highlights the importance of effectively communicating sustainable efforts throughout the supply chain to meet the sustainability expectations of these environmentally conscious buyers and ensure the continuity of successful business relationships.

On the other hand, the lack of significant discrepancies between the environmental sustainability subfactors related to waste management and resource optimization should be highlighted. This indicates the importance of companies seeking to be sustainable suppliers to address both aspects comprehensively to meet the expectations of their customers in the public sector. Furthermore, the same pattern is observed in the social sustainability subfactors, highlighting the priority given to the eradication of child labor by municipalities. Companies that wish to provide goods and services must consider this social aspect as a priority in their practices and policies, as it has a significant impact on the evaluation of their offers by public sector buyers.

Regarding economic sustainability, the high average weighting of the sub-factors related to product life and maintenance cost reinforces the importance of offering solutions with long life and low maintenance costs. This underlines the need for companies to focus their efforts on developing products and services that are economically sustainable in the long term.

However, in relation to the evaluation of supplier options for desktop computers, respondents' preference for Option 2 stands out, followed by Option 1 and Option 3. These results suggest that companies seeking to serve Municipalities should focus on offering products and services that align with evaluators' preferences. Furthermore, the analysis of variance indicates that there are signifi ant differences between the factors and subfactors of the model, which indicates the importance of considering these factors in decision making related to supplier selection and sustainability.

Finally, it is important to recognize some limitations in this study. First, this analysis is based on data collected from a specific sample and may not fully represent the diversity of perspectives in the broader context. Additionally, results are based on responses provided by raters, which may be subject to individual bias or personal interpretation.

In terms of recommendations for future research, it would be beneficial to further analyze how companies can effectively address the identified sustainability sub-factors, especially in terms of their impact on decision making. Furthermore, an interdisciplinary approach that includes the participation of multiple stakeholders, such as local governments and non-governmental organizations, could enrich the understanding of sustainability in the context of the United Nations Sustainable Development Goals (ODS).

References bibliografic

Aguilar, S. (2005). Fórmulas para el cálculo de la muestra en investigaciones de salud. *Salud en Tabasco*, *11*(1-2), 333-338. https://www.redalyc.org/articulo.oa?id=48711206

Ahí, P. & Searcy, C (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of Cleaner Production*, *52*, 329-341. https://doi.org/10.1016/j.jclepro.2013.02.018

Akhrouf, M. & Derghoum, M. (2023). Use of Analytic Hierarchy Process model for selection of health infrastructure projects. *International Journal of the Analytic Hierarchy Process*, *15*(1), 1-26. https://doi.org/10.13033/ijahp.v15i1.1040.

Ali, A., Bentley, Y., Cao, G., & Habib, F. (2017). Green supply chain management–food for thought? *International Journal of Logistics Research and Applications*, *20*(1), 22-38. *http://dx.doi.org/10.1080/13675567.2016.1226788*

Alzate, M., Calle, L. & Muriel, Y. (2020). *Identificación de estrategias para implementar en la cadena de suministros sostenible en la industria química en Antioquia*, [Tecnológico de Antioquia Institución Universitaria. Medellín- Colombia]. https://dspace.tdea.edu.co/bitstream/handle/tdea/1716/32.%20TGII%20Bustamante%2C%20Palacio%20y%20Calle%20Estrategias%20cadena%20suministro%20sostenible%20.pdf?sequence=1&isAllowed=y

Amindoust, A., Ahmed, S., Saghafinia, A., & Bahreininejad A. (2012). Sustainable supplier selection: A ranking model based on fuzzy inference system. *Appl Soft Comput*, *12*(6), 1668–1677. https://doi.org/10.1016/j.asoc.2012.01.023

Bruno, G., Esposito, E., Genovese, A., & Passaro, R. (2009). *The Analytic Hierarchy Process in the Supplier Selection Problem. Proceedings of 10th Annual International Symposium on Analytic Hierarchy Process*. Pittsburgh, USA.

Bustillos, L., & Carballo, J. (2018). La gestión de la cadena de suministro y su impacto en el desempeño empresarial: Una revisión sistemática de la literatura. *Revista de Administración, Contabilidad y Economía, 16*(1), \ 63-83. https://doi.org/10.22320/S07179103/2018.14.

Carter, C. R., Hatton, M. R., Wu, C., & Chen, X. (2020). Sustainable supply chain management: continuing evolution and future directions. *International Journal of Physical Distribution and Logistics Management*, *50*(1), 122-146. https://doi.org/10.1108/IJPDLM-02-2019-0056

Christopher, M. (2016). *Logistics & supply chain management*. Pearson UK.

