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Análisis y Determinación de las Principales Causas de las Infecciones y Enfermedades Periodontales mediante Mapas Cognitivos Neutrosóficos (NCM).

Analysis and Determination of the Main Causes of Periodontal Infections and Diseases Using Neutrosophic Cognitive Maps (NCM).

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Resumen. El presente estudio se centra en el análisis y determinación de las principales causas de infecciones y enfermedades periodontales mediante el uso de Mapas Cognitivos Neutrosóficos (NCM), una herramienta innovadora y compleja que permite explorar y comprender las interacciones entre diversos factores. A través de la implementación de NCM, fue posible identificar con precisión la interrelación entre variables como la mala higiene bucal, la predisposición genética, el tabaquismo y la dieta, entre otras. Este enfoque metodológico no sólo facilita la visualización de patrones subyacentes en la etiología de las enfermedades periodontales, sino que también ofrece una plataforma para el desarrollo de estrategias de prevención y tratamiento más eficaces. Los resultados obtenidos revelan que la complejidad de las infecciones periodontales se debe a una confluencia de factores biológicos, ambientales y conductuales, que interactúan de forma dinámica y no lineal. El uso de la NCM nos permitió desentrañar estas complejas interacciones, ofreciendo una perspectiva holística que no podría lograrse mediante los métodos tradicionales. Así pues, este estudio no sólo supone un avance significativo en la comprensión de las enfermedades periodontales, sino que también pone de relieve la importancia de los enfoques interdisciplinarios y novedosos en la investigación odontológica. La adopción de la NCM podría revolucionar la forma de abordar tanto la prevención como el tratamiento de estas afecciones, abriendo nuevas vías para la investigación y la práctica clínica futuras.

Palabras clave: Infecciones , Enfermedades Periodontales, Mapas Cognitivos Neutrosóficos (NCM) , NCM.

Abstract. The present study focuses on the analysis and determination of the main causes of infections and periodontal diseases through the use of Neutrosophic Cognitive Maps (NCM), an innovative and complex tool that allows exploring and understanding the interactions between various factors. Through the implementation of NCM, it was possible to precisely identify the interrelationship between variables such as poor oral hygiene, genetic predisposition, smoking, and diet, among others. This methodological approach not only facilitates the visualization of underlying patterns in the etiology of periodontal diseases, but also offers a platform for the development of more effective prevention and treatment strategies. The results obtained reveal that the complexity of periodontal infections is due to a confluence of biological, environmental and behavioral factors, which interact in a dynamic and non-linear manner. The use of NCM allowed us to unravel these complex interactions, offering a holistic perspective that could not be achieved through traditional methods. Thus, this study not only provides a significant advance in the understanding of periodontal diseases, but also highlights the importance of interdisciplinary and novel approaches in dental research. The adoption of NCM could revolutionize the way both prevention and treatment of these conditions are approached, opening new avenues for future research and clinical practice.

Keywords: Infections, Periodontal Diseases, Neutrosophic Cognitive Maps (NCM), NCM.

1 Introduction

Periodontal infections and diseases represent a significant concern in the field of oral health, affecting a large proportion of the world's population. These conditions not only negatively impact the quality of life of individuals, but are also associated with various systemic complications, underscoring the need for a deep and comprehensive understanding of their causes and underlying mechanisms [1]. Despite advances in dentistry, periodontal disease

incidence rates remain alarmingly high, indicating the persistence of unmitigated risk factors and the potential insufficiency of current preventative strategies. The etiology of periodontal diseases is multifactorial, involving a complex interaction between pathogenic microorganisms, host factors, and environmental factors . Bacterial plaque, a biofilm that continually forms on tooth surfaces, is widely recognized as the main etiological agent of gingivitis and periodontitis. However, not all individuals with plaque buildup develop these diseases, suggesting the influence of additional factors. Individual susceptibility, largely determined by the host's immune response, plays a crucial role in the progression of periodontal disease [2].

Among modifiable risk factors, poor oral hygiene is one of the most critical. The inability to effectively remove bacterial plaque can lead to the formation of dental calculus and subsequent inflammation of the periodontal tissues [3]. Furthermore, smoking has been identified as an important risk factor, exacerbating the severity of periodontal diseases and complicating its treatment. Smoking not only alters the host's immune response, but also modifies the oral microbiota, favoring colonization by periodontal pathogens. Genetic factors also play a significant role in susceptibility to periodontal diseases . Studies have shown that genetic predisposition can influence the inflammatory response and the ability of periodontal tissue to regenerate . Research in periodontal genetics is advancing rapidly, identifying several genetic loci associated with an increased risk of developing these diseases . These findings could eventually lead to more personalized prevention and treatment strategies. In addition to biological factors, social and economic factors also influence the prevalence and severity of periodontal diseases. Limited access to dental care and educational resources can result in poor oral hygiene practices and lack of timely treatment. Socioeconomic disparities in periodontal health are a global problem that requires comprehensive approaches and effective public health policies [4].

Diet is another key factor that contributes to periodontal health. A diet rich in sugars and refined carbohydrates can promote the proliferation of cariogenic and periodontopathogenic bacteria [5]. In contrast, a balanced diet that includes essential nutrients, such as vitamins and minerals, is vital for maintaining the integrity of periodontal tissues and proper immune function. Stress has also been implicated as a risk factor for periodontal disease . Chronic stress can affect the body's immune response, altering the production of cytokines and other inflammatory molecules that play a role in the pathogenesis of periodontal disease. The interrelationship between stress and periodontal health is an emerging area of research that could offer new perspectives for the prevention and management of these conditions. The interconnection between systemic and periodontal diseases has been the subject of numerous studies . Conditions such as diabetes mellitus, cardiovascular diseases and respiratory disorders have shown a bidirectional association with periodontal diseases . These comorbidities not only complicate the clinical management of patients but also highlight the importance of an interdisciplinary approach in healthcare.

Finally, it is essential to recognize that continued research and development in the field of periodontics is essential to address persistent challenges. Emerging technologies, such as approaches based on molecular biology and bioinformatics, are opening new avenues for understanding the pathogenesis of periodontal diseases and identifying new therapeutic targets [6] . Integrating these advances into clinical practice has the potential to transform the management of periodontal diseases and significantly improve health outcomes for patients. Fighting periodontal infections and diseases requires a multifaceted approach that addresses both biological and social and behavioral factors. A deep understanding of the underlying causes and interdisciplinary collaboration are crucial for the development of effective prevention and treatment strategies, which will ultimately contribute to improving the oral and general health of the population.

