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Financial ratios with fuzzy logic approach. New estimation perspective*

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Abstract

The industrial sector of Cuenca represents an icon of development and progress of this city. The problem of studying this sector is that it calculates traditional financial ratios exposed to volatile contexts with high uncertainty. The aim of this research is to estimate financial ratios with fuzzy logic approach in industrial companies of Cuenca city, Ecuador, due to the great importance of estimating these ratios to determine the financial health of these organizations. The research is descriptive, with a quantitative approach, using the development of expert and counter-expertise techniques, applying a form of calculation through Triangular Fuzzy Numbers (TFNs), and confidence intervals, instruments of fuzzy logic. The results obtained at 80% and 90% of the degree of presumption, are equivalent to the bands [1,488, 1,506] and [1,494, 1,503] respectively, corresponding to the liquid ratio; in a similar way the other working capital ratios are presented in the study. This new estimate will allow directors and managers to make more accurate decisions for the benefit of their companies, overcoming traditional barriers to be framed in the objectivity and reality of the current market.

Keywords: Financial ratios; confidence intervals; fuzzy logic; triangular fuzzy numbers.

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Ratios financieros con enfoque de lógica difusa. Nueva perspectiva de estimación

Resumen

El sector industrial de Cuenca representa un icono de desarrollo y progreso de esta ciudad. El problema de estudiar este sector es que calcula ratios financieros tradicionales expuestos a contextos volátiles con alta incertidumbre. El objetivo de esta investigación es estimar ratios financieros con enfoque de lógica difusa en empresas industriales de la ciudad de Cuenca, Ecuador, debido a la gran importancia de estimar estos ratios para determinar la salud financiera de estas organizaciones. La investigación es descriptiva, con un enfoque cuantitativo, utilizando el desarrollo de técnicas de peritaje y contraperitaje, aplicando una forma de cálculo a través de Números Difusos Triangulares (NFT), e intervalos de confianza, instrumentos de la lógica difusa. Los resultados obtenidos al 80% y 90% del grado de presunción, equivalen a las bandas [1,488, 1,506] y [1,494, 1,503] respectivamente, correspondientes al ratio de liquidez; de forma similar se presentan en el estudio los demás ratios de capital circulante. Esta nueva estimación permitirá a los directivos y gestores tomar decisiones más acertadas en beneficio de sus empresas, superando las barreras tradicionales para enmarcarse en la objetividad y realidad del mercado actual.

Palabras clave: Ratios financieros; intervalos de confianza; lógica difusa; números difusos triangulares.

1. Introduction

The industrial development of Cuenca city, Ecuador, is the result of the investment of local capitals that led to the generation of productivity and work, which promoted its development and diversify its productive activity. However, this sector is exposed to volatile contexts with high uncertainty, the lack of knowledge generates problems associated with financial control and analysis, due to the calculations of its ratios are carried out in the traditional way. Sáenz and Sáenz (2019) consider the financial ratios as ratios of traditional use in the analysis of the financial status of organizations, to detect financial problems and later try to solve them. Nava (2009), establishes that financial analysis is a key managerial and analytical tool in all business activity that determines not only the financial conditions in the present, but also the management of available financial resources that helps to predict the future of the organization.

The financial ratios evaluate the current and previous financial situation of the companies, determining estimates and predictions about future environments, under traditional calculations. Van Horne and Wachowicz (2010) explain that

financial ratios facilitate comprehensive reviews of various aspects related to the financial health of companies. On the other hand, for Murillo, Ruiz and Benavides (2013), the financial ratios have a relationship between variables, coming from the history of the financial statements, because their calculation allows evaluating the performance of the companies in terms of investment, operations, or from any financing source.

The aim of this research is to estimate financial ratios (liquid ratio, liquidity ratio, current ratio, asset turnover ratio and inventory turnover ratio) with fuzzy logic approach, using Triangular Fuzzy Numbers (TFNs) and confidence intervals, thereby reducing the uncertainty in the analysis of financial information. Kaufmann and Gil-Aluja (1987) explain that a Triangular Fuzzy Number (TFN) is defined by three numbers: one below which it will not go down, another above which it will not be possible to reach, and the third which represents the maximum level of presumption. In addition, Casanovas and Fernández (2003:20), establish: "we can define a confidence interval as an uncertain datum to predict the value of a certain variable between two extremes, one lower and one higher".

