



Sustainable Supplier Selection using Neutrosophic Multi-Criteria Decision Making Methodology

Zenat Mohamed¹ , Mahmoud M.Ismail^{2,*} , Amal F.Abd El-Gawad³ 

¹Decision support department, Faculty of Computers and Informatics, Zagazig University, Zagazig 44519, Sharqiyah, Egypt; zenatahmed@fci.zu.edu.eg.

²Decision support department, Faculty of Computers and Informatics, Zagazig University, Zagazig 44519, Sharqiyah, Egypt; mmsabe@zu.edu.eg.

³Faculty of Computers and Informatics, Zagazig University, Zagazig 44519, Sharqiyah, Egypt; amgawad2001@yahoo.com.

*Correspondence: mmsabe@zu.edu.eg.

Abstract: Sustainable supplier selection is an important part of supply chain management since it encourages ethical and eco-friendly procedures. This study examines the most important criteria and factors for judging the sustainability performance of suppliers and presents a thorough overview of sustainable supplier selection. A decision-making framework for sustainable supplier selection is created via a review of relevant research, case studies, and best practices. Key factors for assessing suppliers include environmental performance, social responsibility, and economic viability, all of which are included in the framework. The results stress the need to take into account suppliers' energy efficiency, waste management, and social responsibility initiatives including fair labor practices and community involvement. Other essential considerations for long-term sustainability include economic viability and supply chain resilience. Organizations may improve their environmental impact, reduce supply chain risks, and boost overall performance by using sustainable supplier selection practices. This study used the TOPSIS method to rank sustainable suppliers. The TOPSIS method is employed with the single-valued neutrosophic set to deal with vague information. A case study in a food company is conducted to show the best supplier.

Keywords: Sustainable Supplier, TOPSIS Method, Supply Chain, Neutrosophic Set, Uncertainty

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1. Introduction

The desire to strike a balance between economic, environmental, and social concerns has propelled the notion of sustainability to the forefront of many sectors in recent years. Sustainable supplier selection has evolved as an important part of supply chain management for encouraging ethical and eco-friendly practices. Choosing suppliers that share your commitment to sustainability is good for the environment, your company's image, the safety of your supply chain, and your bottom line [1], [2]. Sustainable supplier selection goes beyond just looking at things like pricing, quality, and delivery dependability to include a company's environmental, social, and economic impact. This research attempts to develop a decision-making framework

that takes sustainability into account throughout the supplier selection process by investigating the many different aspects of sustainable supplier selection [3]–[6].

It's becoming harder and harder for decision-makers (DMs) since, on the one hand, Sustainable supplier selection decision-making groups often include a large number of DMs from a variety of specialized departments, including procurement, manufacturing, quality control, and so on. choice makers (DMs) and stakeholders (stakeholders) may have varying preferences and motives; hence[7], [8], it is important to make the best choice possible by considering and weighing all relevant factors. However, the SSS procedure is acknowledged as an intricate and uncertain multi-criteria decision-making (MCDM) issue that requires consideration of several potential vendors and several criteria by which to judge their performance [9], [10]. Decision makers (DMs) sometimes find it challenging to provide precise numerical values when expressing their views on unclear and inadequate decision information. In addition, traditional approaches to sustainable supplier selection only conducted approximate distance analyses between alternatives, failing to account for DMs' weights in a neutrosophic context [11], [12]. This paper integrated the single-valued neutrosophic with the TOPSIS method to select the best sustainable supplier.

2. Challenges of sustainable supplier Selection

Sustainable supplier selection practices might be difficult to implement for many different reasons. Among the most significant difficulties are:

One of the biggest obstacles is the lack of high-quality data on the sustainability performance of suppliers. It's possible that suppliers don't have standardized reporting systems or don't have the data needed to prove their commitment to sustainability. It may be difficult to compare and assess suppliers when businesses have difficulty gathering reliable and consistent data [13].