2 Related work

2.1 Infections and Periodontal Diseases.

Periodontal infections and diseases are one of the main oral health concerns worldwide, affecting millions of people without distinction of age, gender or social status. Despite advances in dentistry and the wide availability of oral care products, these conditions continue to present significant challenges for healthcare professionals and patients alike. What makes these diseases so prevalent and difficult to eradicate?

First, it is crucial to understand the multifactorial etiology of periodontal diseases. These are not caused by a single pathogenic agent, but by a complex interaction of microorganisms, host factors and environmental elements. Bacterial plaque is the main contributor, but it does not act alone. The host inflammatory response plays a crucial role in disease progression, and not everyone responds in the same way to the presence of periodontal bacteria. This is where genetics and immunological factors come into play, further complicating the picture [7]. In addition to genetics, lifestyle habits play a fundamental role. Smoking, for example, is a known risk factor for the development of periodontal diseases. Smokers not only have a greater predisposition to these diseases, but also respond worse to periodontal treatment. Nicotine and other chemicals in tobacco negatively affect the oral microbiota and the healing capacity of tissues, creating a vicious cycle that is difficult to break.

Poor oral hygiene is another key factor. Many people underestimate the importance of regular brushing and flossing, leading to a buildup of plaque bacteria that eventually turns into tartar. Once tartar forms, it can only be removed professionally, and its presence perpetuates inflammation and periodontal damage [8]. It's amazing how something as simple as daily hygiene can have such a profound impact on periodontal health. Another aspect to consider is the influence of diet on periodontal health. Diets high in sugars and refined carbohydrates not only promote dental cavities, but also periodontal diseases by feeding pathogenic bacteria. On the other hand, a diet rich in fruits, vegetables and other anti-inflammatory foods can help maintain healthy periodontal tissues. However, changing ingrained eating habits is not an easy task and requires continued education and conscious effort.

Access to dental care is a socioeconomic factor that cannot be ignored. In many parts of the world, dental care remains an unaffordable luxury for much of the population. Disparities in access to oral health services result in late diagnoses and insufficient treatments, perpetuating the cycle of disease. This problem requires a political and social response to ensure that preventive and curative dental care is available to everyone [9]. Stress, a ubiquitous condition in modern society, has also been linked to periodontal disease. Chronic stress can alter the body's immune response, exacerbating inflammation and making it difficult for periodontal tissues to heal. The relationship between stress and periodontal health highlights the need for a holistic approach in the treatment of these diseases, considering both physical and psychological aspects. Systemic diseases, such as diabetes and cardiovascular diseases, are also closely related to periodontal health. Chronic inflammation of the gums can negatively influence blood glucose control in diabetics, while periodontitis has been associated with an increased risk of heart disease. These interconnections reinforce the importance of treating periodontal disease not only for oral health, but also for the patient's overall well-being.

In terms of treatment, although there are multiple effective approaches, from professional teeth cleaning to periodontal surgery, prevention remains the most effective strategy. This requires continued education on the importance of oral hygiene and control of risk factors such as smoking and diet. Public health programs should focus on prevention from an early age to instill healthy habits that last a lifetime. Finally, research and development in the field of periodontics is constantly evolving. New technologies and approaches, such as therapy based on immune system modulation and the use of oral probiotics, are emerging as potential solutions to improve the treatment and prevention of periodontal diseases. Integrating these advances into clinical practice is essential to advance the management of these diseases and improve patient outcomes [10].

Periodontal infections and diseases are a complex challenge that requires a multidimensional approach. From biology and genetics to lifestyle and socioeconomic factors, every aspect must be considered to develop effective prevention and treatment strategies. Interdisciplinary collaboration and continued research are crucial to address this challenge and improve the oral and general health of the population.

a. Neutrosophic cognitive maps.

Neutrosophic Cognitive Maps (NCM) represent an advanced and sophisticated tool used to model and analyze complex and ambiguous systems where uncertainty, imprecision and inconsistency are prevalent. Developed from the foundations of Neutrosophic logic, these maps allow a more flexible and realistic representation of the relationships between variables in contexts where traditional methods may be insufficient. Next, an analysis and assessment is presented in ten paragraphs on the applicability and usefulness of NCM in various fields [11]. First of all, NCMs are distinguished by their ability to handle three types of information: true, false and indeterminate. This triple assessment allows for greater precision in the representation of reality, especially in systems where uncertainty and ambiguity are intrinsic. For example, in the field of medicine, NCMs can be used to model the relationship between symptoms, diagnoses and treatments, considering the variability and subjectivity of clinical data. Furthermore, NCMs are particularly useful in multi-criteria decision making. In situations where multiple factors must be considered and weighted, NCMs provide a clear and coherent structure for evaluating the interactions and dependencies between these factors. This is crucial in areas such as strategic planning and project management, where decisions must be informed and balanced [12].

Another notable aspect of NCM is its applicability in risk analysis. By allowing the integration of imprecise and conflicting data, NCMs facilitate the identification and assessment of potential risks in various scenarios. In the business field, for example, NCMs can help anticipate and mitigate financial, operational and market risks, contributing to more robust and resilient management. The ability of NCMs to model complex systems is also invaluable in the engineering field. In infrastructure and technological development projects, NCMs can be used to simulate and analyze the behavior of interconnected systems, considering both technical variables and human and environmental factors. This allows for more integrated and sustainable planning. In the field of social sciences, NCMs offer a powerful tool for studying complex phenomena such as group dynamics, organizational behavior, and processes of social change. By enabling the representation of qualitative and quantitative relationships, NCMs

facilitate a deeper and more nuanced understanding of social phenomena, which can inform more effective policies and intervention strategies [13].

Education can also benefit from NCMs, especially in the design and evaluation of educational programs. By modeling the relationships between learning objectives, teaching methods, and student outcomes, NCMs can help identify areas of improvement and optimize the educational process. This is especially relevant in diverse and changing educational contexts, where flexibility and adaptability are key. In the field of artificial intelligence and robotics, NCMs provide a framework for developing more intelligent and adaptive systems. By incorporating neutrosophic logic, these systems can better handle uncertainty and variability in the environment, improving their ability to make decisions and perform complex tasks [14]. This has applications in fields such as industrial automation, service robotics and space exploration. Environmental sustainability is another area where NCMs can have a significant impact. By modeling interactions between environmental, economic and social factors, NCMs can help develop more integrated and effective strategies for natural resource management and climate change mitigation. This is crucial to addressing global sustainability and development challenges.

