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Information for Authors and Subscribers

*"***Neutrosophic Systems with Applications***"* has been created for publications on advanced studies in neutrosophy, neutrosophic set, neutrosophic logic, neutrosophic probability, neutrosophic statistics that started in 1995 and their applications in any field, such as the neutrosophic structures developed in algebra, geometry, topology, etc.
The submitted papers should be professional, in good English, containing a brief review of a problem and obtained results.
Neutrosophy is a new branch of philosophy that studies the origin, nature, and scope of neutralities, as well as their interactions with different ideational spectra.
This theory considers every notion or idea <A> together with its opposite or negation <antiA> and with their spectrum of neutralities <neutA> in between them (i.e., notions or ideas supporting neither <A> nor <antiA>). The <neutA> and <antiA> ideas together are referred to as <nonA>.
Neutrosophy is a generalization of Hegel's dialectics (the last one is based on <A> and <antiA> only). According to this theory every idea <A> tends to be neutralized and balanced by <antiA> and <nonA> ideas - as a state of equilibrium.
In a classical way <A>, <neutA>, <antiA> are disjointed two by two. But, since in many cases the borders between notions are vague, imprecise, Sorites, it is possible that <A>, <neutA>, <antiA> (and <nonA> of course) have common parts two by two, or even all three of them as well.
Neutrosophic Set and Neutrosophic Logic are generalizations of the fuzzy set and respectively fuzzy logic (especially of intuitionistic fuzzy set and respectively intuitionistic fuzzy logic). In neutrosophic logic a proposition has a degree of truth (T), a degree of indeterminacy (I), and a degree of falsity (F), where T, I, F are standard or non-standard subsets of $]^-0, 1^+[$.
Neutrosophic Probability is a generalization of the classical probability and imprecise probability.
Neutrosophic Statistics is a generalization of classical statistics.
What distinguishes neutrosophic from other fields is the <neutA>, which means neither <A> nor <antiA>.
<neutA>, which of course depends on <A>, can be indeterminacy, neutrality, tie game, unknown, contradiction, ignorance, imprecision, etc.
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An Electric Vehicle Analysis Model for Sustainable Environment in Devoicing Nationals

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Abstract: The usage of fossil fuels is regarded as the generation of energy alternative towards electric vehicles (EVs) in third-world nations for a cleaner transportation sector. The rapid development of EVs is the most effective solution, even if the short-term ecological benefits for third-world nations cannot cover the short-term expenses. Since ecological issues have opened the door for certain developing nations to catch up to the worldwide competition, it is important to weigh other options to bring EVs to the marketplace. Hence, the study proposes a model of neutrosophic set combined with entropy to deal with uncertain cases. The proposed model uses the single-valued neutrosophic to compute the weights of criteria and rank alternatives. A case study with three options, eight criteria, and ten alternatives are proposed to examine the EVs implementation decision-making procedure. The results show that the performance criterion as the best criteria in EVs. Consumers place a high value on the speed, maneuverability, and interior comfort of EVs.

Keywords: Electric vehicles; Sustainability; Entropy; MCDM; Neutrosophic set.

1. Introduction

Electric vehicles' positive effects impact on environment. Many electric vehicle models are recommended for widespread use. The market for electric vehicles is growing and diversifying to meet consumer demand. The rising tide of patents indicates that EVs will dominate the market in the near future. However, policymakers should be concerned about the increasing demand for power that would result from the widespread adoption of EVs. Unfortunately, the upfront costs of EV use might outweigh the immediate advantages in certain situations [1, 2].

The development of EVs technologies vary from one nation to the others depending on various factors, e.g., macroeconomic circumstances and worldwide standing of national industry, that can lead to the failure of the effort to reform the current system. The demands of the stakeholders and the state of the micro and macro economy should inform technical strategy. There may be a roadblock in the social adoption of the latest innovations even if financial and technical circumstances are favorable. However, policy combinations at both the macro and micro levels alleviate some of the issues and ready the current system for the transition [3, 4].

For EVs development, policymakers should encourage even radical shifts in popular culture and consumer habits. Traditions should be considered throughout the planning stages of company-wide and system-level modifications. The literature provides enough evidence of the challenges policymakers face when attempting to deploy EVs, both in terms of the financial sector at large and the spread of new technologies. The proposed study aims to provide light on the decision-making process and draw policy implications for the introduction of EVs in countries where green energy generation is also a priority [5, 6].

For deploying and analyzing EVs strategic choice a variety of scenarios are explored that mimic real-world settings and expose the bottlenecks of the transition difficulties. The study particularly concerned about the impact of EVs on the framework of the power market and the pace of transformation in the use of fossil fuels [7, 8]. The high cost of infrastructure improvements is a major financial barrier in the transportation and energy industries. The financial backing of the stakeholders is necessary, since the effects of change on the automobile sector are more visible. Though costly, incorporating EV technology has far-reaching effects on the financial system.

Regarding the power of the market, the process of change has the greatest immediate impact on consumer appetite for hydrogen and power as the need for fossil fuels for cars declines. Electric vehicles have the potential to lessen transportation's reliance on fossil fuels. If energy generation does not rely on fossil fuels, it is more probable that the installation of EVs will accomplish effective environmental measures in a shorter amount of time. The future of wealthy nations with their investments in green power resources have grown overall [9], [10].

However, the majority of the developing world's power still comes from fossil fuels. For instance, the new EV innovations may provide a chance for developing nations to catch up to the global rivalry in the automobile sector, since hydrogen consumption is predicted to treble by 2040. The question is not whether to deploy EVs, but rather how to execute them for maximum efficiency. Hence, it is crucial to provide decision-makers in developing countries with an awareness of alternative ways to use EVs. Frameworks for decision-making with a fuzzy basis have been effectively applied to many issues [11, 12].

The Reset of the paper is structured as follows: Section 2 shows the use of battery electric vehicles for sake of clean transportation. Section 3 proposed a neutrosophic entropy model that will be used to rank EVs alternatives with respect to certain criteria. Section 4 illustrates a result of numerical case study with optimal ranking of alternatives to aid decision makers. Section 5 concludes the summary and the future work of the current study.

2. Battery Electric Vehicles

Recently, the replacement of combustion cars with cleaner technology is being driven in part by increasing prevalence of ecological legislation, sustainability practices, health concerns, and ecological awareness. Unfortunately, most automobiles today still rely on fossil fuels, that produce harmful emissions. According to Kumar and Alok, greenhouse gas (GHG) emissions such as CO, CH4, N2O, and CO2 from the transportation sector are the primary cause of smog and loss of ozone causes in global warming. Therefore, people have started swapping out their combustion automobiles with cleaner ones that run on renewable energy [13, 14].

Non-renewable-based technology, like combustion-powered automobiles, poses a greater risk of causing warming and climate change. Sustainable development offers hope for future generations in terms of social, ecological, and financial advancement. Environmental preservation and financial and social stability are twin pillars of sustainable development. Environmental sustainability, sustainable transportation offers several potential benefits for the environment, society, and economy. Many wealthy nations have switched to EVs in an effort to combat environmental pollution and promote sustainable development. Hence, electric vehicles have been seen as a practical means of contributing to safer, less polluting petrol emissions [15, 16].

The broad adoption of EVs plays a crucial role in addressing the automobile industry's ecological and financial challenges. However, several studies pointed out that the environmental benefits of clean cars and the EU's zero-emission aim on transport are only possible if power is generated from green sources such solar and wind [17, 18].

EVs are a viable option for traditional vehicles because of improvements that have reduced their limitations, such as high price, limited battery range, and slow peak speed. Battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and plug-in HEVs are the three kinds of EVs on the market. Zero-emission cars, referred to as BEVs, are powered only by electricity from a generator and onboard batteries. Cleaner transportation is provided by BEVs since they don't use fossil fuels. Furthermore, BEVs may be seen as a critical component in the shift to a civilization powered by renewable energy. Environmental worry and expectation that BEVs would mitigate environmental dangers are both positively correlated with BEV adoption, as shown by Chen et al. As a result, increasing the availability of BEVs is probably the best bet for sustainable transportation networks [19, 20].