Sustainable supplier selection requires well-defined assessment criteria and indicators, but defining and implementing these may be challenging. As a multifaceted concept, sustainability necessitates that businesses identify the criteria and measures that will help them achieve their unique sustainability objectives. It might be difficult to create all-encompassing, uniform frameworks that operate for a wide variety of businesses and supply chain situations [14], [15]. A major obstacle to implementing sustainable business practices is gaining suppliers' buy-in and cooperation. Some vendors may be averse to change or unable to carry out sustainability programs due to a lack of resources or expertise. Investment in supplier connections, assistance, and training in the value and necessity of sustainability are all worthwhile activities for any company. Transparency and Complexity in Supply Chains Modern supply chains often consist of many interconnected parts and span numerous countries. When working with suppliers from various locations with varied norms and standards, it may be difficult to ensure transparency and traceability across the supply chain. Beyond their immediate contacts, organizations may have difficulty obtaining reliable data about the procedures of their suppliers [16], [17]. Economic and Monetary Factors Audits, certifications, and the installation of monitoring systems are all examples of sustainable supplier selection practices that may contribute to the bottom

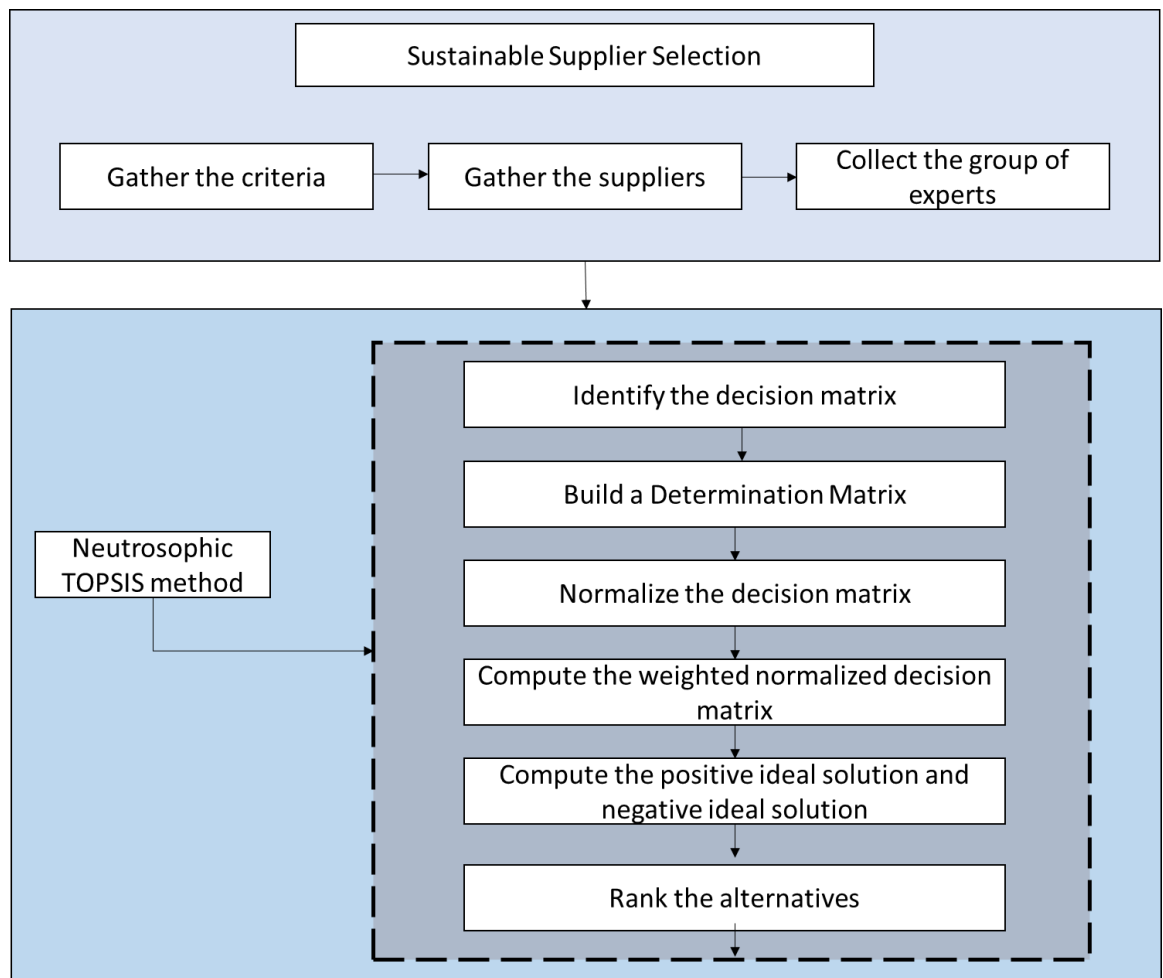


Figure 1. The selection of best sustainable supplier under neutrosophic TOPSIS method

line. It may be difficult for businesses to strike a balance between their sustainability aims and their bottom line when considering the possible rise in expenses connected with sustainable practices [16], [18].