Scientific research can also benefit from NCMs, especially in interdisciplinary areas where the integration of knowledge and data is essential. NCMs facilitate collaboration across disciplines, providing a common tool to represent and analyze complex systems from multiple perspectives. This can accelerate the advancement of knowledge and innovation. In conclusion, Neutrosophic Cognitive Maps represent an innovative and versatile tool for analysis and decision making in complex systems. Their ability to handle uncertainty and ambiguity, together with their applicability in a wide range of fields, makes them a valuable addition to traditional methodologies. The adoption and continued development of NCMs can significantly contribute to improving the understanding and management of complex challenges in modern society.

In this study, neutrosophic cognitive maps will be used, so we explain them below.

Definition 1: Let X be a universe of discourse. A Neutrosophic Set (NS) is characterized by three membership functions, $u_A(x)$, $r_A(x)$, $v_A(x) : X \rightarrow]-0,1+[$, which satisfy the condition $-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3+$ for all $x \in$ $u_A(x)$, $r_A(x)$ and $v_A(x)$ are the true, indeterminate and falsity membership functions of x in A, respectively, and their images are standard or non-standard subsets of]-0 ,1 + [. [fifteen]

Definition 2: Let X be a universe of discourse. A single-valued neutrosophic set (SVNS) A on X is a set of the form [16] :

$$A = \{ \langle x, u_A(x), r_A(x), v_A(x) \rangle : x \in X\} \quad (1)$$

Where $u_A, r_A, v_A : \in u_A(x)$, $r_A(x)$ and $v_A(x)$ are the true, indeterminate and falsity membership functions of x in A, respectively. For convenience, a single-valued neutrosophic number (SVNN) will be expressed as A = (a, b, c), where a, b, c $\in [0,1]$ and satisfies $0 \leq a + b + c \leq 3$.

Other important definitions are related to graphs.

Definition 3 : A *neutrosophic graph* contains at least one indeterminate edge , represented by dotted lines [17] .

Definition 4 : A *neutrosophic directed graph* is a directed graph that contains at least one indeterminate edge, which is represented by dotted lines [18] .

Definition 5: A *neutrosophic cognitive map (NCM) is a* neutrosophic directed graph , whose nodes represent concepts and whose edges represent causal relationships between the edges [19,28] .

If there are k vertices $C_1, C_2, \ldots, C_k$, each can be represented by a vector $(x_1, x_2, \ldots, x_k)$ where xi ∈ {0,1, I} depending on the state of the vertex C_i at a specific time or situation:

- $x_i = 0$: Vertex C_i is in an activated state.
- $x_i = 1$: Vertex C_i is in disabled state.
- $x_i = I$: The state of vertex C_i is indeterminate.

Definition 6 : An NCM that has edges with weights in {−1, 0, 1, I} is called *a simple neutrosophic cognitive map* [20] .

Connections between vertices: A directed edge from C_m to C_n is called a connection and represents causality from C_m to C_n .

Associate weights to each vertex: Each vertex in the NCM is associated with a weight within the set { 0 , 1, -1, I}. The edge weight $C_m C_n$, denoted as α_{mn}, indicates the influence of C_m on C_n and can be:

$-\alpha_{mn} = 0$: Cm has no effect on C_n .

$-\alpha_{mn} = 1$: An increase (decrease) of C_m results in an increase (decrease) of C_n .

$-\alpha_{mn} = -1$: An increase (decrease) of C_m results in a decrease (increase) of C_n .

$-\alpha_{mn} = I$: The effect of C_m on C_n is indeterminate.

Definition 7: If $C_1, C_2, \ldots, C_k$ are the vertices of an NCM. The neutrosophic matrix N(E) is defined as $N(E) = \alpha_{mn}$), where α_{mn} denotes the weight of the directed edge $C_m C_n$, with $\alpha_{mn} \in [-1,0,1, I]$. N(E) is called *the neutrosophic adjacency matrix* of the NCM.

Definition 8: Let $C_1, C_2, \ldots, C_k$ be the vertices of an NCM. Let $A = (a_1, a_2, \ldots, a_k)$, where am ∈ {-1, 0, 1, I}. A is called *the neutrosophic instantaneous state vector* and means an on-off-indeterminate state position of the vertex at a given instant.

- $a_m = 0$ if C_m is disabled (has no effect),
- $a_m = 1$ if C_m is activated (takes effect),
- $a_m = I$ if C_m is indeterminate (its effect cannot be determined).

Definition 9: Let $C_1, C_2, \ldots, C_k$ be the vertices of an NCM. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \overrightarrow{C_3C_4}, \ldots, \overrightarrow{C_mC_n}$ the edges be the NCM, then the edges constitute a *directed cycle* .

- The NCM is said to be *cyclical* if it has a directed cycle. It is said to be *acyclic* if it does not have any directed cycle.

Definition 10: An NCM containing loops is said to have *feedback* . When there is feedback in the NCM it is said to be a *dynamic system* .

Definition 11: Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \overrightarrow{C_3C_4}, \ldots, \overrightarrow{C_{k-1}C_k}$ be a cycle. when C_m is activated and its causality flows around the edges of the cycle and is then the cause of C_m itself, then the dynamical system is circulating. This is valid for each vertex C_m with m = 1, 2,…, k. The equilibrium state of this dynamic system is called the *hidden pattern* .

Definition 12: If the equilibrium state of a dynamic system is a single state, then it is called a *fixed point* . An example of a fixed point is when a dynamical system begins by being activated by C_1. If the NCM is assumed to be set to C_1 and C_k, meaning that the state remains as (1, 0,…, 0, 1), then this neutrosophic state vector is called a fixed point.

Definition 13: If the NCM establishes a neutrosophic state vector that repeats in the form:

$A_1 \rightarrow A_2 \rightarrow \cdots \rightarrow A_m \rightarrow A_1$LCM *limit cycle* .