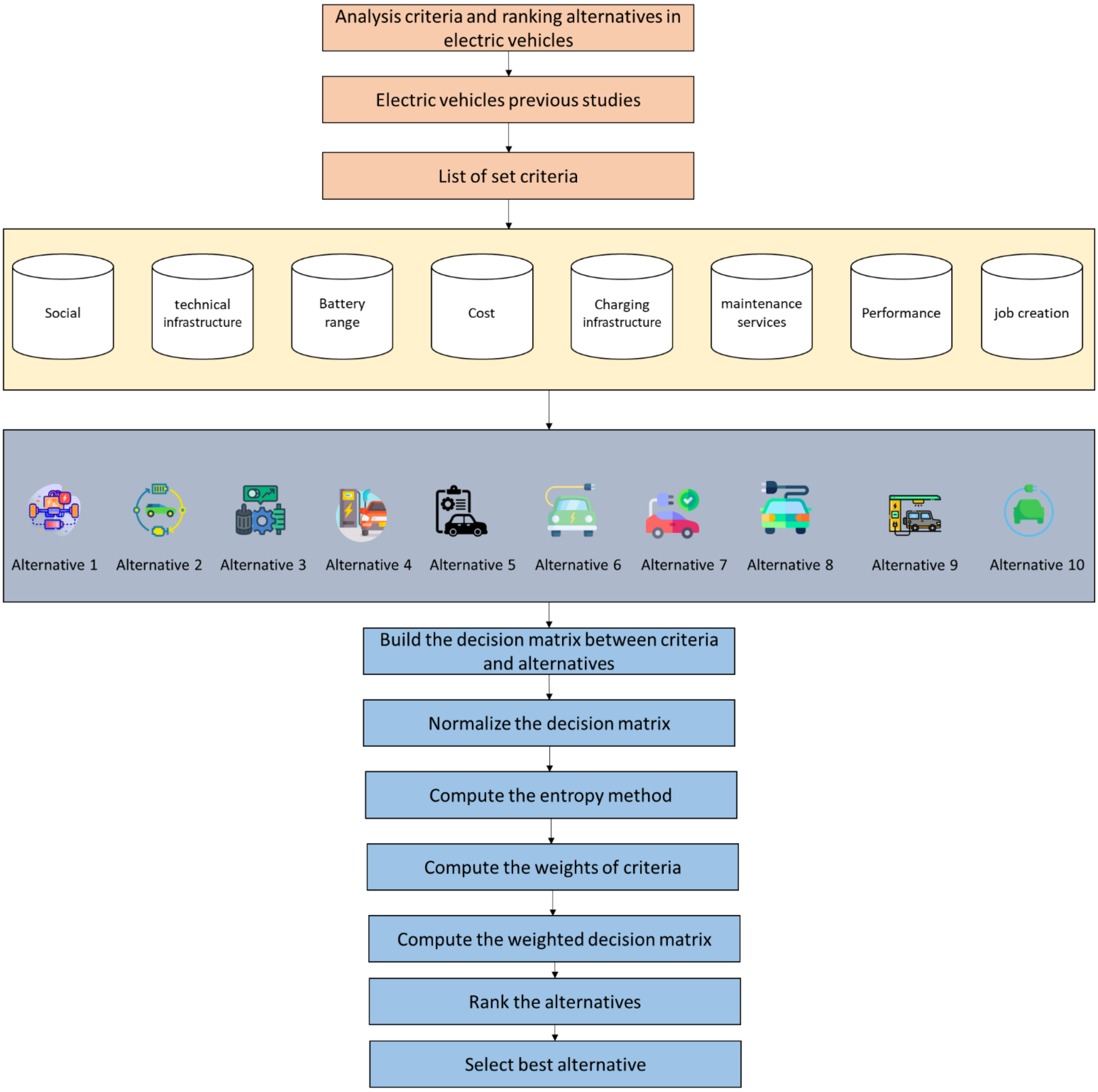

Figure 1. The model of electric vehicles analysis.

3. Neutrosophic Entropy model

The proposed model ranks various alternatives of EVs with respect to certain criteria. The study combined neutrosophic theory with entropy to efficiently handle uncertain cases.

The proposed model highlighted the steps of the single-valued neutrosophic set with the entropy method to compute the weights of criteria and rank the alternatives. The study used the single-valued neutrosophic set [21, 22]. Zadeh's fuzzy set theory has great potential for improving surface modification methods in a wide range of reinforcement settings. Since its inception, however, fuzzy sets have undergone a process of rehabilitation that has resulted in a wide variety of new forms, such as intuitionistic "fuzzy sets," single-valued "neutrosophic" sets, interval-valued "fuzzy sets," and so on [23]–[26]. Figure 1 shows the framework of this study. The steps of the proposed model are mentioned as follows:

Step1: Build the decision matrix between criteria and alternatives.

Step 2: Normalize the decision matrix.

$$E_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \quad (1)$$

Where $i = 1,2, \dots m; j = 1,2,3, \dots . n$

Step 3: Compute the entropy method.

$$n_j = -\frac{\sum_{i=1}^{m} E_{ij} \ln(E_{ij})}{\ln(m)} \quad (2)$$

Step 4: Compute the weights of criteria.

$$w_j = \frac{1-n_j}{\sum_{i=1}^{n}(1-n\_j)} \quad (3)$$

Step 5: Compute the weighted decision matrix.

Step 6: Multiply the weights of criteria by the decision matrix.

Step 7: Rank the alternatives by the highest value of each row.

4. Results of Electric Vehicles

This section introduces the results of the analysis criteria and ranking the alternatives of the proposed neutrosophic entropy model. EVs are gaining popularity as a viable replacement for conventional petrol and diesel cars. The advantages of driving an electric car are 1) cleaner air and less greenhouse gas emissions are the result of electric vehicles' lack of exhaust emissions, 2)electric cars have lower operating expenses than conventional vehicles since they are more fuel-efficient and need fewer repairs, 3)electric vehicles improve national energy security by decreasing reliance on foreign oil, and 4) electric vehicles (EVs) improve the driving experience in a number of ways compared to conventional automobiles.

The proposed method illustrated eight criteria and ten alternatives. The criteria of electric cars are:

How far an electric car can drive on a single charge is mostly determined by its battery, making range an essential requirement. The broad adoption of EVs depends on the accessibility of charging infrastructure. Electric cars are costlier than conventional automobiles, hence their price is a major factor for purchasers. Consumers place a high value on the acceleration, handling, and interior comfort of electric vehicles. Social, technical infrastructure, job creation, and maintenance services. The decision-makers evaluate the criteria and alternatives to build the decision matrix. Then normalize the decision matrix by using Eq. (1) as shown in Table 1. Then compute the value of entropy by using Eq. (2) as shown in Table 2. Then compute the weights of the criteria as shown in Figure 2. Then rank the alternatives by multiplying the weights of criteria by the decision matrix then compute sum of each row as shown in Figure 3. The results show that the performance criteria as the best criteria in EVs. Consumers place a high value on the speed, maneuverability, and interior comfort of EVs, and EVA10 is the best alternative.

Table 1. Normalization input between criteria and alternatives.

	EVC_1	EVC_2	EVC_3	EVC_4	EVC_5	EVC_6	EVC_7	EVC_8
EVA_1	0.048001	0.069544	0.159571	0.088515	0.064011	0.091837	0.067858	0.035945
EVA_2	0.11992	0.069544	0.084966	0.061409	0.211863	0.091837	0.06846	0.113063
EVA_3	0.075052	0.048247	0.084966	0.1789	0.187658	0.188153	0.204033	0.202355
EVA_4	0.048001	0.069544	0.058947	0.093552	0.066508	0.099303	0.073329	0.077985
EVA_5	0.075052	0.054655	0.129407	0.093552	0.096425	0.064709	0.105697	0.077695
EVA_6	0.1139	0.161327	0.084966	0.064527	0.064283	0.097063	0.150669	0.035832
EVA_7	0.079323	0.181493	0.054342	0.063567	0.091233	0.091588	0.105697	0.164957
EVA_8	0.048001	0.069544	0.059154	0.061409	0.063294	0.091837	0.111713	0.078217
EVA_9	0.196884	0.107237	0.084966	0.088515	0.063294	0.091837	0.044685	0.106975
EVA_{10}	0.195867	0.168865	0.198715	0.206055	0.091431	0.091837	0.067858	0.106975

Table 2. Values of entropy in the entropy method

	EVC_1	EVC_2	EVC_3	EVC_4	EVC_5	EVC_6	EVC_7	EVC_8
EVA_1	-0.0633	-0.08051	-0.12719	-0.0932	-0.07641	-0.09523	-0.07929	-0.05192
EVA_2	-0.11046	-0.08051	-0.09098	-0.07441	-0.14278	-0.09523	-0.07973	-0.10703
EVA_3	-0.08441	-0.06352	-0.09098	-0.13371	-0.13636	-0.1365	-0.14084	-0.14041
EVA_4	-0.0633	-0.08051	-0.07248	-0.09626	-0.07829	-0.0996	-0.08321	-0.08641
EVA_5	-0.08441	-0.06899	-0.11492	-0.09626	-0.09795	-0.07694	-0.10315	-0.08621
EVA_6	-0.10746	-0.12782	-0.09098	-0.0768	-0.07662	-0.09832	-0.12385	-0.0518
EVA_7	-0.0873	-0.13451	-0.06873	-0.07608	-0.09487	-0.09508	-0.10315	-0.1291
EVA_8	-0.0633	-0.08051	-0.07264	-0.07441	-0.07587	-0.09523	-0.10634	-0.08656
EVA_9	-0.13896	-0.10398	-0.09098	-0.0932	-0.07587	-0.09523	-0.06032	-0.10384
EVA_{10}	-0.13868	-0.13044	-0.13945	-0.14136	-0.09499	-0.09523	-0.07929	-0.10384