At the methodological level, the research is explanatory; the study explains the development of the avant-garde tools of the fuzzy logic, such as expertise and counter-expertise. Its approach is directed to the quantitative plane from the information obtained through the survey technique. Twenty professional experts in the financial area answered a questionnaire in order to reduce uncertainty in the determination of financial ratios of industrial companies of Cuenca city.

Due to the above, it is necessary to apply novel techniques of fuzzy logic, in order to reduce the uncertainty, imprecision and vagueness of the information. Regarding these explanations, D'Negri and De Vito (2006:128), consider that "fuzzy logic is used when the complexity of the process in question is very high and there are no precise mathematical models for highly non-linear processes, and when definitions and knowledge are not strictly defined (imprecise or subjective)".

Gutiérrez (2006:84), considers that "it is inevitable that the application of fuzzy logic to the problems of economic and financial management will grow in importance in the coming years". Thus, for Muñoz and Avilés (2014:69) "The reason why the incursion of fuzzy logic in the schemes that have traditionally been used to deal with decision problems in the field of business activity, is increasingly broad, enriching administrative science".

From this perspective, it is important to provide the industrial sector companies with a new way of estimating financial ratios, since this will allow them to strengthen business management. The fuzzy logic theory represents a valuable contribution for decision making within these organizations.

2. Literature Review: Financial Ratios

Financial ratios are an option for addressing the financial situation within an organization, they represent the basis on which financial analyzes are carried out, which consist of interpreting the accounting results of the company with the purpose of obtaining a diagnosis of the current reality in order to make future projections. With this, managers can make better decisions. Morelos, Fontalvo and De la Hoz Granadillo (2012), explain

the importance of financial analysis, as the only way to know the real situation of an organization or company, to make decisions to achieve objectives that generate profits.

Nava (2009) explains that the objectives of financial analysis are based on measuring the level of solvency, liquidity, profitability and, in general, the current financial situation of the organization; the author clarifies that full compliance with these objectives is subject to the quality of the accounting and financial information used for its application. For Luna, et al. (2019), Nava (2009), and Pasqual (2007), financial ratios are of real importance in organizations and industrial sectors, due to the information they offer to management.

When evaluating the relationship between the measures of operational and financial performance, the calculation of traditional financial ratios is used, in addition to concepts such as the generation of value, and the drivers that allow its measurement and evaluation, in cooperative, non-profit entities belonging to the solidarity sector (Correa, Gómez and Londoño, 2018). Arimany, Farreras and Rabaseda (2016) expose the most important economic and financial ratios with the purpose of diagnosing the health of organizations, through a short and long-term analysis of changes in equity and cash flows of wine companies.

The analysis of the financial statements is carried out through financial ratios to evaluate the current and previous financial situation of an organization, determining estimates and predictions about future environments. Van Horne and Wachowicz (2010) explain that the tools used to evaluate the financial condition and performance of the company are the financial ratios, these facilitate a complete review of different aspects of financial health.

The review of the literature carried out by Gerschewski and Xiao (2014), establishes that the measurement of the performance of new international companies includes internationalization patterns, networks and entry strategies of these companies, as well as financial performance; the authors point out that financial indices are considered more important than operational ratios, finding out that productive companies tend to give greater importance to financial performance than service companies.

Malichová and Ďurišováa (2015), explain that the measurement of the financial performance of companies and their evaluation belong to the basic identifiers of the general success of companies in the market, the ratios that represent the financial performance related to the dynamic environment in which they operate, and those related to the constant pressure of their environment to improve. They consider that it is necessary to evaluate the financial condition of companies operating in the IT sector based on the establishment of financial ratios, while the operating results of companies are analyzed using selected financial ratios.

2.1. Financial ratios of the industrial sector under the blurred focus

The companies of the industrial sector of Cuenca carry out the calculation and analysis of their ratios from a traditional point of view, for this reason we present a new way of estimating the financial ratios since they represent a valuable instrument for decision making within the organizations. For the

managers and senior management of a company it is important to know the financial situation in which it finds itself, for this it is necessary to analyze the financial statements through ratios.

The financial ratios will be analyzed using fuzzy logic tools, through confidence intervals and Triangular Fuzzy Numbers (TFNs); the main purpose is to break the imprecision and reduce the uncertainty in their calculations.