3 Results and discussion.

After a study through a survey on the main causes of infections and periodontal diseases among a group of 50 experts, a total of 8 causes could be obtained, which are listed below:

Cause 1: **Bacterial Plaque** : The accumulation of bacterial plaque is the main cause of periodontal diseases. The bacteria in plaque produce toxins that irritate and inflame the gums, which can lead to gingivitis and, if left untreated, periodontitis.

Cause 2: **Poor Oral Hygiene** : The lack of a proper brushing and flossing routine allows plaque to accumulate and harden in the form of tartar, making it difficult to remove and increasing the risk of periodontal diseases.

Cause 3: **Smoking** : Tobacco use is a significant risk factor for periodontal diseases. Smoking affects the body's immune response, reduces blood circulation in the gums and facilitates the colonization of pathogenic bacteria.

Cause 4: **Genetic Factors** : Genetic predisposition can influence a person's susceptibility to periodontal diseases. Some individuals may have a greater tendency to develop these conditions due to their genetic makeup.

Cause 5: **Systemic Diseases** : Conditions such as diabetes mellitus can affect periodontal health. Diabetes, in particular, can increase inflammation and make it harder for the gums to heal, increasing the risk of periodontitis.

Cause 6: **Stress** : Chronic stress can weaken the immune system, hindering the body's ability to fight infections, including periodontal infections. Additionally, stress can lead to less rigorous oral care habits.

Cause 7: **Unhealthy Diet** : A diet rich in sugars and refined carbohydrates can encourage the growth of harmful bacteria in the mouth. Lack of essential nutrients, such as vitamins and minerals, can also weaken periodontal tissues and immune response.

Cause 8: **Neglect in Regular Dental Care** : Lack of regular visits to the dentist for cleanings and exams can allow minor problems to develop into serious conditions. Professional cleanings are essential to remove plaque and tartar that cannot be removed with regular brushing.

The process began by developing an NCM to represent the causal connections between the eight major causes of periodontal infections and diseases. This stage involved defining the interactions between various strategies and visualizing them in a neutrosophic cognitive map, detailed in Figure 1.

Figure 1: Neutrosophic cognitive map of the main causes of infections and periodontal diseases . Source: self made.

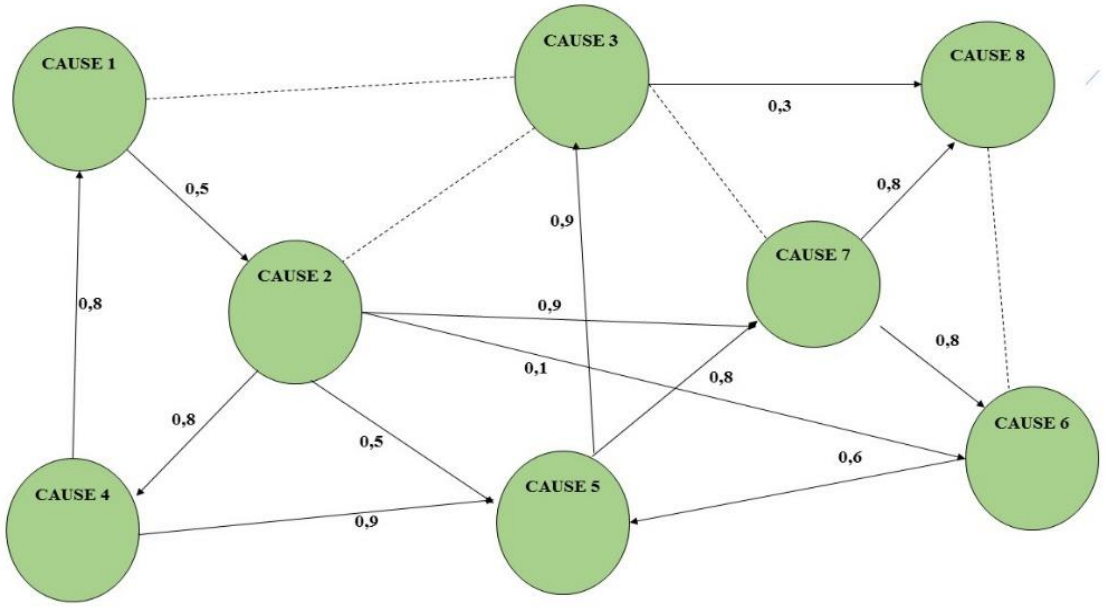
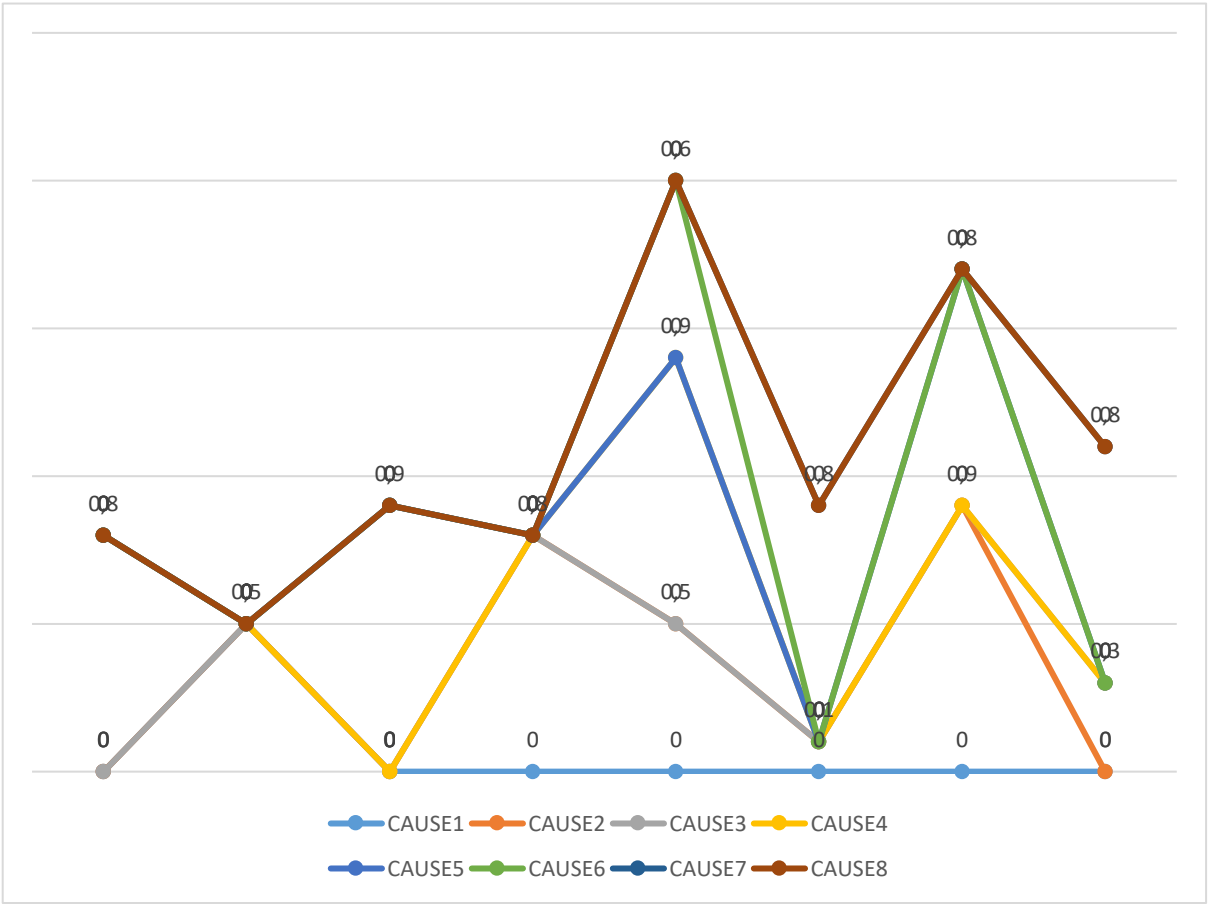