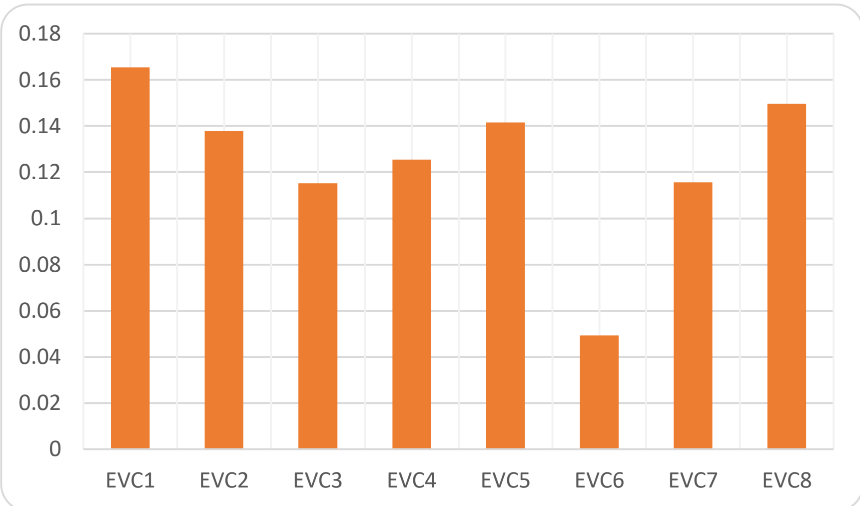

Figure 2. The weights of criteria by the entropy method.

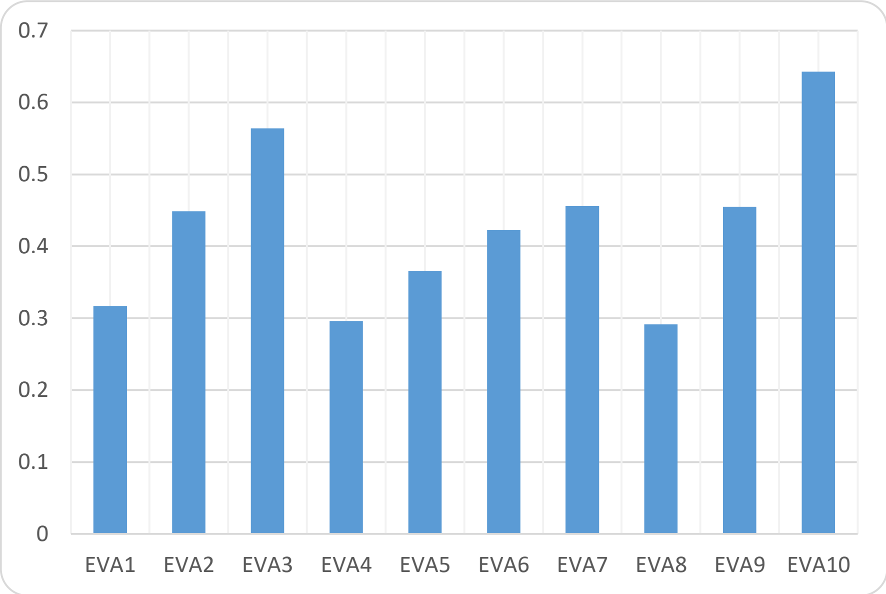

Figure 3. The score value of alternatives.

5. Conclusion

Despite the fact that electric cars have the potential to greatly decrease GHG emissions and enhance air quality, there are still obstacles that must be overcome before their widespread adoption can be achieved. Electric vehicle adoption may be influenced by charging infrastructure, advancements in battery technology, government regulations and incentives. This study analysis criterion and rank the alternatives in EVs. In this research, we investigate the factors that go into deciding whether or not to introduce EVs into a developing nation where fossil fuels are the primary source of energy. Three options are evaluated in a hypothetical situation that is used to examine the decision-making process. Since the immediate environmental costs may outweigh the long-term advantages of EVs, solutions should center on when to introduce them. While the model predicts an increase in the usage of fossil fuels in the short term, it also predicts that the new system will be put into effect more quickly. This research examines the findings and discusses their potential policy consequences. Since the expected long-term benefits are so high, the temporary setbacks are manageable. There is already a lot of work involved in getting things set up, and you'll need to devote a certain amount of resources (both time and money) to the process. Investment in renewable energy generation is important; but, this should not delay the immediate introduction of EVs. This study used the neutrosophic entropy model to compute the weights of criteria then rank the alternatives. The proposed model aid decision makers to achieve suitable alternatives according to certain criteria. A numerical case study illustrated to show the applicability and efficiency for the proposed model.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

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

Ethical approval

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

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Neutrosophic Framework for Assessment Challenges in Smart Sustainable Cities based on IoT to Better Manage Energy Resources and Decrease the Urban Environment's Ecological Impact

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Abstract: Sustainable smart cities based on the Internet of Things (IoT) technology provide promising prospects for improving quality of life. However, in order to facilitate the widespread implementation of IoT-based smart city solutions, there is a need to concern about data privacy and security, standardization, interoperability, scalability, and sustainability. Reducing the environmental effect of urban activities, optimizing the management of energy resources, and designing novel services and solutions for inhabitants are all examples of how the smart city concept is inextricably linked to sustainability. There is a need to assess challenges in smart sustainable cities based on IoT. This paper intended to introduce a new neutrosophic framework for assessment challenges in smart sustainable cities based on IoT for better-managing energy resources and decreasing the urban environment's ecological impact. The proposed framework used nine criteria and five alternatives. Also, the proposed framework applied the neutrosophic Weighted Product Method (WPM) to compute the weights of criteria and rank challenges. Moreover, the proposed framework integrated the single-valued neutrosophic set to deal with uncertain data. The results indicated that the proposed framework can handle uncertain data and give more effective results in assessing challenges in smart sustainable cities based on IoT to better manage energy resources and decrease the urban environment's ecological impact.

Keywords: Internet of Things; Smart Cities; Sustainability; Neutrosophic Weighted Product Method.

1. Introduction

The United Nations (UN) has developed a set of guidelines, known as sustainable development objectives, to help nations improve the living conditions of their populations and make the planet a better place for all forms of life. The most pressing issues facing humanity now were identified using this guide. The difficulties of creating truly sustainable cities are one such issue. Megacities and the people who live in them continue to grow, as do the issues they face, many of which stem from the cities' declining livability. The UN has recommended a wide variety of solutions to these issues, and these proposals are not conditional on the economic, environmental, or social circumstances of the nations. In these circumstances, a prioritization method is required to apply various solution possibilities in any order [1, 2]. The practical implications of these theoretical notions for people's daily lives must be taken into account before they can be put into practice. This is because of the new opportunities presented by the current wave of technological innovation, and specifically because of the rising popularity of devices and organizations that make use of IoT technology [3, 4]. The IoT paradigm is a driving force in the development and application of technology across a wide range of domains and use cases, involving as it does a vast network of interoperable devices that are able to sense their surrounding environment and adjust their actions accordingly [5, 6]. Defining and deploying a reliable communication infrastructure, which is usually provided by wireless connections due to the greater flexibility and lower cost of installation that they offer for sharing data, is the first step towards achieving these ambitious goals. However, due to the difficulty of environmentally friendly smart city instances, in most instances heterogeneous communication methods and different network structures should be implemented, based on the features of particular amenities that need to be executed (such as the needed low or high data bit rate), or operational limitations (such as the accessibility of a power source), the area to be covered (which means long-range or short-range connectivity links), and other elements [7, 8]. Defining the usage level in various elements of urban administration allows for the provision of services that are relevant to individuals and institutions when a solid connection facility the foundation of an IoT-based intelligent city, has been deployed. There is a need to assess challenges in smart sustainable cities based on IoT. to better manage energy resources and decrease the urban environment's ecological impact. Unfortunately, Fuzzy Sets (FSs) theories can't deal with ambiguous or contradictory data, even if they're a useful tool for handling situations involving ambiguity. Neutrosophic Sets (NSs), a generalization of FSs, and Intuitionistic Fuzzy Sets (IFSs) are one such sophisticated computational tool that has found use in the field of material selection. The issue of smart sustainable challenges ranking has not been investigated in any previous research employing the class of NSs. Multi-criteria decision-making (MCDM) takes into account the perspectives of several experts with varying degrees of expertise, interests, and experience to tackle difficult technical and scientific challenges. Therefore, in order to assess the efficacy of a group's MCDM solution, it is necessary to compile the views of many specialists [9, 12]. The WPM is an MCDM methodology used to compute the weights of criteria and rank challenges. This paper intended to introduce a new neutrosophic framework for assessment challenges in smart sustainable cities based on IoT for better-managing energy resources and decreasing the urban environment's ecological impact. The proposed framework used nine criteria and five alternatives. Also, the proposed framework applied the Neutrosophic Weighted Product Method (WPM) to compute the weights of criteria and rank challenges. Moreover, the proposed framework integrated the single-valued neutrosophic set to deal with uncertain data. This study sheds light on approaches that may be used to address these obstacles and pave the way for the long-term viability of IoT-based smart city deployment.