Fuzzy logic was created by Zadeh (1965), a professor at the University of Berkeley (California), who decided to apply multivalued logic to systems theory, because when systems became more complex, the precise statements had less meaning. From that, other authors promoted this technique. Among them, Kaufmann and Gil-Aluja (1986), who explain the theory of fuzzy subsets to the management of companies, through the use of Triangular Fuzzy Numbers (TFNs) in the treatment of uncertainty, being known since the beginning of the incorporation of fuzzy logic in organizational problems.

On the other hand, Reig and González consider that "fuzzy logic is revealed as a very powerful instrument (...) by allowing, on the one hand, to collect the uncertainty generated by the company's environment, and on the other, to deal with the subjectivity that all expert opinion implies" (2002:436). Instead, Medina (2006) analyzes the applications of fuzzy set theory and fuzzy inference systems in solving financial problems, thereby criticizing traditional financial decision-making models. He explains that they do not clearly capture the dynamics of the behavior of the markets, asserts that with this approach it is possible to collect the economic and financial phenomena with all imprecision and treat them mathematically, also incorporating the analysis of the experts' criteria.

Rico and Tinto (2010) state that fuzzy logic systems are more flexible, accept the imprecision, subjectivity and vagueness (uncertainty) of the data, and allow effective solutions to be obtained to adequately support decision-making. For Domínguez, Sánchez and Ruiz (1992:49) "a fuzzy number is the association of two concepts that of confidence intervals linked to uncertainty and that of the level of presumption, linked to subjectivity".

Díaz, Coba and Navarrete (2017) use fuzzy logic in financial risk ratios, applying financial ratios of cooperatives in the Ecuadorian financial sector, thereby validating the level of relevance of this ratio when compared to the standardized objective of the CAMEL model and its risk rating, using linguistic variables whose ranges were evaluated on scales 0-1. They explain that the fuzzy methodology applied to financial risks presents a higher level of relevance towards a good credit rating, ensuring a low level of risk and a very good solvency.

On the other hand, Tseng-Chung & Li-Chiu (2005), apply a Receiver Operating Characteristics (ROC) curve analysis to compare the performance of the logit model with that of fuzzy logic. They evidence that no other paper has discussed the application of ROC curve analysis in the commercial and financial literature. The research shows that fuzzy logic is superior in overall accuracy and in classifying companies in default. Logit is preferable in situations where greater accuracy in classifying companies that are not in default is required, it demonstrates the security of the models.

Luna and Sarmiento (2019) evaluate, from an economic perspective, the situation of manufacturing MSMEs in the city of Cuenca-Ecuador, especially

those dedicated to the manufacture of wooden furniture, in order to reduce uncertainty and minimize risk, using tools offered by fuzzy logic by calculating the internal rate of return and the fuzzy net present value,

But it is Kaufmann and Gil-Aluja (1987), who made the greatest contribution to the knowledge of fuzzy logic through their publication "Operative management techniques for the treatment of uncertainty", explaining that a fuzzy number is like a finite sequence or infinite number of confidence intervals. This work has been of great support and benefit for the development of knowledge.

These techniques are explained later, through an analysis of financial ratios considering confidence intervals and Triangular Fuzzy Numbers (TFNs), with the purpose of breaking the uncertainty and inaccuracy in their calculation. Zadeh (2008), asserts that fuzzy logic attracts a large number of followers, since its expressions are neither completely true nor completely false; that is, it is the logic adaptable to concepts that can take any value of veracity in a set of values that fluctuate between two extremes: absolute truth and total falsity, therefore what is diffuse, complex or imprecise is not logic itself, but the object it intends to study.

In this context, this technique is so successful in the business field; one of its disadvantages would be the difficulty of interpreting its fuzzy values, which is not the case in this study. Its values are presented in bands, for this reason it is necessary to have a culture of improvement, overcoming and organizational change, knowing that venturing into this new knowledge has no cost, since every company has qualified personnel. Only basic knowledge in geometry and knowing how to operate Excel are needed, taking the benefit of these tools to companies in the industrial sector of the city of Cuenca-Ecuador, to make better financial decisions. With this, it is expected that these organizations will focus on using this new process for their own benefit and thus continue contributing to local, regional and national development.

To demonstrate the importance of these tools offered by fuzzy logic, the liquid ratio is determined, developing the techniques of expertise and counter-expertise, which are explained below.