Forman, E. (2001). *Decision by Objectives - How to convince others that you are right*. River Edge, World Scientific Publishing

Ghayebloo, S., Tarokh, M. J., Venkatadri, U., & Diallo, C. (2015). Developing a bi-objective model of the closed-loop supply chain network with green supplier selection and disassembly of products: The impact of parts reliability and product greenness on the recovery network. *Journal of Manufacturing Systems*, *36*, 76–86. https://doi.org/10.1016/j.jmsy.2015.02.011

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. *Journal of Cleaner Production*, *98*, 66–83. https://doi.org/10.1016/j.jclepro.2013.06.046

Hernández, R., Fernández, C., & Baptista, L. (2014). *Metodología de la investigación*. (6ta. ed.). McGRAW-HILL.

Huang, Y. y Keskar, H. (2007). A multi-criteria decision-making approach for supplier evaluation and selection. *International Journal of Production Research*, *45*(18-19), 4257-4274.

Huo, B., Qi, Y., Wang, Z., & Zhao, X. (2014). The impact of supply chain integration on firm performance: The moderating role of competitive strategy. *Supply Chain Management: An International Journal*, *19*(4), 369–384. https://doi.org/10.1108/scm-03-2013-0096

Hwang, C.L. and Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications*. Springer-Verlag.

Ilbahar, E., Kahraman, C., & Cebi, S. (2022). Risk assessment of renewable energy investments: A modified failure mode and effect analysis based on prospect theory and intuitionistic fuzzy AHP. *Energy (Oxford, England)*, *239*(121907), 121907. https://doi.org/10.1016/j.energy.2021.121907

Jamal, T., Urmee, T.& Shafiullah, G. (2020), Planning of off-grid power supply systems in remote areas using multi-criteria decision analysis. *Energy*, *201*, 117580. https://doi.org/10.1016/j.energy.2020.117580.

Juríк, L., Horňáková, N., Šantavá, E., Cagáňová, D., & Sablik, J. (2022). Application of AHP method for project selection in the context of sustainable development. *Wireless Networks*, *28*(2), 893–902. https://doi.org/10.1007/s11276-020-02322-2

Kabir, G., Ahmed, S., Aalirezaei, A. & Ng, K. (2022), Benchmarking Canadian solid waste management system integrating fuzzy analytic hierarchy process (FAHP) with efficacy methods. *Environmental Science and Pollution Research*, 29(34), 51578-51588.

Khan, A., & Ali, Y. (2020). Analytical hierarchy process (AHP) and analytic network process methods and their applications: a twenty-year review from 2000-2019. *International Journal of the Analytic Hierarchy Process*, *12*(3), 369-379. https://doi.org/10.13033/ijahp.v12i3.822

Kim, B., Kim, J., & Kim, J. (2019). Evaluation model for investment in solar photovoltaic power generation using fuzzy analytic hierarchy process. *Sustainability*, *11*(10), 2905. https://doi.org/10.3390/su11102905

Kuczynski, P. P. & Thorne, A. (2017, March 19). Decreto Supremo que modifica el Reglamento de la Ley N.º 30225, Ley de Contrataciones del Estado, aprobado por el Decreto Supremo N.º 350-2015-EF. El Peruano, pp. 5-50. http://portal.osce.gob.pe/osce/sites/ default/files/Docume tos/legislacion/ley/2017- Reg_DL1341/DS-056-MODIFICACIONES%20AL%20REGLAMENTO%20LEY%2030225.pdf

Kuse, H., Endo, H. & Iwao, E. 2010. Logistics facility, road network and district planning: Establishing comprehensive planning for city logistics. *Procedia-Social and Behavioral Sciences*, *2*(3), 6251-6263. https://doi.org/10.1016/J.SBSPRO.2010.04.035

Kushwaha, G. (2010). Sustainable development through strategic green supply chain management. *International Journal of Engineering and Management Science*, *1*(1), 7-11. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1053.4639&rep=rep1&type=pdf

Ley 28611 de 2005. Ley General del Ambiente, (2005). https://www.minam.gob.pe/wp-content/uploads/2017/04/Ley-N%C2%B0-28611.pdf

Ley No. 1017. Ley de Contrataciones del Estado y su Reglamento. https://www.gob.pe/institucion/osce/normas-legales/246545-1017-ley-de-contrataciones-del-estado-y-su-reglamento

Mendoza, A., Santiago, R., & Ravi, A. (2008). A multi-objective optimization model for supply chain design considering risk. *International Journal of Production Economics*, *116*(1), 129-138. https://doi.org/10.1016/j.ijpe.2018.06.008

Ministerio de Medio Ambiente y Desarrollo Sostenible (2019). Producción y Consumo Sostenible. Home: Minambiente. https://www.minambiente.gov.co/asuntos-ambientales-sectorial-y-urbana/produccion-y-consumo-sostenible/

Moghadam, S.T. & Lombardi, P. (2019), An interactive multi-criteria spatial decision support system for energy retrofitting of building stocks using communtiyVIZ to support urban energy planning. *Building and Environment*, *163*, 106233. https://doi.org/10.1016/j.buildenv.2019.106233.