This paper is organized as follows: the first section presents the introduction for this work; the second section introduces the concept of the smart sustainable city; the third section introduces the challenges of smart cities; the fourth section provides the concept of neutrosophic WPM; the fifth section introduces evaluation the challenges of smart sustainable cities based on IoT; the sixth section provides conclusion; finally give the references.

2. Smart Sustainable City

To be considered a smart sustainable city, a smart city must improve its attractiveness, sustainability, inclusivity, and equilibrium for its residents, workers, and tourists. Therefore, it may be argued that the participation of enterprises, multi-utility firms, and public transport participants is a crucial plus in order to achieve these objectives. Creating cross-disciplinary teams comprised of experts in fields as varied as power, urban planning, movement, and information and communication technology is one practical and effective approach to the problem of how to integrate urban policies in order to evolve towards a smart town [13, 14]. The actions that follow and their accompanying plans are provided as an illustration of what a municipality could be engaged in doing to increase its level of sustainability. The city's Strategic Environmental Assessment Plan (SEAP) aims to improve the ecological situation in the area by cutting carbon dioxide emissions by a certain amount. Growing inter-modality and linking with various urban transmit structures; - decreasing private cars' usage and permitting individuals to travel more efficiently, sustainably, and safely; - enhancing public transport to meet actual consumer demands in terms of effectiveness, reliability, and fast availability of data; Safe and sustainable energy administration is the end goal of the Sustainable Energy and Climate Action Plan (SECAP), which aims to (i) reduce ecological effects by accelerating carbon reduction management, (ii) adjust to the impacts of global warming, and (iii) boost the effectiveness of energy use. Based on the nature of the offerings to be deployed, it may be necessary to utilize a diverse collection of communication methods and multiple network architectures to provide connection across a wide variety of application situations. Wireless networks often provide communication among IoT devices, allowing for information sharing with adaptable and inexpensive installations. When end-to-end communications are not possible due to power limits or impediments, alternatives such as networked devices and limited-range communication methods are preferred. Information may be sent from IoT devices (data producers) to data users (servers, border routers, etc.) and vice versa using hop-by-hop connections between devices. When direct and dependable communication lines among a central "hub" and all the IoT devices within its reach are available, however, constellation networks and far-reaching communication methods are preferred [15, 16].

3. Challenges of Smart Cities

The ecology of a smart city relies heavily on technology, but it also has to account for human and social capital. numerous modern smart city deployments are founded on one-off technologies and solutions; however, they may not be transferable to other cities throughout the world, and in certain cases, just a fraction of the numerous factors involved may be relevant. The following is a summary of the most significant problems, concerns, and open challenges related to smart cities that have been uncovered in the research so far [17, 18]. It is important to consider the privacy issue while handling private information and data at the home level when designing a smart city from the perspective of its residents. Because some people may see the introduction of new technology as threatening or obtrusive, this is of utmost importance. Equal access to the benefits of smart city technology for all residents is also crucial, as is ensuring that no urban neighborhood is overlooked in the effort to close the divide between the suburbs and the city [19, 20]. The smart city idea necessitates a shift in government algorithms to be more adaptable and to incorporate institutional guidelines with bottom-up campaigns, thereby improving and encouraging territorial cohesion, cooperation, and interaction among various entities and preventing the proliferation of multiple identical efforts that don't work together in an effective manner. In order to provide an equitable, environmentally friendly, effective transportation system for both commodities and individuals in the urban region, the mobility component is widely acknowledged in research as one of the most significant factors of smart city implementation [21, 22]. In addition, research has yet to adequately explore environmental considerations in the development of smart city facilities, such as the handling of energy and water resources efficiently and sustainably, pollution, and the overall influence of urban activities on the natural world. Since smart city implementations are often built on private and isolated solutions, interoperability is a crucial cross-dimensional component that is regarded as a probable impediment to progress. Instead, equipment based on open standards must be deployed across the board if we're going to get the economies of scale and optimum outcomes we're after. Coordination among data collecting and analytical procedures across multiple systems is also necessary from a software compatibility perspective [23, 24]. Figure 1 shows the ranking challenges of sustainable smart cities based on IoT and the neutrosophic model.

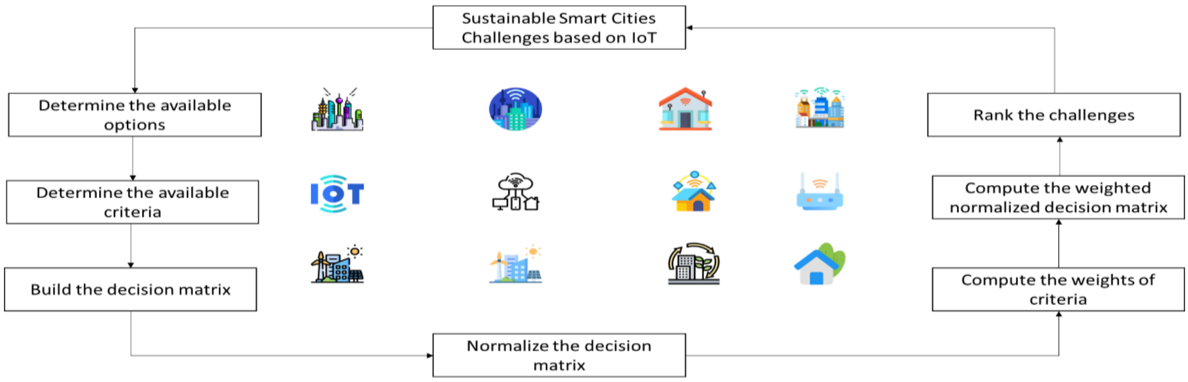

Figure 1. The ranking challenges of sustainable smart cities based on IoT.

4. Neutrosophic Weighted Product Method

The WPM is a MCDM method. It used to compute the weights of criteria and rank the alternatives [25, 26]. The WPM is integrated with the single valued neutrosophic sets as the follows:
Step 1. Determine the available options and their defining characteristics. For each chosen characteristic, a numerical or qualitative rating is to be given. The suggested method will be used to assess the identified options. Attribute values for prioritized options are derived from available data or the decision maker's best guesses.
Step 2. Build the decision matrix.
Step 3. Normalize the decision matrix by applying a normal distribution to the data using the decision matrix's beneficiary and non-beneficiary characteristics.

$$y_{ij} = \frac{a_{ij}}{\max a_{ij}} \quad (1)$$

$$y_{ij} = \frac{\min a_{ij}}{a_{ij}} \quad (2)$$

Step 4. Compute the weights of criteria.
Step 5. Compute the weighted normalized decision matrix.

$$r_i = \prod_{j=1}^{M} [y_{ij}]_j^w \quad (3)$$

Step 6. Rank the alternatives.