3. Theory of expertise and counter-expertise

For Luna and Sarmiento (2019:553), "expertise is the consultation made to a defined group of experts in affinity with a certain topic, with the intention of limiting uncertainty". On the other hand, Rico and Tinto (2010:133) propose "counter expertise as an arithmetic procedure based on fuzzy subsets that allows to reduce the entropy in the variables or categories studied by applying the formula: Ei + ([Es - Ei] × experton)".

In the present investigation, the experts are represented by personnel from the financial area of the companies in the industrial sector of Cuenca, who, through the survey technique, deliver the financial information from the accounting books of the previous five years. As an example, some financial ratios of an organization are presented, for reasons of confidentiality it is designated as company "X" (Table 1).

Table 1
Financial ratios

Industrial Company "X"					
FINANCIAL RATIOS	YEARS				
	2020	2019	2018	2017	2016
Liquid Ratio (Quick Ratio/Acid Test)	1.46	1.49	1.53	1.44	1.47
Liquidity Ratio	0.94	0.88	0.93	0.89	0.82
Current Ratio	1.52	1.55	1.42	1.54	1.48
Asset Turnover Ratio	0.72	0.78	0.84	0.87	0.98
Inventory Turnover Ratio	2.17	2.32	2.25	1.95	1.96

Source: Own elaboration

As a first step, the development of the techniques of expertise and counter expertise of fuzzy logic is explained. For this it is necessary to apply the endecadary scale in the information collection instrument, in order to reduce the entropy or uncertainty and adjust the examined values. Kaufmann and Gil Aluja (1989:26), establish that "the introduction of a nuanced valuation between 0 and 1 allows levels of truth to intervene in the notion of incidence. (...) Values from 0 to 1 (the so-called endecadary valuation)" (Table 2).

Table 2
Endecadary scale

DEGREE OF PRESUMPTION α	INCIDENCE
0	It has no incidence
0.1	Virtually no incidence
0.2	Almost without incidence
0.3	It has a very weak incidence
0.4	Has a weak incidence
0.5	Median incidence
0.6	Has a noticeable incidence
0.7	It has a lot of incidences
0.8	It has a strong incidence
0.9	It has a very strong incidence
1	It has the highest incidence

Source: Own elaboration

The confidence interval of the liquid ratio [1.44, 1.53] is established, based on the history presented in Table 1 of an industrial company. The left value belongs to the year 2017, and the right value to the year 2018. Considering the endecadary scale, 20 financial experts from the industrial sector are asked to answer the question: What is the importance of the liquid ratio, in the years with optimistic and pessimistic value? (Table 3).

Table 3
First Opinion of the Expert Panel

No. SURVEYED	PESSIMISTIC VALUE	VALUE OPTIMISTIC
1	0.3	0.8
2	0.1	0.7
3	0.1	1.0
4	0.0	0.9
5	0.3	0.8
6	0.5	1.0
7	0.3	1.0
8	0.4	0.6
9	0.0	0.9
10	0.2	1.0
11	0.0	1.0
12	0.3	0.8
13	0.3	0.9
14	0.3	1.0
15	0.6	0.9
16	0.1	0.7
17	0.4	0.8
18	0.3	1.0
19	0.4	0.9
20	0.3	0.6

Source: Own elaboration

From Table 3, considering the pessimistic value of the liquid ratio, the response of 0 and 0.1 is repeated three times, 0.2 once, and so on successively until concluding with all the experts consulted. For the optimistic value, the same procedure is carried out.

Next, frequency normalization is performed. The frequency values reached in each degree of presumption of the endecadary scale are divided by the number of experts (20); for the pessimistic value of the liquid ratio (Pr), *3÷20 = 0.15*, *1÷20 = 0.05, and so on.*

The same procedure is followed for the optimistic value of the liquid ratio (Or).

The next step is the accumulation of frequencies, starting with the sum from the end of the series, until obtaining the unit, considering from there the value one (1.00) in each band. This whole process is known as expertise.

