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Neutrosophic evaluation through the PESTEL method

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Abstract. This study addresses the complexity of assessing key factors in strategic decision-making through PESTEL analysis applied with a neutrosophic perspective. In a context of increasing uncertainty, organizations face challenges in accurately interpreting political, economic, social, technological, environmental and legal factors, which are fundamental for sustainable development and informed decision-making. The importance of this topic lies in the need to integrate approaches that not only describe these factors in a static manner, but also address the ambiguity and complexity inherent in the variables that compose them. By applying the PESTEL method in its neutrosophic version, the study aims to go beyond conventional approaches, capturing the dimensions of uncertainty that often go unnoticed in traditional analyses. In terms of methodology, the study uses neutrosophic analysis on the PESTEL framework, incorporating flexible variables that allow capturing the multiple perspectives of experts in each of the factors analyzed. The findings reveal that by integrating the neutrosophic approach, it is possible to offer more dynamic and accurate assessments of the challenges faced by organizations in complex environments. This research contributes significantly to the field by proposing a new approach to strategic analysis that overcomes the limitations of previous static models. In practical terms, the results provide tools to enhance organizational resilience by enabling a more nuanced assessment of external factors, thereby facilitating more informed and adaptive decision-making. In conclusion, this study not only enriches theoretical knowledge about strategic analysis but also contributes practical solutions that can be applied to a variety of business and public policy contexts.

Keywords: Neutrosophic assessment, PESTEL method, Strategic decision making, Uncertainty, Political, economic, social, technological, environmental and legal factors, Strategic analysis

1. Introduction

In the early days, there was a notable increase in private sector participation in space efforts, especially in Western countries such as the United States. The commercial benefits derived from this have become significant at a global level [1]. This evolution has generated the need to review the regulations of international space law, as various questions arise due to the growth of private capital and technological progress, such as differences in the interpretation of terms such as use and exploration related to space [2].

In the absence of international legislation, some countries regulate the actions of private entities through national laws [3]. This has given rise to the idea of a global interaction between the State and the private sector, as evidenced by the legislation regulating the International Space Station (ISS). However, legal solutions are still lacking in areas such as satellite operations [4]. It is crucial to establish international regulations for satellite launches, independent of political considerations and applicable to all, including private actors.

Space tourism via space shuttles (RLV) must ensure a safe return for crew, passengers and cargo, as well as generating economic benefits [2]. However, detailed procedures are required, especially regarding transport (ship equipment, routes, insurance, emergencies and spaceport infrastructure, among others).

The commercialization of space services is a natural consequence of continuing technological development, but it raises numerous legal issues regarding civil liability [4]. Some advocate leaving this responsibility to the market, while others propose separate and specific international regulation for space transportation and telecommunications.

Currently, in some countries, private companies only need permission from the state of registration to operate. However, to ensure safety, proper notification of the departure of the aircraft from Earth is required. However, not everyone agrees with excessive liberalization of space, arguing that differences of opinion and state demands must be considered.

The main task of this paper is to identify the challenges and opportunities arising from the increasing work between government and the private sector in space, and to propose recommendations for effective regulation that will foster the sustainable development of commercial space operations worldwide. In addition, civil liability and the need for a new branch of space law addressing commercial diligence in space will be explored [3].

2. Materials and methods

2.1. PESTEL method

The PESTEL study [5], which covers several aspects, is a fundamental tool for identifying the environment in which entities are managed. Its main objective is to provide elements that allow the organization to anticipate new situations and circumstances. This analysis involves identifying and examining key elements:

1. Political: Political elements that may influence the future activity of the organization are analyzed, such as government policies and regulations.
2. Economic: Current and future economic conditions that could affect the organization's strategy are considered, including economic development, poverty and inequality.
3. Social: Sociocultural aspects are examined that may reveal current trends in the company's activity, such as changes in consumer quantities and preferences.
4. Technological: The relationship between ICT and the potential transformations that could arise , which can affect the way entities are managed and offer their products or services.
5. Ecological: Possible changes related to ecology and the environment are considered, as well as the opportunities and challenges that these changes may pose for the organization.
6. Legal: Changes in legal regulations that may positively or negatively affect the organization are analyzed, such as government regulations or labor laws.

All these aspects are crucial to understanding the market and represent the basis of strategic management. They cover elements such as government policies, poverty levels, inequality, economic development, access to resources and how all of this impacts the company [6].