Sustainability performance and more conventional supplier selection factors, such as price, quality, and delivery dependability, may provide trade-offs for businesses. Finding the sweet spot where sustainability factors are given due weight without sacrificing other critical elements of supplier performance may be difficult [19], [20]. Changing an organization's culture and thinking is frequently necessary to implement sustainable supplier selection practices. To achieve sustainability objectives, your organization may need to overcome opposition to change, include stakeholders from throughout the organization, and align various departments or functions. Successful implementation is driven by change management initiatives and clear communication. A proactive and deliberate strategy is needed to deal with these issues. Organizations need to link sustainability goals with broader company objectives, invest in data management systems, interact with suppliers, promote transparency, and more. A more responsible and environmentally aware supply chain will result from companies overcoming these obstacles and adopting sustainable supplier selection practices [15], [21].

3. Neutrosophic TOPSIS Method

TOPSIS is a multi-criteria decision making (MCDM) strategy for assessing and ranking potential solutions. When applied to difficult decision situations, it aids decision-makers in making educated decisions[22], [23]. The TOPSIS technique is a methodical procedure for selecting the best option by evaluating its resemblance to a benchmark solution we integrated the neutrosophic set with the TOPSIS method as shown in Figure 1. If you want to successfully apply the TOPSIS model, you may do so by following these steps:

First, you must identify the decision matrix.

Define the issue precisely and label the options and criteria concerned, as shown in the tree diagram. Alternatives are the many possibilities, and criteria are the standards by which they are judged.

Second, Build a Determination Matrix

Make a decision matrix that summarizes how each possibility fares in terms of each criteria. As can be seen from the limit matrix, the degree of performance of each option was previously computed. The "m" rows represent possible solutions, while the "n" columns represent criteria. Input values that reflect how well each option meets each condition into the appropriate cells of the matrix.

$$X (m_i \times n_j) = \begin{bmatrix} q_{11} & \cdots & q_{1j} \\ \vdots & \ddots & \vdots \\ q_{i1} & \cdots & q_{ij} \end{bmatrix} \quad (1)$$

Third, Normalize the decision matrix.

$$U_{ij} = \frac{q_{ij}}{\sqrt{\sum_{i=1}^m q_{ij}^2}} \quad (2)$$

Fourth, Compute the weighted normalized decision matrix

$$WU_{ij} = U_{ij} \times w_j \quad (3)$$

Fifth, Compute the positive ideal solution and negative ideal solution

$$R_i^+ = \sqrt{\sum_{j=1}^n (WU_{ij} - \max U_j)^2} \quad (4)$$

$$R_i^- = \sqrt{\sum_{j=1}^n (WU_{ij} - \min U_j)^2} \quad (5)$$

Sixth, Compute the relative closeness.

$$RC = \frac{R_i^-}{R_i^- + R_i^+} \quad (6)$$

Seventh, Rank the alternatives. 1

The alternatives are ranked based on *RC* 2

4. Results 3

We collected eleven criteria and eight suppliers in food company to select best supplier. 4
Criteria for selecting sustainable suppliers are crucial for ensuring that all company operations 5
are conducted in an ethical and ecologically responsible manner. The following factors may be 6
used to evaluate a supplier's sustainability performance when making purchasing decisions: 7
Suppliers' performance in this area will speak volumes about their dedication to environmental 8
sustainability and their willingness to take steps to lessen their impact on the environment. 9
Among the most important factors are: 10

- Energy audits, renewable energy sources, and energy-saving technology are all examples 11
of energy efficiency measurements that may be used to evaluate a company's commitment 12
to lowering its energy footprint. 13
- Waste management: assessing how well a supplier cuts down on trash, recycles, and dis- 14
poses of garbage. The environmental impact may be reduced with the support of suppli- 15
ers that have efficient waste management systems. 16
- Emissions Reduction: Judging how well suppliers are doing in terms of reducing their 17
carbon footprint and emissions of greenhouse gases and other air pollutants via activities 18
like monitoring emissions and switching to eco-friendly technology. 19
- Sustainable Materials and Resource Usage: Taking into account suppliers' efforts to min- 20
imize resource consumption and maximize resource efficiency, as well as suppliers' usage 21
of sustainable materials such as recycled or biodegradable materials. 22