To apply the counter-expertise technique, the formula is developed: Ei + ([Es - Ei] × experton) explained by Rico and Tinto (2010), where: Ei denotes the lower end, and Es is the upper end. In the case of the liquid ratio, the acronym Ei is replaced by Pr (pessimistic ratio), and Es by Or (optimistic ratio), to determine the values of the first counter-expertise band at the level of the degree of presumption zero, we have:

$$Pr + ([Or - Pr] \times experton)$$
$$1.44 + ([1.53 - 1.44] \times 1.0) = 1.53$$
(Equation 1)

This process is carried out for all the pessimistic and optimistic values from the degree of presumption zero to one, and proceeds with the sum of the counter-expertise bands; the total is divided by 10, without considering the degree of presumption zero. The original interval of the liquid ratio was [1.44, 1.53], developing this tool reduces the existing entropy in the band, obtaining a new interval [1.46, 1.52]. This process is presented in Table 4.

Table 4
Values of Expertise and Counter-expertise

DEGREE OF PRESUMPTION α	FREQUENCY		FREQUENCY NORMALIZATION		ACCUMULATION OF FREQUENCIES (expert)		COUNTER-EXPERTIZED BANDS	
	Pr	**Or**	**Pr**	**Or**	**Pr**	**Or**	**Pr**	**Or**
0	3	0	0.15	0.00	1.00	1.00	1.53	1.53
0.1	3	0	0.15	0.00	0.85	1.00	1.52	1.53
0.2	1	0	0.05	0.00	0.70	1.00	1.50	1.53
0.3	8	0	0.40	0.00	0.65	1.00	1.50	1.53
0.4	3	0	0.15	0.00	0.25	1.00	1.46	1.53
0.5	1	0	0.05	0.00	0.10	1.00	1.45	1.53
0.6	1	2	0.05	0.10	0.05	1.00	1.44	1.53
0.7	0	2	0.00	0.10	0.00	0.90	1.44	1.52
0.8	0	4	0.00	0.20	0.00	0.80	1.44	1.51
0.9	0	5	0.00	0.25	0.00	0.60	1.44	1.49
1	0	7	0.00	0.35	0.00	0.35	1.44	1.47
TOTAL	**20**	**20**	**1.00**	**1.00**			**14.63**	**15.18**
			NEW BAND				**1.46**	**1.52**

Source: Own elaboration

This process is carried out as many times as necessary, until the right value of the interval remains constant; the value found represents the maximum assumption or the optimal value of the financial ratio of liquid. As the value of the optimistic ratio coincides with the band of the third counter-expertise, it means that the financial ratio of 1.50 represents the maximum level of presumption.

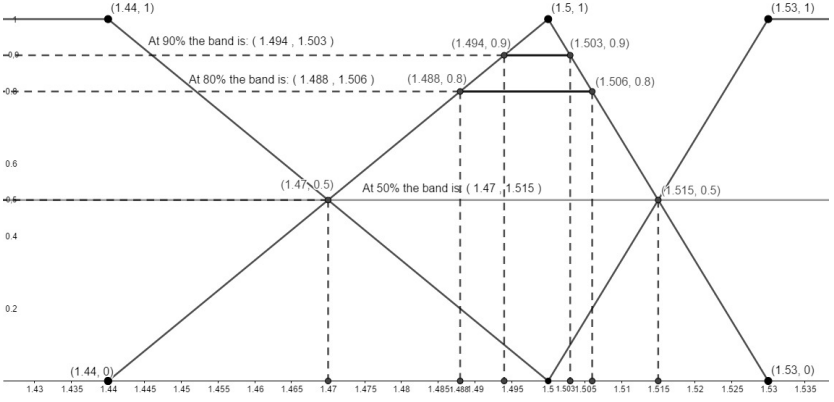
A geometric trace is made, through a scalene triangle, in which the pessimistic, ideal and optimistic levels are determined with the support of fuzzy logic. This technique, known as expertise and counter-expertise, allows managers of companies in the industrial sector of Cuenca to make decisions from a broader point of view and with greater certainty within the financial area of their organizations.

4. Financial ratios in confidence intervals

From the Triangular Fuzzy Number (TFN) [1.44, 1.50, 1.53], the geometric trace of a scalene triangle is made, the left value corresponds to the liquid ratio of the year 2017, the right value corresponds to the liquid ratio of the year 2018, and the central value represents the maximum degree of presumption or the maximum possibility of occurrence of this ratio.

Through this process, it is shown that as the alpha cutoff (α) approaches 100%, the confidence interval decreases. With the complete mathematical procedure, considering an alpha cutoff of 80%, the band [1.488, 1.506] and another at 90% [1.494, 1.503] are obtained; this means that any value within these bands will be ideal for organizational purposes. This is about reducing uncertainty, leaving company managers to make the best decisions based on the optimal levels defined.