Figure 2: Map of neutrosophic relationships between problems – Source: Own elaboration.



The NCM is developed through the collection and representation of relevant knowledge. The adjacency matrix obtained, which is based on the neutrosophic values provided by the specialists, is detailed in Table 1 as an essential tool to analyze and interpret the causal connections within the framework of the study.

Table 1: Adjacency matrix. Source: self made.

	CAUSE1	**CAUSE 2**	**CAUSE3**	**CAUSE4**	**CAUSE5**	**CAUSE6**	**CAUSE7**	**CAUSE8**
CAUSE1	0	0.5	0	0	0	0	0	0
CAUSE2	0	0	0	0.8	0.5	0.1	0.9	0
CAUSE3	I	I	0	0	0	0	I	0.3
CAUSE 4	0.8	0	0	0	0.9	0	0	0
CAUSE5	0	0	0.9	0	0	0	0.8	00
CAUSE6	0	0	0	0	0.6	0	0	
CAUSE7	0	0	0	0	0	0.8	0	0.8
CAUSE8	0	0	0	0	0	I	0	0

Following this perspective, the calculated centrality measures are presented below (Table 2). These metrics provide a quantitative analysis of the relative relevance of nodes within the network framework, which is crucial to understanding the dynamics and impact of the various components in the analyzed system.

Table 2: Centrality analysis Source: Own elaboration.

Node	***od(vi)***	***identification(vi)***	***td(vi)***
CAUSE1	0.5	0.8+I	1.3+I
CAUSE2	23	0.5+I	2.8+I
CAUSE3	0.3+3I	0.9	1.2+3I
CAUSE4	1.7	0.8	2.5
CAUSE5	1.7	2	3.7
CAUSE6	0.6	0.9+I	1.5+I
CAUSE7	1.6	1.7+I	3,3+I
CAUSE8	0+I	1.1	1.1+I

In the context of static analysis in the NCM, initial results are obtained that incorporate the element of indeterminacy "I" within its neutrosophic values. To refine these results, it is essential to carry out a process known as deneutrosification, recommended by [23]. This process consists of replacing the indeterminacy parameter I, which ranges between 0 and 1, considering in this case "I" as 0.5. The importance of this method lies in its ability to produce more defined and precise results, which significantly simplifies the understanding of the interconnections present in the analysis in question (Table 3).

Table 3: Neutrosified centrality. Source: self-made.

nod	*td(vi)*
CAUSE1	1.8
CAUSE2	3.3
CAUSE3	2.7
CAUSE4	2.5
CAUSE5	3.7
CAUSE6	2.0
CAUSE7	3.8
CAUSE8	1.6

Figure 3: Deneutrosified centrality Source: own elaboration.

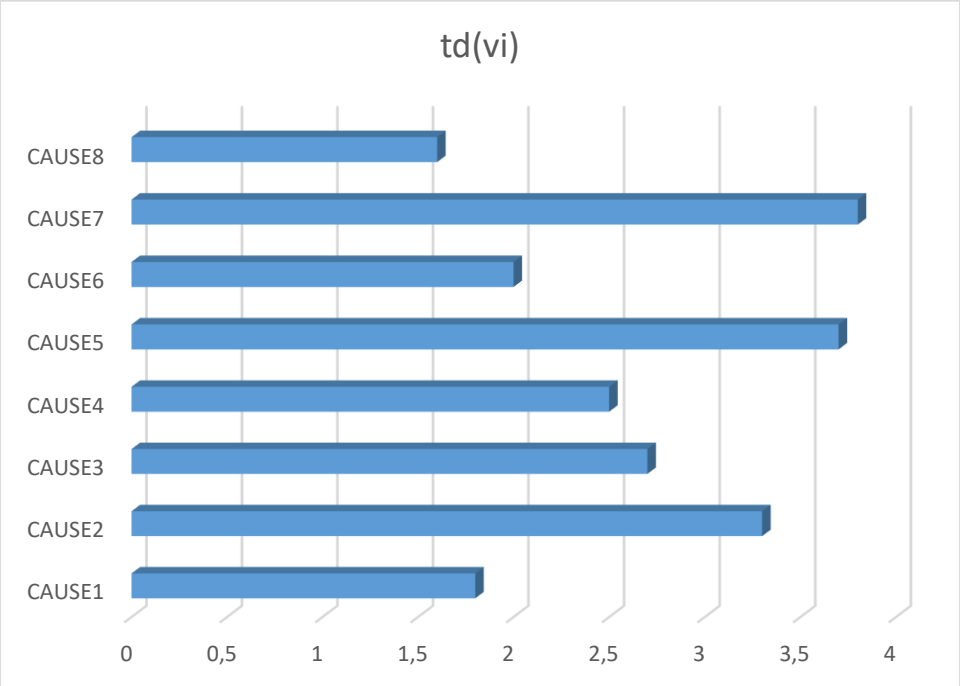


Table 4: Deneutrosified centrality ordered from highest to lowest. Source: self made.