Suppliers' commitment to social responsibility may be shown in their support of equitable 23
working conditions, observance of human rights, and promotion of a welcoming and diverse 24
workplace. Among the most important factors are: 25

- Labor Standards: Assessing suppliers' compliance with labor regulations, including 26
fair salaries, acceptable working hours, and safe working conditions. The suppliers 27
you deal with should show that they care about their employees and their safety on 28
the job. 29
- Diversity and Inclusion, assessing how well suppliers encourage and support diver- 30
sity, equality, and inclusion at all levels of the company's operations. Equal pay for 31
equal labor is only one part of making the workplace more equitable and welcoming 32
for people of all backgrounds. 33
- Assessing suppliers' dedication to ethical sourcing practices includes responsible 34
supply chain management, transparency, and the absence of child labor and forced 35
labor in their operations and supply networks (also known as "ethical sourcing"). 36

Suppliers' contributions to the social and economic well-being of the communities in which 37
they operate should be taken into account, as should their support for community development 38
programs and observance of indigenous rights. Suppliers should be able to provide evidence of 39
their continued financial health and long-term viability. Among the most important factors are: 40

Suppliers' financial health, stability, and performance in meeting contractual responsibili- 41
ties are evaluated. a. This guarantees that the quality of products, the dependability of deliveries, 42
and the viability of the supplier's company can be consistently maintained. 43

Suppliers' dedication to innovation, R&D, and ongoing product, process, and sustainabil- 44
ity practice improvement will be evaluated under b. Innovation and Continuous Improvement. 45
Proactive suppliers that care about the environment are more likely to contribute to a company's 46
long-term success. Assessing suppliers' capacity to handle supply chain risks, such as those con- 47
nected with raw material procurement, transportation, and interruptions, is known as supply 48

chain resilience. Maintaining a steady supply of products or services requires suppliers to show resilience and have backup plans in place.

It's worth noting that the sustainability objectives, organizational setting, and industry may all affect the precise criteria for choosing sustainable suppliers. Organizations could modify the criteria to meet their specific needs and think about having conversations with their suppliers to learn more about their sustainability efforts and commitments. A more ecologically and socially responsible business ecosystem may be fostered when organizations use these factors in their supplier selection processes to promote sustainable supply chains. First, we built the decision matrix between criteria and suppliers by the single valued neutrosophic set.

Second, we built the single valued neutrosophic decision matrix by using Eq. (1).
 Third, we obtain the normalized decision matrix by using Eq. (2) as shown in Table 1.

Table 1. The normalized decision matrix

	SPPC ₁	SPPC ₂	SPPC ₃	SPPC ₄	SPPC ₅	SPPC ₆	SPPC ₇	SPPC ₈	SPPC ₉	SPPC ₁₀	SPPC ₁₁
SPPA ₁	0.145844	0.346421	0.361883	0.341018	0.245463	0.412318	0.505982	0.30812	0.270967	0.54273	0.315678
SPPA ₂	0.228036	0.242606	0.361883	0.341018	0.281836	0.204039	0.193881	0.072279	0.173301	0.147892	0.45926
SPPA ₃	0.32506	0.242606	0.362503	0.281193	0.341797	0.219646	0.124	0.309349	0.270967	0.162957	0.282395
SPPA ₄	0.228036	0.346421	0.361883	0.341018	0.281354	0.463857	0.276372	0.30812	0.386256	0.36182	0.458778
SPPA ₅	0.390566	0.420123	0.391673	0.458426	0.499056	0.332359	0.209643	0.215784	0.270967	0.589437	0.515589
SPPA ₆	0.325616	0.38725	0.440177	0.28114	0.341797	0.253797	0.333643	0.30812	0.175504	0.253824	0.21331
SPPA ₇	0.595119	0.262199	0.253181	0.126427	0.373356	0.364246	0.507032	0.500572	0.417832	0.223971	0.220814
SPPA ₈	0.395386	0.497047	0.253869	0.516597	0.398817	0.466266	0.449761	0.563143	0.628584	0.253136	0.197768