2.2 Neutrosophic statistics

Neutrosophic analysis replaces exact numerical quantities with interval-type quantities. This methodology can be used for both parameters and random variables, while recognizing that the sample size

is uncertain or imprecise. In this framework, information may present ambiguity, vagueness, inaccuracy, incompleteness or uncertainty [7].

Analyses performed through neutrosophic facilitate the interpretation and sorting of neutrosophic (ambiguous, vague, imprecise, incomplete, or unrevealed) information to detect underlying patterns. In summary, neutrosophic reasoning, neutrosophic collections, and neutrosophic probabilities and analysis find wide utility in various research domains and constitute a rapidly evolving field of research. Descriptive analysis of neutrosophic encompasses all methodologies for summarizing and elucidating the attributes of neutrosophic numerical information. Neutrosophic quantities are delineated as N = a + b $_i$, where a and b are real or complex quantities, and "I" denotes the indeterminacy component of the neutrosophic quantity.[8]

The study of neutrosophy statistics refers to a neutrosophy random variable. The mean of the neutrosophy variable is formulated as follows [9,10,11]:

$$X_N = X_l + X_u I_N;\ I_N \in [I_l, I_u] \tag{1}$$

$$\text{Where, , , ,} \bar{x}_a = \frac{1}{n_N}\sum_{i=1}^{n_N} X_{il}\ \bar{x}_b = \frac{1}{n_N}\sum_{i=1}^{n_N} X_{iu}\ n_N \in [n_l, n_u] \tag{2}$$

This is a neutrosophic random sample. However, for the calculation of the neutral squares (NNS) it can be calculated as follows [11, 12, 13]

$$\sum_{i=1}^{n} N(X_i - \bar{X}_{iN})^2 = \sum_{i=1}^{n} N\left[\begin{matrix}\min\begin{pmatrix}(a_i + b_i I_L)(\bar{a} + \bar{b} I_L), (a_i + b_i I_L)(\bar{a} + \bar{b} I_U)\\ (a_i + b_i I_U)(\bar{a} + \bar{b} I_L), (a_i + b_i I_U)(\bar{a} + \bar{b} I_U)\end{pmatrix}\\ \max\begin{pmatrix}(a_i + b_i I_L)(\bar{a} + \bar{b} I_L), (a_i + b_i I_L)(\bar{a} + \bar{b} I_U)\\ (a_i + b_i I_U)(\bar{a} + \bar{b} I_L), (a_i + b_i I_U)(\bar{a} + \bar{b} I_U)\end{pmatrix}\end{matrix}\right], I \in [I_L, I_U] \tag{3}$$

Where . The sample variance of neutrosophy can be calculated by:$a_i = X_l b_i = X_u$ [14,15]

$$\boldsymbol{S_N^2 = \frac{\sum_{i=1}^{n_N}(X_i - \bar{X}_{iN})^2}{n_N};\ S_N^2 \in [S_L^2, S_U^2]} \tag{4}$$

The neutrosophic value (NCV) measures the consistency of the variable. The lower the NCV value, the more consistent the performance of the item compared to that of the other items. The NCV can be calculated as follows [16, 17, 18] .

$$\boldsymbol{CV_N = \frac{\sqrt{S_N^2}}{\bar{X}_N} \times 100;\ CV_N \in [CV_L, CV_U]} \tag{5}$$

3 results

To apply the PESTEL method to the case study and determine the negative elements of legal and economic challenges in the modern space, it is necessary to examine the following aspects:

1. Policy: Government regulations and policies related to space missions, both nationally and internationally, must be taken into account. This may include intellectual property laws, safety regulations, and collaboration protocols between different countries.
2. Economic: The costs associated with the development and operation of commercial space procedures, as well as the potential financial risks, must be analyzed.

3. Social: Society's perceptions and attitudes towards space tasks should be examined, as well as the potential social impacts of these tasks, such as unequal distribution of benefits and exclusion of certain population groups.
4. Technological: The current state and future development of space technology should be assessed, as well as possible technological advances that could influence commercial space procedures. The risks associated with dependence on technology in space should also be considered.
5. Ecological: The potential environmental impacts of space missions, such as the generation of space debris and pollution of outer space, should be analyzed. Environmental mitigation measures and sustainability protocols in space should also be considered.
6. Legal aspects: Existing legal standards and potential gaps in legislation relating to commercial space due diligence should be examined. This may include issues of civil liability, ownership of space resources and international jurisdiction in space.