5. Evaluation of the Challenges of Smart Sustainable Cities based on IoT

The Problems Facing Sustainable Smart Cities:
Large sums of money may need to be spent on infrastructure, technology, and planning before smart, sustainable cities may be built.
Problems with compatibility and interoperability may arise from the existing lack of standardization in the creation of smart sustainable cities.
Concerns about privacy and security are raised by the collecting, storage, and use of personal data, which is facilitated by the use of technology and data in smart sustainable cities.
Some neighborhoods may be left behind owing to a lack of access to technology and resources as a result of the implementation of smart sustainable cities, which may worsen preexisting social and economic inequities. difficulties relating to data privacy and security, standardization, interoperability, scalability, and power consumption are only some of the obstacles to creating smart cities that are sustainable on the basis of the Internet of Things.
There are five challenges needed to be ranked:

i. Analyses of Strategy

Once the concept of "Smart Sustainable Cities" has been established, evaluations based on that meaning will be required. There is a requirement for the creation and adoption of procedures and practices. To determine which remedies are necessary, we need techniques that evaluate their efficacy from a systems-level viewpoint.

ii. Precautions to Take

Historically, increased prosperity and quality of life have resulted from increased investment in the development of essential infrastructure. Transportation, water, electricity, and sewage management procedures have enhanced the quality of life for billions of people.

iii. Both from above and below

Large corporations like Cisco, Ericsson, IBM, and Siemens may provide initial inspiration for the goods, services, and systems that make up the smart sustainable city. Such top-down solutions may be advantageous since the aforementioned giants have the financial resources to carry out the analyses necessary, and they may serve as actual providers of the resources and services that municipal governments may like to put into place.

iv. Competence

Successful approaches from large companies were highlighted in a previous post. They might also be effective methods of putting up desirable options. However, in the present tense, corporate ICT expertise is so much more than that of municipal governments, making cities poor consumers.

v. Governance

Connected gadgets and organizations are essential for a smart, sustainable city, but this raises new questions about who should be engaged in the city's design and administration.

Let experts evaluate the nine criteria and five challenges of smart sustainable cities based on IoT. This paper used single-valued neutrosophic numbers to evaluate the criteria and alternatives. Then normalize the decision matrix as shown in Table 1.

Table 1. Normalization valued between criteria and challenges.

	STC_1	STC_2	STC_3	STC_4	STC_5	STC_6	STC_7	STC_8	STC_9
STA_1	0.519518	0.163098	0.468314	0.156654	1	0.300469	1	0.298751	0.000114
STA_2	0.809211	0.245322	0.413181	0.712294	0.819315	1	0.297613	0.276462	0.000109
STA_3	0.561404	1	0.713561	1	0.245067	0.276995	0.296482	0.302206	0.000157
STA_4	0.809211	0.77027	1	0.577947	0.583593	0.300469	0.325377	1	1
STA_5	1	0.546778	0.747275	0.755387	0.245067	0.276995	0.572864	0.276462	0.0001

Compute the weights of criteria to obtain the weighted normalized decision matrix as shown in Table 2. Then rank the alternatives based on the product valued of weighted normalized decision matrix as shown in Figure 2.

Table 2. Weighted normalization valued between criteria and challenges.

	STC_1	STC_2	STC_3	STC_4	STC_5	STC_6	STC_7	STC_8	STC_9
STA_1	0.043175	0.008789	0.044675	0.014731	0.240306	0.045664	0.141674	0.020198	8.22E-06
STA_2	0.06725	0.013221	0.039416	0.066982	0.196886	0.151974	0.042164	0.018691	7.82E-06
STA_3	0.046656	0.053891	0.068071	0.094038	0.058891	0.042096	0.042004	0.020431	1.13E-05
STA_4	0.06725	0.04151	0.095396	0.054349	0.140241	0.045664	0.046097	0.067607	0.07201
STA_5	0.083106	0.029466	0.071287	0.071035	0.058891	0.042096	0.08116	0.018691	7.21E-06

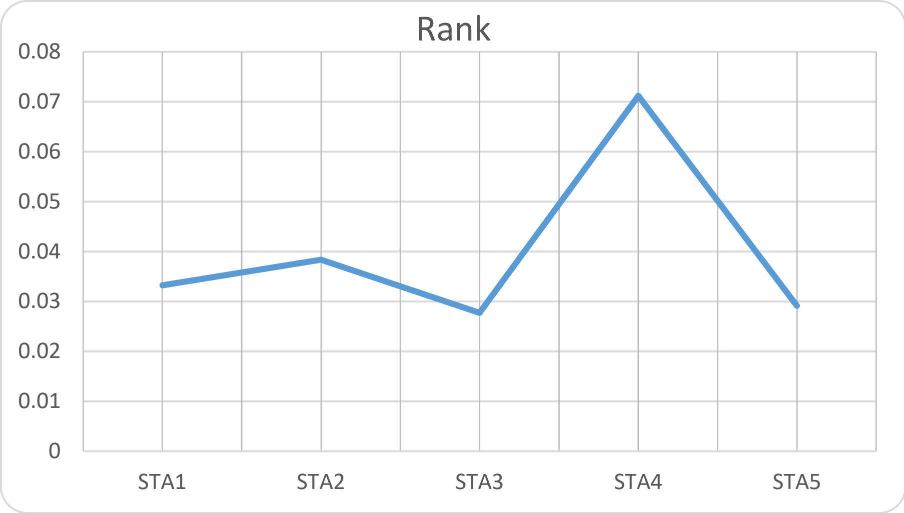

Figure 2. The orders challenges of smart sustainable cities based on IoT.

The proposed framework used nine criteria and five alternatives. Also the proposed framework applied the Neutrosophic Weighted Product Method (WPM) to compute the weights of criteria and rank challenges. Moreover, the proposed framework integrated the single-valued neutrosophic set to deal with uncertain data.

As shown in Figure 2, the results indicated that the proposed framework can handle uncertainty data and give more accurate results in assessing challenges in smart sustainable cities based on IoT to better manage energy resources and decrease the urban environment's ecological impact.

6. Conclusion

The IoT has enormous potential for implementing sustainable smart cities, which may improve urban sustainability and quality of life. While there is great potential in this new area of study, there are also a number of obstacles that must be overcome before widespread use can be achieved. This study lists data privacy and security, standardization, interoperability, scalability, and power consumption as some of the obstacles to be overcome. Stakeholders including government, business, and people must work together to address these difficulties. Standards and protocols to facilitate interoperability, scalable and energy-efficient technologies, increased citizen engagement and education, and the development of clear policies and regulations regarding data privacy and security are all possible responses to these problems. The full potential of IoT-based sustainable smart cities can only be realized by overcoming these obstacles and adopting a sustainable, inclusive, and collaborative strategy. These challenges are ranked based on the singe-valued neutrosophic WPM method. The results indicated that the proposed framework can handle uncertain data and give more effective results in assessing challenges in smart sustainable cities based on IoT to better manage energy resources and decrease the urban environment's ecological impact.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

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

Ethical approval

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

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Identify the most Productive Crop to Encourage Sustainable Farming Methods in Smart Farming using Neutrosophic Environment

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Abstract: Only with careful management can the data provided by crops be used to make smart, profitable choices. Data has become the central ingredient in contemporary agriculture, and the recent advancements in handling it are contributing greatly to the meteoric rise of smart farming. Gains in efficiency and longevity may be realized to a significant degree by using the objective data collected by sensors. These data-driven farms can maximize output while minimizing waste and environmental impact thanks to the information they collect and analyze. Various criteria and factors in smart farming can aid in productivity. Sensors, drones, Global Positioning System (GPS) mapping, and other technologies are used in "smart farming" to track variables such as crop development, soil quality, and weather to optimize yields. These technologies are used in smart farming to increase sustainability, decrease food waste, and maximize agricultural yields. This paper suggested a mean weighting methodology to analyze and select the best criteria in smart farming. This method is integrated with the neutrosophic set to deal with uncertain data. This paper achieved the sustainability criteria as the best criteria.

Keywords: Smart Farming; Sustainability; Neutrosophic Set; Productivity; Crops.

1. Introduction

Finding the most beneficial crop using demographic variables is a sustainable practice. Excellent for rural usage. Greenhouses and mechanized farming using precision farming techniques are at the heart of modern agriculture, which also works to preserve and improve the planet's dwindling renewable resources. Drip and sprinkler irrigation systems are an innovative way to save water. Rapid population expansion calls for greater productivity from each plot of land. Sustainable farming practices have increased in significance among needs and supply to control variability [1, 2].

Now is the time to focus on raising people's living standards and safeguarding the planet's natural resources. The financial, social, and ecological benefits of sustainable agriculture are all interconnected. Farmers' sense of competence and happiness are intimately linked to these elements. Value in the marketplace and how much money farmers make from their crops. The high temperatures and little rainfall in the dry zone make for a difficult natural environment. Food safety and economic growth are both bolstered by the farming sector [3, 4].

Natural soil nutrients, the retail value of crop output, the condition of water, and the retention of carbon are all crucial aspects of the farming industry, as stated by the Food and Agriculture Organization (FAO) [5, 6].

Farming is now much easier thanks to mechanization. Computerized platforms with sensors provide choices for farmers to track and perform agricultural tasks. Several methods that make use of machines have been suggested in the literature, and these methods make use of computer and database technology [7, 8]. However, it is more cost-effective and useful for field management. Producers need a straightforward answer right now. To address the aforementioned problems, it is proposed to implement an autonomous system consisting of a master controller and the necessary sensors. Developed with the farmer in mind. Sensors may possess a significant part in computer autonomy. To capitalize on agriculture's global advantages, the government has developed several different Internet of Things (IoT) policies [9]–[11]. This analysis has uncertain data. So, the neutrosophic set is used to compute the weights of the criteria.