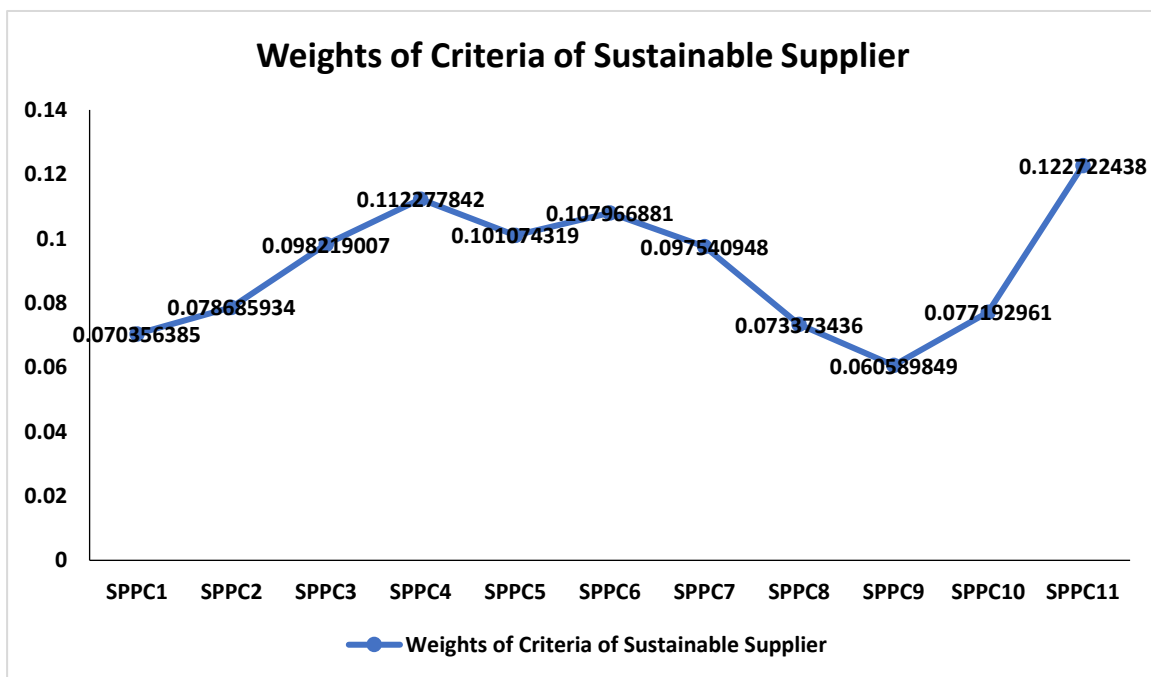


Figure 2. The weights of criteria of sustainable supplier.

Fourth, then compute the weight of criteria shown in Figure 2. Then compute the weighted normalized decision matrix by using Eq. (3) as shown in Table 2.

Table 2. The weighted normalized decision matrix

	SPPC ₁	SPPC ₂	SPPC ₃	SPPC ₄	SPPC ₅	SPPC ₆	SPPC ₇	SPPC ₈	SPPC ₉	SPPC ₁₀	SPPC ₁₁
SPPA ₁	0.010261	0.027258	0.035544	0.038289	0.02481	0.044517	0.049354	0.022608	0.016418	0.041895	0.038741
SPPA ₂	0.016044	0.01909	0.035544	0.038289	0.028486	0.02203	0.018911	0.005303	0.0105	0.011416	0.056362

SPPA ₃	0.02287	0.01909	0.035605	0.031572	0.034547	0.023714	0.012095	0.022698	0.016418	0.012579	0.034656
SPPA ₄	0.016044	0.027258	0.035544	0.038289	0.028438	0.050081	0.026958	0.022608	0.023403	0.02793	0.056302
SPPA ₅	0.027479	0.033058	0.03847	0.051471	0.050442	0.035884	0.020449	0.015833	0.016418	0.0455	0.063274
SPPA ₆	0.022909	0.030471	0.043234	0.031566	0.034547	0.027402	0.032544	0.022608	0.010634	0.019593	0.026178
SPPA ₇	0.04187	0.020631	0.024867	0.014195	0.037737	0.039327	0.049456	0.036729	0.025316	0.017289	0.027099
SPPA ₈	0.027818	0.039111	0.024935	0.058002	0.04031	0.050341	0.04387	0.04132	0.038086	0.01954	0.024271