By applying the PESTEL method to this case study, negative elements related to each of these aspects can be identified, which will provide a more complete understanding of the legal and economic challenges in the modern space.

Table 1: Evaluation of matrices and variables.

Dimension	Element	Possible solutions
Political.	Political foundations	• **Challenge:** Disparity in spatial regulations between different countries. • **Solution:** Promote international cooperation to establish uniform regulations and legal agreements governing space procedures at a global level.
Economic	Improve economic elements.	• **Challenge:** High costs associated with the development and launch of satellites and other space missions. • **Solution:** Encourage public and private investment in space exploration and exploitation, as well as promote collaboration between companies and governments to share costs and resources.
Social	Perception of equal rights.	• **Challenge:** Unequal access to space and its benefits, which could increase the gap between developed and developing countries. • **Solution:** Implement inclusive policies that encourage equitable participation of all countries and communities in space efforts, as well as educational programs that promote public awareness and interest in space.

Dimension	Element	Possible solutions
Technological	Electronic development.	• **Challenge:** Risks associated with dependence on space technology and equipment obsolescence. • **Solution:** Continue investing in technological research and development to improve the reliability and efficiency of space systems, as well as diversify sources of technology to reduce dependence on a single supplier.
Legal	Rights of those involved.	• **Challenge:** Gaps in international law to address issues such as ownership of space resources and liability for damage caused by spacecraft. • **Solution:** Promote the creation and adoption of international treaties and agreements that address these issues, as well as strengthen cooperation between countries and international organizations to enforce existing laws and develop new regulations when necessary.

3. Development of the method

In the neutrosophic statistical modeling process, experts select five variables known as PESTEL Dimensions, which are significant within the neutrosophic sets. These results are disseminated to a team of specialists for evaluation and identification of primary trends.

One of the variables analyzed is the incidence of spatial challenges. This variable is examined for a sample size of n=60, and each element (f) is analyzed individually. It is important to note that the ecological aspect is not applicable to the variable analyzed, specifically about the evaluation of the elements.

Table 2: Neutrosophic frequencies of each element.

Days	Neutrosophic Frequency.				
	1	**2**	**3**	**4**	**5**
1	[6; 7]	[0; 0]	[2; 2]	[0; 7]	[0; 2]
2	[3; 7]	[3; 7]	[2; 6]	[23]	[0; 7]
3	[0; 3]	[3; 6]	[23]	[0; 3]	[0; 0]
4	[0; 2]	[3; 3]	[0; 3]	[2; 6]	[0; 2]
5	[0; 2]	[0; 0]	[23]	[2; 7]	[0; 3]
6	[23]	[3; 3]	[3; 6]	[0; 2]	[0; 3]
7	[0; 0]	[3; 3]	[3; 7]	[0; 3]	[0; 2]
8	[2; 2]	[2; 2]	[3; 3]	[0;6]	[0; 0]
9	[23]	[3; 6]	[0; 0]	[0; 3]	[0; 0]
10	[3; 6]	[3; 7]	[3; 7]	[0; 0]	[0; 7]
11	[3; 6]	[0; 0]	[0; 2]	[0; 0]	[0; 2]

Days	Neutrosophic Frequency.				
	1	**2**	**3**	**4**	**5**
12	[3; 3]	[2; 6]	[0; 2]	[2; 2]	[0; 2]
13	[0; 2]	[0; 2]	[3; 7]	[0; 3]	[0;6]
14	[0; 3]	[3; 3]	[0; 2]	[0;6]	[0; 3]
15	[6; 7]	[0; 2]	[0; 0]	[0; 0]	[0; 7]
16	[3; 7]	[0; 3]	[0; 0]	[0; 3]	[0; 2]
17	[3; 3]	[0; 2]	[0; 2]	[23]	[0; 7]
18	[3; 7]	[3; 3]	[0; 0]	[0; 3]	[0; 2]
19	[0; 0]	[2; 2]	[3; 3]	[2; 2]	[0; 0]
20	[6; 7]	[0; 3]	[3; 7]	[2; 7]	[0; 7]
0-60	[141; 204]	[122; 201]	[106; 238]	[61; 218]	[25; 193]

Table 2 analyses the elements over a 60-day period, with an incidence range of [0; 7] for each element per day. Total levels of indeterminacy were recorded for elements f_1=62, f_2=80, f_3=132, f_4=157 and f_5=166, with a level of representativeness that falls within the interval [30.24%; 86.46%]. It is noteworthy that on days when 7 incidences were observed per element, a higher incidence of 60% was perceived in the political element. Given the prevailing indeterminacy, conventional statistical methodologies are considered inadequate, so it is necessary to adopt neutrosophic statistics for a more comprehensive understanding.