The fuzzy set (FS) theory was first proposed by Zadeh (1965) to deal with gaps in understanding. To express membership and non-membership functions, Atanassov further extended the FSs theory to intuitionistic FSs. Smarandache later introduced the neutrosophic sets, which are an extension of FSs. The use of neutrosophic sets to solve difficult decision-making issues has been fruitful [12]–[14]. This study used the triangular neutrosophic number with the mean weights to compute the weights of the criteria.

2. Farming Management

For statistics or photos to be interpreted clearly into useful information, the raw observations of crops' important properties must be processed rapidly. Even while crop management using field data had already progressed by the time Precision Agriculture was discovered thirty years ago, the advent of the digital data age has undoubtedly had a profound effect. Field administration has always included farmers visually assessing the progress of crops to arrive at an assessment with which they make judgments and activate offering various treatments to crops. This is especially true in areas where automation has not yet arrived [15, 16].

This method is grounded on the knowledge and observations made by producers in the field. Growers who are part of a cooperative may also rely on the advice of experts and engineers employed by the organization. Field administration on farms using cutting-edge technologies differs with each phase of production [7, 17].

The crop itself serves as the foundation for this data-driven, data-driven management approach, which makes use of the crop's inherent spatial and temporal variability. The sensors are the particular components via which reliable information is gathered, and the base is the physical method by which this is accomplished. The characteristics of the crop, soil, and environment are all sources of information that may be found in the data [18, 19].

Information from the sensors may be retrieved in several different ways, for as by copying and pasting it onto a pen drive and then putting it into a USB port, or by using software programs that are synchronized with the Internet. Connecting the data and decision-making phases requires sophisticated algorithms and filtering processes to extract relevant information and guide the grower toward optimal outcomes. Actuation, or the actual carrying out of a decision system's directive, is often accomplished by high-tech machinery outfitted with a computerized control unit. The cycle begins and ends at the crop level when each operation is performed upon it; the crop's reaction is then recorded by specialized sensors, and the loop is repeated methodically until harvest. Figure 1 shows the smart farming system. The crop is the first stage, then the platform. Then the data and decision. Then apply the mean weighting method to compute the weights of criteria by the triangular neutrosophic set.

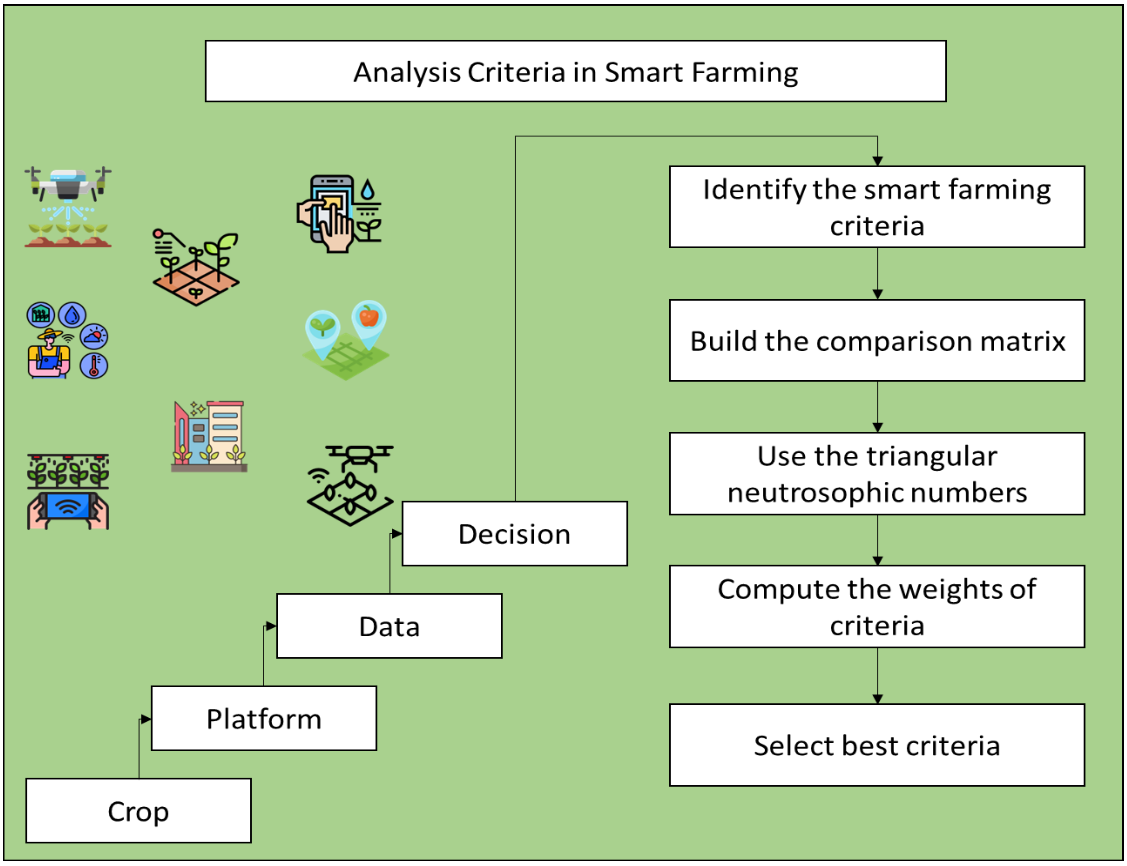

Figure 1. The smart farming system.

3. Agriculture 4.0

Agriculture 4.0, Digital Farming, and Smart Farming are all names for the same data-centric farming philosophy that emerged when sensors and data administration were added to the well-established idea of precise farming to boost operational precision. Thus, precision farming is the foundation of Agriculture 4.0, with farmers adopting data-generating technology to better inform operational and strategic choices. Farmers have always relied on field checks to inform their judgments, which are based on years of expertise [20, 21].

As certain areas have become too vast to be maintained successfully considering the triple factors that will lead to next year's efficiency, sustainability, and accessibility (for people) this technique is no longer viable. Smart farming's focus on advanced systems of administration is yielding real-world benefits. Even though some farmers have extensive field expertise, technology may give a systematic method to uncover unexpected issues that would be difficult to spot with just eye examination on infrequent visits [22, 23].

Young farmers have a more favorable attitude towards embracing contemporary equipment than their more seasoned counterparts do; this is likely because these instruments may supplement the former's limited expertise in the field [16, 24].

4. Neutrosophic Mean Method

When applied to real circumstances, the crisp-based, classical theory does not appear well-suited for dealing with ambiguity. In 1986, Atanassov created an intuitionistic fuzzy set (IFS), a generalization of the FS. The aforementioned sets are not without their flaws. To overcome these limitations, a new theory known as neutrosophic logic and sets was created. Neutrosophic sets are expansions of sets that are classical, fuzzy, or IFS. A neutrosophic set's membership function includes degrees of truth, falsehood, and ambiguity. In this case, indeterminacy provides more accurate results than FSs or IFS. As a result, neutrosophy will provide better results than fuzzy and IFSs [25]–[28]. We can define the triangular neutrosophic set as:

$$T(a_i) = \begin{cases} \left(\frac{a_i - x}{y - x}\right) g_x, & x \le a_i \le y \\ g_x, & a_i = y \\ \left(\frac{z - a_i}{z - y}\right) g_x, & y \le a_i \le z \\ 0, & otherwise \end{cases} \quad (1)$$

$$I(a_i) = \begin{cases} \left(\frac{y - a_i}{y - x}\right) v_x, & x \le a_i \le y \\ v_x, & a_i = y \\ \left(\frac{a_i - z}{y - x}\right) v_x, & y \le a_i \le z \\ 1, & otherwise \end{cases} \quad (2)$$

$$F(a_i) = \begin{cases} \left(\frac{y - a_i}{y - x}\right) k_x, & x \le a_i \le y \\ k_x, & a_i = y \\ \left(\frac{a_i - z}{y - x}\right) k_x, & y \le a_i \le z \\ 1, & otherwise \end{cases} \quad (3)$$

The simplest weighing method is the MW, which gives equal weight to each property.
Compute the weights of the criteria.

$$w_j = \frac{a_j}{\sum_{j=1}^{n} a_j} \quad (4)$$

5. Smart Farming Analysis

This section analysis the sustainability criteria to achieve productivity in smart farming. This paper collected ten criteria to analyze it.