Causes	Deseutrosophized Centrality
Unhealthy Diet : A diet rich in sugars and refined carbohydrates can encourage the growth of harmful bacteria in the mouth. Lack of essential nutrients, such as vitamins and minerals, can also weaken periodontal tissues and immune response.	**3.8**
Systemic Diseases : Conditions such as diabetes mellitus can affect periodontal health. Diabetes, in particular, can increase inflammation and make it harder for the gums to heal, increasing the risk of periodontitis.	**3.7**
Poor Oral Hygiene : The lack of a proper brushing and flossing routine allows plaque to accumulate and harden into tartar, making it difficult to remove and increasing the risk of periodontal disease.	**3.3**
Smoking : Tobacco use is a significant risk factor for periodontal diseases. Smoking affects the body's immune response, reduces blood circulation in the gums and facilitates the colonization of pathogenic bacteria.	**2.7**
Genetic Factors : Genetic predisposition can influence a person's susceptibility to periodontal diseases. Some individuals may have a greater tendency to develop these conditions due to their genetic makeup.	**2.5**
Stress : Chronic stress can weaken the immune system, hindering the body's ability to fight infections, including periodontal infections. Additionally, stress can lead to less rigorous oral care habits.	**2**
Bacterial Plaque : The accumulation of bacterial plaque is the main cause of periodontal diseases. The bacteria in plaque produce toxins that irritate and inflame the gums, which can lead to gingivitis and, if left untreated, periodontitis.	**1.8**
Neglect in Regular Dental Care : Failure to make regular visits to the dentist for cleanings and exams can allow minor problems to become serious conditions. Professional cleanings are essential to remove plaque and tartar that cannot be removed with regular brushing.	**1.6**

The main causes of infections and most determining periodontal diseases according to the study carried out are:

1 **Unhealthy Diet**: A diet rich in sugars and refined carbohydrates can encourage the growth of harmful bacteria in the mouth. Lack of essential nutrients, such as vitamins and minerals, can also weaken periodontal tissues and immune response.

2 **Systemic Diseases**: Conditions such as diabetes mellitus can affect periodontal health. Diabetes, in particular, can increase inflammation and make it harder for the gums to heal, increasing the risk of periodontitis.

3 **Poor Oral Hygiene**: The lack of a proper brushing and flossing routine allows plaque to accumulate and harden into tartar, making it difficult to remove and increasing the risk of periodontal disease.

Periodontal infections and diseases represent a significant challenge in oral health, and understanding their most important causes is crucial for prevention and effective treatment. A recent study has identified several key factors that contribute to the development of these conditions, and three of them are explored in detail below: unhealthy diet, systemic diseases and poor oral hygiene. Firstly, an unhealthy diet plays a critical role in the

development of periodontal diseases. Eating foods high in sugars and refined carbohydrates not only increases the risk of cavities, but also creates a favorable environment for the growth of harmful bacteria in the mouth. These bacteria, by feeding on the sugars present, produce acids that can damage periodontal tissues. Furthermore, a diet lacking essential nutrients, such as vitamins and minerals, weakens the structure of the gums and the body's immune response, leaving the periodontal system vulnerable to infection.

The impact of systemic diseases, such as diabetes mellitus, on periodontal health is another crucial factor that cannot be underestimated. Diabetes, in particular, is known for its ability to increase inflammation in the body and make it difficult for wounds, including the gums, to heal. Diabetic patients have a significantly increased risk of developing periodontitis, an advanced form of periodontal disease, due to their compromised immune response. Additionally, there is a bidirectional relationship between diabetes and periodontal disease, as chronic inflammation in the gums can, in turn, make it difficult to control blood sugar levels, creating a vicious cycle. Poor oral hygiene is, perhaps, the most direct and preventable cause of periodontal diseases. The accumulation of bacterial plaque on the teeth, resulting from inadequate cleaning, is the main precursor to these conditions. If not removed through brushing and flossing, plaque hardens and turns into tartar, which is much more difficult to remove and acts as a reservoir for bacteria. This continued buildup of tartar can lead to inflammation of the gums, known as gingivitis, which if left untreated, can progress to periodontitis. Prevention and treatment of periodontal diseases require a comprehensive approach that addresses all of these factors. In terms of diet, it is essential to promote healthy eating habits that include a variety of essential nutrients to strengthen periodontal tissues and the immune system. Reducing your consumption of sugars and refined carbohydrates is also vital to minimize harmful bacterial growth in your mouth.

For those with systemic diseases such as diabetes, it is crucial to maintain close control of the underlying condition to mitigate its impact on periodontal health. This includes not only managing blood sugar levels, but also adopting healthy lifestyle habits and working closely with dental and medical health professionals to monitor and treat any signs of periodontal disease early. Regarding oral hygiene, educating the population about the importance of a proper cleaning routine is essential. This includes brushing your teeth at least twice a day with a fluoride toothpaste, flossing daily, and making regular visits to the dentist for professional cleanings and checkups. Early detection and removal of plaque and tartar can prevent the progression of gingivitis to periodontitis.

It is evident that the fight against periodontal diseases cannot be based on a single intervention, but must be a combined effort that includes education, prevention and comprehensive treatment. By understanding and addressing the underlying causes, such as an unhealthy diet, systemic diseases and poor oral hygiene, we can make significant progress in reducing the prevalence of these conditions and improving the oral and overall health of the population. Finally, continued research in this field is essential to discover new strategies and treatments that can help combat periodontal diseases more effectively. Advances in medicine and dentistry, along with a proactive focus on prevention and patient education, are key to effectively addressing this public health challenge.

Conclusion.

The conclusions derived from this study highlight the urgent need to adopt a multidimensional approach to combat periodontal infections and diseases. Research has revealed that unhealthy diet, systemic diseases, and poor oral hygiene are driving factors that, if not addressed comprehensively, perpetuate the risk of these conditions. Promoting a balanced diet, rich in essential nutrients, is essential to strengthen periodontal health and the body's immune response, thus mitigating the proliferation of harmful bacteria in the oral cavity. It is crucial that dietary interventions not only focus on reducing the consumption of sugars and refined carbohydrates, but also on including foods that provide essential vitamins and minerals. This strategy not only combats the incidence of cavities and periodontal diseases, but also improves the overall health of the individual, creating a solid foundation for long-term prevention. The positive impact of a healthy diet on periodontal health should be a fundamental pillar in health education campaigns. The bidirectional relationship between systemic diseases, such as diabetes mellitus, and periodontal health underscores the importance of comprehensive patient health management. Diabetes, by increasing inflammation and making healing more difficult, exacerbates the risk of periodontitis. Therefore, it is essential that health professionals collaborate closely to monitor and manage both aspects of health simultaneously. Coordination between dentists and doctors can break the vicious cycle that aggravates both diabetes and periodontal diseases.