Figure 1
Analysis of the liquid ratio with fuzzy logic approach



Source: Own elaboration

Following the same process of developing the techniques of expertise, counter-expertise and triangular tracing, the most important financial ratios indicated above for the industrial company "X" were determined, through Triangular Fuzzy Numbers (TFNs), and from them the bands or confidence intervals at 80% and 90% of the possibility of achieving these financial ratios at the end of an accounting period. Table 5 presents the results.

Table 5
Triangular fuzzy numbers and confidence intervals

Industrial Company "X"		
FINANCIAL RATIOS	**DEGREE OF PRESUMPTION 0.8**	**DEGREE OF PRESUMPTION 0.9**
Liquid Ratio	[1.44, 1.50, 1.53]	
	[1.488, 1.506]	[1.494, 1.503]
Liquidity Ratio	[0.82, 0.92, 0.94]	
	[0.90, 0.924]	[0.91, 0.922]
Current Ratio	[1.42, 1.51, 1.55]	
	[1.492, 1.518]	[1.501, 1.514]
Asset Turnover Ratio	[0.72, 0.90, 0.98]	
	[0.864, 0.916]	[0.882, 0.908]
Inventory Turnover Ratio	[1.95, 2.21, 2.32]	
	[2.158, 2.232]	[2.184, 2.221]

Source: Own elaboration

From the development of these innovative tools offered by fuzzy logic, fuzzy financial ratios are obtained:

- The central value of the triangular fuzzy number referred to by [1.44, 1.50, 1.53], of the liquid ratio, represents the highest degree of presumption or the maximum possibility of occurrence of this financial ratio; it does not express a simple average number between the extreme values. This is about breaking the subjectivity and imprecision of the calculation of financial ratios by reducing uncertainty.
- Determining confidence intervals or bands in each of these financial ratios allows the management of the company under study to have a more accurate vision, since from a geometric trace it can be considered a cutoff of 80% and 90%, with their bands of [1.488, 1.506] and [1.494, 1.503]. The results indicate that any value within these intervals will be ideal for business objectives.
- Developing the tools offered by fuzzy logic such as expertise and counter-expertise, allows obtaining values attached to reality with a greater approximation to accuracy,

for this reason it can be affirmed that the liquid ratio measures the company's ability to pay off its short-term obligations, the result of which should always be greater than one (1) with a tendency to move away from it, to reach higher amounts. The greater the weight of the items less liquid assets and lower the rate of conversion of current assets. With this contribution, senior executives and management of industrial companies will be able to carry out a more efficient analysis of financial ratios.

- Through this new calculation of financial ratios, directors and managers of companies in the industrial sector will be able to improve financial management through efficient decision-making at the managerial level.

The calculation of financial ratios with the support of fuzzy logic enhances the management of industrial companies in Cuenca city, Ecuador. A confidence interval allows demonstrate that the cost benefit is favorable for the company. This process will lead the organization to remain within the market and thereby continue supporting social development, both at the local, regional and national.

5. Conclusions

The reasons or financial ratios represent instruments or tools of great importance for the financial health of any organization, they direct the ideal path for business stability, through a correct analysis of financial information, the capacity for liquidity, solvency, indebtedness and profitability of companies can be measured. The usefulness they provide is aimed at evaluating and improving the decisions made by the directors and management of the company under study. Financial analyzes are always supported by financial reasons that, in an orderly manner, support decision-making in organizations.

The tools of fuzzy logic, such as expertise and counter-expertise, allow uncertainty management to be analyzed in a more real way; its calculation breaks traditional schemes giving rise to a new conception of reality. Estimating financial ratios in confidence intervals through the determination of Triangular Fuzzy Numbers (TFNs), allows companies, particularly those in the industrial sector, to have a broader view of the financial landscape. The calculations obtained represent confidence intervals and not simply a common number. Any value that is within these bands, denotes the financial reality of today's world. This new estimate will allow determining important trends in financial projections.

With this contribution, the managers of companies in the industrial sector of Cuenca city, Ecuador, will be able to carry out financial analysis from a new perspective, making more efficient and assertive decisions, directing their organizations along the path of greater financial effectiveness.

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