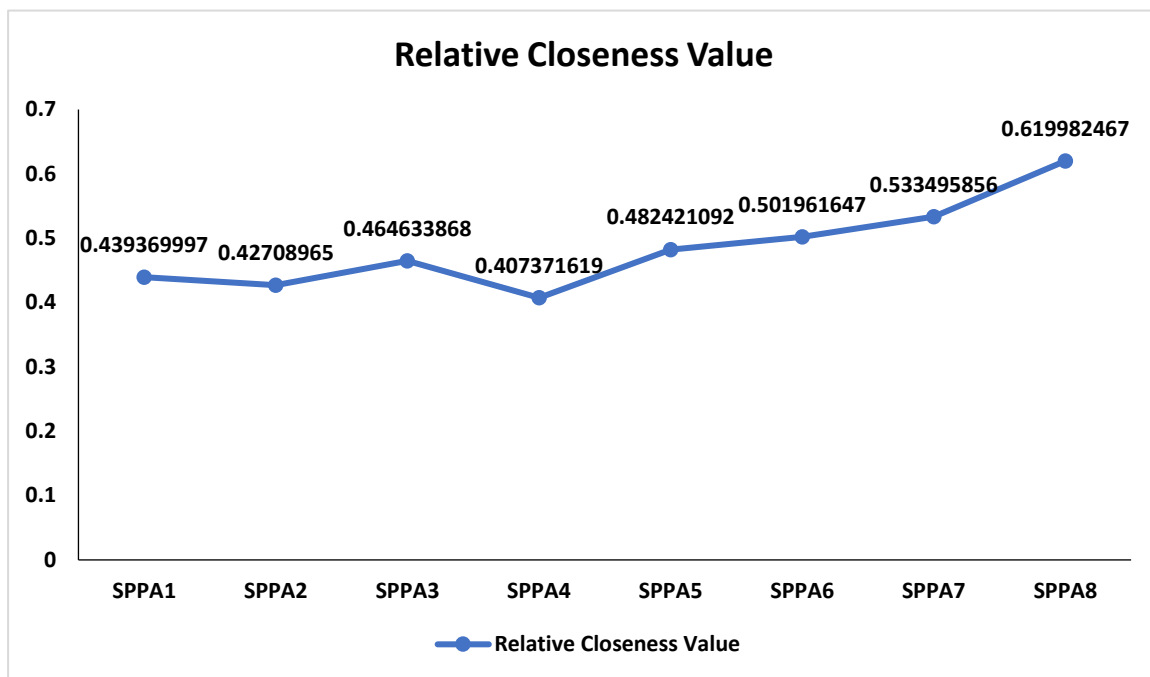


Figure 3. The rank of supplier.

Fifth, then we obtained the positive and negative ideal solution by using Eqs. (4 and 5).

Sixth, then we obtained the relative closeness by using Eq. (6)

Seventh, then we ranked the alternatives based on the largest value of relative closeness as shown in Figure 3. The supplier eight is the best.

5. Conclusions

This study sheds light on the most important factors to take into account when assessing the sustainability performance of suppliers. It is clear from the results that environmental performance, social responsibility, and economic viability are all crucial factors to think about when choosing sustainable suppliers. In conclusion, selecting sustainable suppliers calls for an integrated strategy that takes into account the natural world, the community, and the bottom line. Companies should evaluate their suppliers using a thorough framework that takes into account the above factors. Businesses may reduce supply chain risks, promote long-term sustainability, and support socially and ecologically responsible business practices by choosing suppliers based on their sustainability performance. Organizations can advance their sustainability goals and drive positive environmental and social impacts throughout their supply chains if more study is done into the implementation challenges and strategies for effectively integrating sustainability into supplier selection processes. This study integrated the neutrosophic set with the TOPSIS method to select the best sustainable supplier in the food company. This study used eleven criteria and eight suppliers. The results show the best supplier is number eight.

Supplementary Materials

Not applicable.

Author Contributions

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Data Availability Statement

All data generated or analyzed during this study are included in this article.ss

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