A fundamental aspect of prevention lies in education about oral hygiene. The accumulation of bacterial plaque and its subsequent hardening in the form of tartar represent the first steps towards gingivitis and periodontitis. It is imperative that public health strategies focus on instilling proper oral hygiene habits from an early age, including regular brushing, flossing, and regular visits to the dentist. Continuing education and accessibility to dental hygiene products are crucial to maintaining a healthy mouth. The fight against periodontal diseases cannot be effective without a combination of education, prevention and comprehensive treatment. Implementation of health programs that address diet, hygiene, and systemic disease control is necessary to significantly reduce the prevalence of these conditions. Furthermore, it is essential to promote sustained behavioral change in the population, supported by

health policies that facilitate access to the resources and knowledge necessary for good oral health. Continued research is another vital component in this battle. The development of new strategies and treatments can revolutionize the way we approach periodontal diseases. Innovation in dental technology and medical knowledge must be supported by investments in research and development, ensuring that we are always one step ahead in the prevention and treatment of these diseases. Finally, it is imperative to recognize that periodontal health is a reflection of overall health. Strategies that seek to improve oral health also have benefits that extend beyond the oral cavity, positively impacting the cardiovascular, metabolic and general health of the individual. Adopting a holistic view in healthcare can lead to a significant improvement in people's quality of life, reducing the burden of periodontal and systemic diseases simultaneously. In conclusion, implementing a comprehensive approach that addresses diet, systemic diseases, and oral hygiene is essential to effectively combat periodontal infections and diseases. Through education, prevention and continued research, we can address this public health challenge, improving the oral and general health of the population and, ultimately, raising standards of well-being and quality of life.

References.

[1] J. Lindhe, T. Karring, and NP Lang, "Clinical Periodontology and Implant Dentistry," 5th ed. Wiley-Blackwell, 2008.

[2] NB Lang and PM Bartold, "Periodontal Health," Journal of Periodontal Research, vol. 54, no. 5, pp. 378-383, Oct. 2019.

[3] J. Meyle and C. Chapple, "Molecular aspects of the pathogenesis of periodontitis," Periodontology 2000, vol. 69, no. 1, pp. 7-17, Jun. 2015.

[4] R. Genco and WS Borgnakke, "Risk factors for periodontal disease," Periodontology 2000, vol. 62, no. 1, pp. 59-94, Oct. 2013.

[5] I. Van Dyke and JD Kornman, "Host responses in periodontal disease: Current concepts," Journal of Periodontology, vol. 89, no. S1, pp. S63-S71, Jun. 2019.

[6] KS Kornman, JL Giovannoli, and PM Holtfreter, "Microbial and host response factors in periodontal diseases," Journal of Periodontal Research, vol. 43, no. 3, pp. 282-287, May 2008.

[7] M. Preshaw, I. Bissett, "Periodontitis and diabetes," British Dental Journal, vol. 227, pp. 577-584, Oct. 2019.

[8] PN Papapanou, "Epidemiology of periodontal diseases: An update," Journal of the International Academy of Periodontology, vol. 14, no. 3, pp. 37-42, Mar. 2012.

[9] RJ Lamont, H.F. Koo, and G. Hajishengallis, "The oral microbiota: dynamic communities and host interactions," Nature Reviews Microbiology, vol. 16, no. 12, pp. 745-759, Dec. 2018.

[10] E. Van Winkelhoff, "Antibiotics in the treatment of periodontitis," Journal of Clinical Periodontology, vol. 38, no. S11, pp. 135-151, Nov. 2011.

[11] F. Smarandache and M. Leyva Vazquez, “Fundamentals of Neutrosophic Logic and Sets and Their Role in Artificial Intelligence (Fundamentals of Neutrosophic Logic and Sets and Their Role in Artificial Intelligence),” *Neutrosophic Comput. Mach. Learn.* , vol. 1, pp. 3-8, 2018, [online]. Available: https://digitalrepository.unm.edu/math_fsp/520/

[12] SR Herrera Meza and S. Tobón, "The school director from the socio-formative approach. Documentary study through conceptual cartography," Revista de Pedagogía, vol. 38, no. 102, pp. 164-194, 2017. [Online]. Available: http://surl.li/mcgfo

[13] M. Hurtado, MP Fierro, CA Duque Romero, DX Puerta Cortés, and L. Cupajita Rodríguez, "Parental competencies to facilitate the development of executive functions in early childhood," Indagare, vol. 10, pp. 105-115, 2022. [Online]. Available: https://doi.org/10.35707/indagare/1011

[14] I. Karamitri, F. Kitsios, and MA Talias, "Development and Validation of a Knowledge Management Questionnaire for Hospitals and Other Healthcare Organizations," Sustainability, vol. 12, no. 7, 2020. [Online]. Available: https://doi.org/10.3390/su12072730

[15] N. Kholis, D. Mardapi, and B. Kartowagiran, "Development and Validation of an Instrument to Measure a Performance of Vocational High School," European Journal of Educational Research, vol. 9, no. 3, pp. 955–966, 2020. [Online]. Available: https://doi.org/10.12973/eujer.9.3.955

[16] L. Z. Lara Moran and I. Álvaro Gaibor González, "Family functionality and its relationship with subjective well-being in high school students: Family Functionality and Its Relationship with Subjective Well-Being in High School Students," LATAM Revista Latinoamericana De Ciencias Sociales Y Humanidades , vol. 4, no. 1, pp. 987–996, 2023. [Online]. Available: https://doi.org/10.56712/latam.v4i1.311

[17] F. López Piza, "Teaching socio-emotional education in primary school from the perspective of socio-

formation," Forhum International Journal of Social Sciences and Humanities, vol. 3) No. 4, pp. 149–161, 2021. [Online]. Available: https://doi.org/10.35766/j.forhum2021.04.03.12