Smart farming, also known as precision agriculture, is a kind of farming that makes use of information and communication technologies to increase productivity, decrease waste, and enhance environmental friendliness. Sensors, drones, GPS mapping, and other technologies are used in "smart farming" to track variables such as crop development, soil quality, and weather to optimize yields.

Some components of efficient farming are: Temperature, humidity, and soil moisture are just a few examples of the environmental parameters that may be measured with sensors. Robotics: Robots may be employed in agriculture to replace human labor in planting, harvesting, and pest control. Drones: Farmers may benefit from using drones to gather information on crop development, soil conditions, and other things. Precision planting and fertilization are made easier with the use of GPS maps of farms. Large volumes of data acquired by sensors and drones may be processed using data analysis techniques to provide insights into crop development and soil health.

Considerations for efficient farming include: The goal of "smart farming" should be to make agriculture more sustainable and less harmful to the environment. Efficient production: Smart farming aims to maximize crop output while decreasing waste. Value for money: Farmers should see a profit from adopting smart agricultural practices. All farmers, from hobbyists to corporate giants, should have access to cutting-edge agricultural technology. Smart farming technologies should be adaptable and simple to use, so that they may be incorporated into current agricultural systems.

The experts built the pairwise comparison between ten criteria as shown in Table 1. Then replace their opinions by using the numbers of triangular neutrosophic. Then compute the weights of criteria by the mean weighting method as shown in Figure 2.

Table 1. The Comparison matrix between criteria of smart farming.

	SFC_1	SFC_2	SFC_3	SFC_4	SFC_5	SFC_6	SFC_7	SFC_8	SFC_9	SFC_{10}
SFC_1	1	{(0,1,2); 0.30, 0.75, 0.70}	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	{(2,3,4); 0.90, 0.10, 0.10}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(2,3,4); 0.90, 0.10, 0.10}	{(0,1,2); 0.30, 0.75, 0.70}
SFC_2	{(0,1,2); 0.30, 0.75, 0.70}	1	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}
SFC_3	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	1	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(4,4,4); 1.00, 0.00, 0.00}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(4,4,4); 1.00, 0.00, 0.00}
SFC_4	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	1	{(4,4,4); 1.00, 0.00, 0.00}	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(2,3,4); 0.90, 0.10, 0.10}
SFC_5	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	1	{(1,2,3); 0.80, 0.15, 0.20}	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(1,2,3); 0.80, 0.15, 0.20}
SFC_6	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	1	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(0,1,2); 0.30, 0.75, 0.70}	{(0,1,2); 0.30, 0.75, 0.70}
SFC_7	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(4,4,4); 1.00, 0.00, 0.00}	{(1,2,3); 0.80, 0.15, 0.20}	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	1	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}
SFC_8	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	1	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}
SFC_9	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	1	{(4,4,4); 1.00, 0.00, 0.00}
SFC_{10}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	{(2,3,4); 0.90, 0.10, 0.10}	{(1,2,3); 0.80, 0.15, 0.20}	{(0,1,2); 0.30, 0.75, 0.70}	{(1,2,3); 0.80, 0.15, 0.20}	{(1,2,3); 0.80, 0.15, 0.20}	{(4,4,4); 1.00, 0.00, 0.00}	1

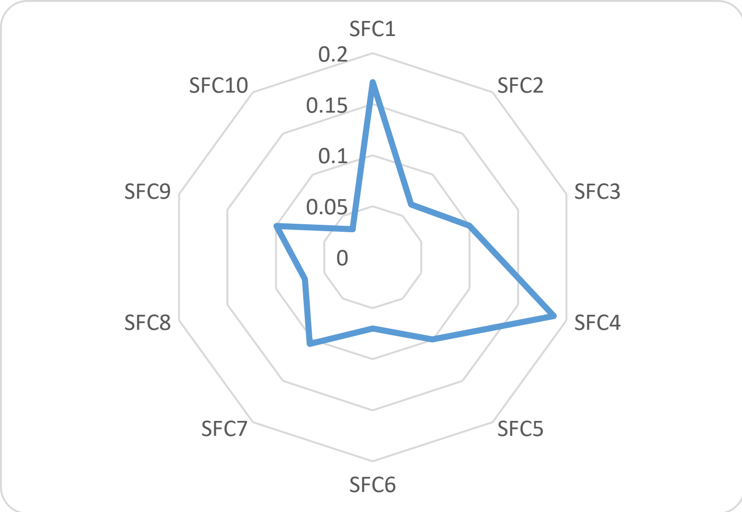

Figure 2. The weights of factors in smart farming.

The sustainability criterion is the best. Smart farming could lessen negative effects on the environment and boost agricultural sustainability.

6. Conclusion

Smart farming, also known as precision agriculture, is a kind of farming that makes use of information and communication technologies to increase productivity, decrease waste, and enhance environmental friendliness. Sensors, drones, GPS mapping, and other technologies are used in "smart farming" to track variables such as crop development, soil quality, and weather to optimize yields. As well as lowering environmental impacts and increasing food security, "smart farming" has the potential to greatly increase agricultural productivity, sustainability, and profitability. This paper used the ten criteria in smart farming and used the mean weighting method to compute the weights of these criteria and rank them. This paper used the triangular neutrosophic set to deal with uncertain data. We obtained the sustainability criterion as the best. Smart farming could lessen negative effects on the environment and boost agricultural sustainability.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

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

Ethical approval

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

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Lagrange Multipliers and Neutrosophic Nonlinear Programming Problems Constrained by Equality Constraints

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Abstract: Operations research science is defined as the science that is concerned with applying scientific methods to complex problems in managing and directing large systems of people, including resources and tools in various fields, private and governmental work, peace and war, politics, administration, economics, planning and implementation in various domains. It uses scientific methods that take the language of mathematics as a basis for it and uses computer, without which it would not have been possible to achieve numerical solutions to the raised problems, those that need correct solutions, when the solutions abound and the options are multiple, so we need a decision based on correct scientific foundations and takes into account all the circumstances and changes that you can encounter the decision-maker during the course of work, and nothing is left to chance or luck, but rather everything that enters into the account and plays its role in decision-making, and we get that when we use the concepts of neutrosophic science to reformulate what the science of operations research presented in terms of methods and methods to solve many practical problems, so we will present in this research a study aimed at shedding light on the most important methods used to solve nonlinear models, which is the Lagrangian multiplier method for nonlinear models constrained by equality and then reformulated using the concepts of neutrosophic science.

Keywords: Operations Research; Nonlinear Programming; Lagrange Multiplier; Neutrosophic Science; Neutrosophic Nonlinear Programming; Lagrange Neutrosophic Multiplier.

1. Introduction

Science is the basis for managing life affairs and human activities. Operations research science is the applied aspect of mathematics. It is one of the most important modern sciences that are concerned with practical issues and meet the desire and demand of decision-makers to obtain ideal decisions through the methods it presented that are appropriate for all issues, meaning that it depends on the attached data. In every issue, these data are values that have been developed through observation, and their accuracy depends on who collects them. They are also specific for a certain period that may not be appropriate for subsequent circumstances. Therefore, they are inaccurate data that are not fully confirmed. Before the advent of neutrosophic science, we used to rely on this data. To study factual issues and accept the results as they are, but after the neutrosophic science that made a great revolution in all fields. Its ability to produce optimal results upon which ideal decisions can be built that take into account all circumstances. Many researchers interested in scientific development tended to reformulate many scientific concepts using this science, so we have neutrosophic numbers - neutrosophic groups - neutrosophic probabilities - neutrosophic statistics - neutrosophic differentiation - neutrosophic integration - neutrosophic linear programming - neutrosophic dynamic programming - neutrosophic simulation, etc. and many more [1-28].

The method of nonlinear programming is one of the most important methods presented by the science of operations research because most of the practical issues devolve into nonlinear models. Therefore, in previous research, we formulated some basic concepts of nonlinear programming using the concepts of neutrosophy [26]. In addition to what we have done earlier, in this research we will paraphrase the Lagrangian multiplication method for nonlinear models constrained by equal constraints using the concepts of neutrosophic science, by taking the data of the issue under study, neutrosophic numbers It has the following standard form N = a+bI where real or composite coefficients, represents a and baspecified part fbI The indefinite part of the numberNindeterminacy and could be $[\lambda_1 , \lambda_2]$or$\{\lambda_1 , \lambda_1 \}$ or something else is any set close to the true value a.

2. Discussion

We know that if the nonlinear programming issue consists of only a target function and the target function is convex or (concave), then there is a single optimal solution at a point where all the derivatives are non-existent. The only optimal, but in most realistic issues the goal is to find the maximum or minimum value of a target function that is subject to several restrictions. To calculate one of the variables in terms of the rest of the variables, then replace it with the objective function statement, thus obtaining a new objective function and a new unrestricted example problem. We will use this technique as mentioned in the references [29,30].