In the modelling process, the political element is emphasized as one of the main drivers (see Table 3). To determine which element hosts a representative mean, the average quantities are meticulously evaluated, along with the variability of the variable to address uncertainties in the final result. This involves incorporating neutrosophic standard deviation quantities for each element. Furthermore, discerning which element requires further attention in the process is facilitated by the values provided by the coefficient of variation.

Table 3: Neutrosophic statistics of the causes of bullying.

Items	$\bar{x}_N$	**SN**	**CVN**
Political	[2.382; 3.427]	[2,848 ; 3,248]	[0.776; 0.822]
Economic	[2.032; 3.367]	[2.202; 2.573]	[0.582; 0.764]
Social	[2.74; 3.85]	[0.877; 2.68]	[0.502; 0.678]
Technological	[2,036; 3,67]	[0.428; 2.642]	[0.424; 0.724]
Legal	[0.434; 3.2]	[0.227; 2.622]	[0.283; 0.828]

Table 4: Undefined values.

Items	$\bar{x}_N$	**SN**	**CVN**
1	$2{,}382 + 3{,}427I; I \in [0; 20.1]$	$2{,}848 + 3{,}248I; I \in [0; 41.3]$	$0.776 + 0.822I; I \in [0; 15.8]$
2	$2.032 + 3.367I, I \in [0; 38.6]$	$2{,}202 + 2{,}573I; I \in [0; 53.3]$	$0.582 + 0.764I; I \in [0; 22.6]$
3	$2.74 + 3.85I; I \in [0; 55.7]$	$0.877 + 2.68I; I \in [0; 7.3]$	$0.502 + 0.678I; I \in [0; 26.1]$

Items	$\bar{x}_N$	SN	CVN
4	$2.036 + 3.67I; I \in [0; 71.7]$	$0.428 + 2.642I; I \in [0; 83.8]$	$0.414 + 0.724I; I \in [0; 42.8]$
5	$0.434 + 3.2I; I \in [0; 86.5]$	$0.227 + 2.622\ I; I \in [0; 85.2]$	$0.283 + 0.828I; I \in [0; 64.2]$

4. Preliminary solutions.

Based on the results obtained and considering the interrelation of the political element with the other aspects involved, the following recommendations are proposed:

1. Establishment of negotiation and arbitration mechanisms to resolve disputes over the ownership and use of space resources.
2. Facilitate access to specialized financing and insurance for space projects, as well as promote the diversification of commercial applications in space to reduce dependence on specific fragments.
3. Implementation of training and technology transfer programs to promote the participation of developing countries in space projects.
4. Invest in research and development of innovative technologies, such as in-situ manufacturing and space mining, and foster international cooperation in space technology exploration and development projects.
5. Establish international standards for managing space debris and protecting the space environment, as well as promoting sustainable practices in the design and operation of satellites and spacecraft.
6. Strengthen international cooperation to develop clear and coherent legal frameworks addressing issues such as liability for damage and ownership of space resources, as well as promote adherence to and compliance with existing treaties and agreements.

5. **Conclusions**

The new phase of space trials poses considerable challenges to governments, as well as to new actors and policy makers in the space field. The current phase of space commercialization requires an adaptation of existing legislation to meet current needs and challenges. Research on space missions in this "new era" has highlighted economic and security challenges, stressing the importance of peaceful cooperation between States.

Since the beginning of this new era, disparities in economic and spatial development have emerged between different countries and societies, leading to different opportunities for access to space. With technological advancement and the arrival of small satellites, access to space has become more accessible and economical, benefiting smaller countries, private entities, scientific institutions and even students.

However, the new space era faces the challenge of resolving various conflicts of interest to ensure the safety of space efforts undertaken by States, while at the same time protecting the space environment from the growing accumulation of space debris. It is crucial to support free and undistorted competition, based on democratic principles, by implementing new national space programs, strategies and regulations to make space accessible to all. In this regard, international cooperation is essential, including between States with different regimes. While this cooperation can be challenging, it is essential to avoid conflicts at a global level. Collaboration between all nations is vital for the sustainability of space efforts in this new Space era.

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