[18] VM Márquez Allauca, RM Reyes Vargas, ML Merchán Gavilánez, and DDR Valle Gavilanes, "Parental competencies in the socio-affective development in girls and boys from 3 to 5 years old," RECIAMUC, vol. 5, no. 3, pp. 182-195, 2021. [Online]. Available: https://doi.org/10.26820/reciamuc/5.(3).agosto.2021.182-195

[19] J. Maya and MV Hidalgo, "Evaluation of the implementation of the Family Training and Support Program with Peruvian families," Apuntes De Psicología, vol. 34, no. 2-3, pp. 113–118, 2022. [Online]. Available: https://doi.org/10.55414/ap.v34i2-3.603

[20] ML Merchán-Gavilánez, ME Morán-Salcán, and CE Fuentes-Merchán, "Socioeconomic level of the family and protective parental competencies," Prohominum, vol. 4, no. 4, 2022. [Online]. Available: https://doi.org/10.47606/acven/ph0160

[21] F. Smarandache *et al.* , "1 - Introduction to Neutrosophic and Neutrosophic Environment", Y. Guo and ASBT-NS in MIA Ashour, Eds. Academic Press, 2019, pp. 3–29. doi: https://doi.org/10.1016/B978-0-12-818148-5.00001-1

[22] A. Latreche, O. Barkat, S. Milles, and F. Ismail, "Single-valued neutrosophic mappings defined by single-valued neutrosophic relations with applications," *Neutrosophic Sets Syst.* , vol. 1, pp. 203–220, 2020, [online]. Available: https://books.google.es/books?hl=es&lr=&id=LEdCEAAAQBAJ&oi=fnd&pg=PA203&dq#v=onepage&q&f=false

[23] Nabeeh, N. (2023) " **Evaluating and contrasting the sustainable growth of various road transportation systems using a multi-criteria intelligent neutrosophic decision-making model** ", *Sustainable Machine Intelligence Journal* , 2, pp. (2): 1–12. doi:10 . 61185/SMIJ . 2023 . 22102 .

[24] M. Akram and A. Luqman, "Certain network models using single-valued neutrosophic directed hypergraphs," *J. Intell. fuzzy system.* , vol. 33, no. 1, pp. 575–588, 2017, [online]. Available: https://content.iospress.com/articles/journal-of-intelligent-and-fuzzy-systems/ifs162347

[25] M. S. Wajid, H . Terashima-Marin, PN Paul Rad, and MA Wajid, "Violence detection approach based on cloud data and neutrosophic cognitive maps," *J. Cloud Comput.* , vol. 11, no. 1, p. 85, 2022, [online]. Available: https://link.springer.com/article/10.1186/s13677-022-00369-4

[26] AJ Peñafiel Palacios, J. Estupiñán Ricardo, IA Cruz Piza and ME España Herrería, "Phenomenological hermeneutic method and neutrosophic cognitive maps in the causal analysis of transgressions against homeless people", *Conjuntos Neutrosóficos Syst.* , vol. 44, pp. 147-156, 2021, [online]. Available: http://fs.unm.edu/NSS2/index.php/111/article/view/1570

[27] *x* . , vol. 34, no. 1, pp. 48–56, 2020, [online]. Available: https://digitalrepository.unm.edu/nss_journal/vol34/iss1/7/

[28] Ben, N.R., Annam, G.H.S., & Rajapushpam, G.H. (2023). A perspective note on the space of μ _N σ Baire. *Neutrosophic Systems with Applications* , *7* , 54-60. https://doi . org/10 . 61356/j . nswa . 2023 . 29

[29] F. Smarandache and M. Leyva Vázquez, "Mental models and neutrosophic cognitive maps", *Neutrosophic Comput. Mach. Learn.* , vol. 1, pp. 22–30, 2018, [online]. Available: https://digitalrepository.unm.edu/cgi/viewcontent.cgi?article=1681&context=math_fsp

[30] Ricardo, JE, Vázquez, MYL, Palacios, AJP, & Ojeda, YEA ¨Artificial intelligence and intellectual property¨. University and society, vol 13 num S3, pp 362-368, 2021.

[31] Nishtar, Z. and Afzal, J. (2023). BER analysis of the BPSK modulation scheme for multiple combining schemes over a flat fading channel. *Neutrosophic systems with applications* , *8* , 1-12. https://doi . org/10 . 61356/j . nswa . 2023 . 30

[32] Smarandache, F., Quiroz-Martínez, MA, Ricardo, JE, Hernández, NB, & Vázquez, MYL ¨Application of neutrosophic compensations for digital image processing¨. Infinite Study, 2020.

[33] Ricardo, JE, Fernández, AJ, & Vázquez, MY ¨Compensatory fuzzy logic with single-value neutrosophic numbers in the analysis of university strategic management¨. International Journal of Neutrosophic Sciences (IJNS), vol 18 num 4, 2022.

[34] Dey, S., & Ray, G. C. (2023). Properties of Redefined Neutrosophic Composite Relation. *Neutrosophic Systems With Applications* , *7* , 1-12. https://doi . org/10 . 61356/j . nswa . 2023 . 27

[35] Pandiselvi, M., & Jeyaraman, M. (2024). Fixed Point Results in Complex Valued Neutrosophic b-Metric Spaces with Application. *Neutrosophic Systems With Applications* , *17* , 21-33. https://doi . org/10 . 61356/j . nswa . 2024 . 17244

[36] Mohamed, Z., M. Ismail, M. and Abd El-Gawad, A. (2023) " **Sustainable Supplier Selection using Neutrosophic Multi-Criteria Decision Making Methodology** ", *Sustainable Machine Intelligence Journal* , 3, pp. (2):1–9. doi:10 . 61185/SMIJ . 2023 . 33102 .

[37] El-Douh, A. (2023) " **A Neutrosophic Multi-Criteria Model for Evaluating Sustainable Soil Enhancement Methods and their Cost Implications in Construction** ", *Sustainable Machine Intelligence Journal* , 5, pp. (1):1–11. doi:10 . 61185/SMIJ . 2023 . 55101 .

[38] Ranulfo Paiva Barbosa (Sobrinho), & Smarandache, F. (2023). Pura Vida Neutrosophic Algebra. *Neutrosophic Systems With Applications* , *9* , 101-106. https://doi . org/10 . 61356/j . nswa . 2023 . 68

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