Mohammady, S. (2006). An Analytic Hierarchy Process-based Multi-criteria Decision Making Model for Supplier Selection. *International Journal of Production Research, 44*(9), 1819-1841. https://doi.org/10.1080/00207540500520491

Moustakas, K., Loizidou, M., Rehan, M. & Nizami, A.S. (2020), A review of recent developments in renewable and sustainable energy systems: Key challenges and future perspective. *Renewable and Sustainable Energy Reviews*, *119*, 109418. https://doi.org/10.1016/j.rser.2019.109418

Olson, D. L. (1996). The analytic hierarchy process. En *Decision Aids for Selection Problems* (pp. 49–68). Springer New York.

Poveda, C. (2023). Using multi-criteria decision-making to assess the importance of human capital in meeting the goals and objectives of sustainable development: An application of the Analytic Hierarchy Process. *International Journal of the Analytic Hierarchy Process*, *15*(1), 1-31. https://doi.org/10.13033/ijahp.v15i1.1067.

Saaty, T. (1980). *The Analytic Hierarchy Process*. McGraw Hill.

Saaty, T. (1997). *Toma de decisiones para líderes: El proceso analítico jerárquico. La toma de decisiones en un mundo complejo*. RWS Publications.

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, *15*(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5

Sadi-Nezhad, S. (2017). A state-of-art

survey on project selection using MCDM techniques. *Journal of project management*, 1–10. https://doi.org/10.5267/j.jpm.2017.6.001

Sánchez, H., & Reyes, C. (2015). *Método Científico. Planificación de la investigación*. (5ta. Ed). Business Support Anneth SRL.

Sarache, W., Costa, Y., & Martínez, J. (2019). Evaluación del desempeño ambiental bajo enfoque de cadena de abastecimiento verde. *DYNA*, *82*(189), 207-215. https://doi.org/10.15446/dyna.v82n189.48550

Seuring, S. & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of leaner production*, *16*(15), 1699-1710. https://doi.org/10.1016/j.jclepro.2008.04.020

Silva, J. (2017). Gestión de la cadena de suministro: una revisión desde la logística y el medio ambiente. *Entre Ciencia e Ingeniería*, *11*(22), 51–59. https://doi.org/10.31908/19098367.3549.

Silvestre, B. S. (2015). A hard nut to crack! Implementing supply chain sustainability in an emerging economy. *Journal of Cleaner Production*, *96*, 171–181. https://doi.org/10.1016/j.jclepro.2014.01.009

Strantzali, E., & Aravossis, K. (2016). Decision making in renewable energy investments: A review. *Renewable and Sustainable Energy Reviews*, *55*, 885–898. https://doi.org/10.1016/j.rser.2015.11.021

Yang, M., Ji, Z., Zhang, L., Zhang, A. & Xia, Y. (2022), A hybrid comprehensive performance evaluation approach of cutter holder for tunnel boring machine. *Advanced Engineering Informatics*, *52*, 101546.

Zanghelini, G.M., Cherubini, E. & Soares, S.R. (2018), How multi-criteria decision analysis (MCDA) is aiding life cycle assessment (LCA) in results interpretation. *Journal of Cleaner Production*, 172, 609-622. https://doi.org/10.1016/J.JCLEPRO.2017.10.230

Zhou, X. (2012). Fuzzy analytical network process implementation with matlab. En *MATLAB - A Fundamental Tool for Scientific Computing and Engineering Applications - Volume 3*. InTech.

Zhu, Y., Tan, J., Cao, Y., Liu, Y., Liu, Y., Zhang, Q. & Liu, Q. (2022), Application of fuzzy analytic hierarchy process in environmental economics education: Under the online and offline blended teaching mode. *Sustainability*, *14*(4), 2414.

Zimmer, K., Fröhling, M., & Schultmann, F. (2016). Sustainable supplier management – a review of models supporting sustainable supplier selection, monitoring and development. *International Journal of Production Research*, *54*(5), 1412–1442. https://doi.org/10.1080/00207543.2015.1079340