To convert nonlinear restricted neutrosophic problems into nonlinear non-restricted neutrosophic problems, and for that, the following information taken from the references must be recalled [27, 28]:

$$f_N'(x) = \lim_{h\to 0} \frac{[\inf f(x+h) - inf f(x), sup f(x+h) - sup f(x)]}{[infH, supH]}$$

This definition is a generalization of the traditional derivative definition.

Text of the constrained neutrosophic nonlinear programming problem:

Based on what is stated in the reference [29], we offer the following:

If it is required to find the (maximum or minimum), value of a function Neutrosophic is continuous, derivable $\boldsymbol{y_0 = f_N(x_1, x_2, ---, x_n)}$ and subject to the neutrosophic constraint $\boldsymbol{g_N(x_1, x_2, ---, x_n) = \alpha}$ Also this function is continuous and derivable.

1. We choose the variable $\boldsymbol{x_n}$ in the constraint and express it with the remaining $\boldsymbol{n-1}$ variables as follows:

$$\boldsymbol{x_n = H_N(x_1, x_2, ---, x_{n-1})}$$

Then we substitute the target function we get

$$\boldsymbol{y_0 = \overline{f_N}\big(x_1, x_2, ---, x_{n-1}, H_N(x_1, x_2, ---, x_{n-1})\big)}$$

Thus, the problem turned into an unrestricted one. Traditional methods can be used to obtain a maximum or minimum limit because the necessary and sufficient condition for the boundary points is that the first derivatives do not exist:

$$\frac{\partial y_0}{\partial \boldsymbol{x_j}} = 0 \quad ; j = 1,2, ---(n-1)$$

Using the chain rule, we get the following:

$$\frac{\partial y_0}{\partial \boldsymbol{x_j}} = \frac{\partial \overline{\boldsymbol{f_N}}}{\partial \boldsymbol{x_j}} + \frac{\partial \overline{\boldsymbol{f_N}}}{\partial \boldsymbol{x_n}} \cdot \frac{\partial \boldsymbol{H_N}}{\partial \boldsymbol{x_j}} \quad ; j = 1,2,---(n-1)$$

Since the $\boldsymbol{g_N}(\boldsymbol{x_1}, \boldsymbol{x_2}, ---, \boldsymbol{x_n}) = \boldsymbol{\alpha}$
We get

$$\frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_j}} + \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_n}} \cdot \frac{\partial \boldsymbol{H_N}}{\partial \boldsymbol{x_j}} = 0 \quad ; j = 1,2,---(n-1)$$

$$\Rightarrow \frac{\partial \boldsymbol{H_N}}{\partial \boldsymbol{x_j}} = -\left. \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_j}} \middle/ \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_n}} \right. \quad ; j = 1,2,---(n-1)$$

On condition: $\frac{\partial g_N}{\partial x_n} \neq 0$
Then we find

$$\frac{\partial y_0}{\partial \boldsymbol{x_j}} = \frac{\partial \overline{\boldsymbol{f_N}}}{\partial \boldsymbol{x_j}} - \left[\frac{\partial \overline{\boldsymbol{f_N}}}{\partial \boldsymbol{x_n}} \cdot \left. \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_j}} \middle/ \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_n}} \right. \right] = 0 \quad ; j = 1,2,---(n-1)$$

If the resulting solution vector is the vector that achieves a (maximum or minimum) value, then$(x^*_{N1}, x^*_{N2}, ---, x^*_{Nn})$, They are the values that make the function maximum or minimum.
We symbolize λ_N the following:

$$\lambda_N = \left. \frac{\partial \boldsymbol{f_N}}{\partial \boldsymbol{x_n}} \middle/ \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_n}} \right.$$

So it is:

$$\frac{\partial \overline{\boldsymbol{f_N}}}{\partial \boldsymbol{x_j}} - \lambda_N \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_j}} = 0 \quad ; j = 1,2,--, n$$

The supporting condition is:

$$\boldsymbol{g_N}(\boldsymbol{x_1}, \boldsymbol{x_2}, ---, \boldsymbol{x_n}) = \boldsymbol{\alpha}$$

And so we have obtained $n+1$ Equation and $n+1$ unknown, these conditions are necessary for an optimal solution, provided that all derivatives do not exist $\frac{\partial g_N}{\partial x_j} \neq 0$

when$(x^*_{N1}, x^*_{N2}, ---, x^*_{Nn})$
From the above, we can write the following:

$$\boldsymbol{y_0} = \overline{\boldsymbol{f_N}}(\boldsymbol{x_1}, \boldsymbol{x_2}, ---, \boldsymbol{x_n}) - \lambda_N [\boldsymbol{g_N}(\boldsymbol{x_1}, \boldsymbol{x_2}, ---, \boldsymbol{x_n}) - \boldsymbol{\alpha}]$$

Then, we calculate the derivatives:

$$\frac{\partial y_0}{\partial \boldsymbol{x_j}} = \frac{\partial \boldsymbol{f_N}}{\partial \boldsymbol{x_j}} - \lambda_N \frac{\partial \boldsymbol{g_N}}{\partial \boldsymbol{x_j}} = 0$$

$$\frac{\partial y_0}{\partial \lambda} = -[\boldsymbol{g_N}(\boldsymbol{x_1}, \boldsymbol{x_2}, ---, \boldsymbol{x_n}) - \boldsymbol{\alpha}]$$

2.1 Example

This example is shown in reference [29] (values are dependent and constraints are classic values)

2.1.1. Find the minimum value of the function

$$f(x) = 3x_1^2 + x_2^2 + 2x_1x_2 + 6x_1 + 2x_2$$

Subject to constraint

$$2x_1 - x_2 = 4$$

The solution

We form the Lagrangian function:

$$L(x,\lambda) = 3x_1^2 + x_2^2 + 2x_1x_2 + 6x_1 + 2x_2 - \lambda(2x_1 - x_2 - 4)$$

The following optimal solution was obtained:

$$x_1^* = \frac{7}{11} \quad , x_2^* = \frac{-30}{11} \quad , \quad \lambda^* = \frac{24}{11}$$

And by testing the function using the Hessian matrix, it was found that this function is a convex function and the constraint is convex

Then the radius of the solution that we obtained is a minimum limit and the value of the function is:

$$f_N^*(x_1^*, x_2^*) = 3.55$$

As we mentioned earlier, if some of the values in the target function or constraints are undefined, ambiguous, or uncertain values, then the issue becomes a neutrosophic issue clearly)

In the previous example, we will take the coefficients x_1^2 uncertain (All values can be undefined; we will suffice with one value to convey the idea of using neutrosophic numbers clearly

2.1.2 Find the minimum value of the neutrosophic function.

$$f(x) = \{2,3,4\}x_1^2 + x_2^2 + 2x_1x_2 + 6x_1 + 2x_2$$

Subject to constraint

$$2x_1 - x_2 = 4$$

The solution

We form the Lagrangian function:

$$L(x,\lambda) = \{2,3,4\}x_1^2 + x_2^2 + 2x_1x_2 + 6x_1 + 2x_2 - \lambda(2x_1 - x_2 - 4)$$

$$\frac{\partial L}{\partial x_1} = \{4,6,8\}x_1 + 2x_2 + 6 - 2\lambda = 0$$

$$\frac{\partial L}{\partial x_2} = 2x_1 + 2x_2 + 2 + \lambda = 0$$

$$\frac{\partial L}{\partial \lambda} = 2x_1 - x_2 + 4 = 0$$

We solve the following set of equations:

$$\{4,6,8\}x_1 + 2x_2 + 6 - 2\lambda = 0$$

$$2x_1 + 2x_2 + 2 + \lambda = 0$$

$$2x_1 - x_2 + 4 = 0$$

We get

We obtained the system of three equations with three unknowns. By solving this system, we get:

$$x_1^* = \left\{\frac{7}{10}, \frac{7}{11}, \frac{7}{12}\right\} \quad , x_2^* = \left\{\frac{-13}{5}, \frac{-30}{11}, \frac{-17}{6}\right\} \quad , \qquad \lambda^* = \left\{\frac{9}{5}, \frac{24}{11}, \frac{15}{6}\right\}$$

They are neutrosophic values, and the value of the target function is as follows:

$$f_N^*(x_1^*, x_2^*) = \{3.1, 3.55, 3.24\}$$

That is, we got the optimal solution vector, which is a neutrosophic value. An extreme of a subordinate, it can be a minor end or a major end. To determine its type we will use the test given in reference [26].

1. The constraint is a linear function, as it is convex and concave at the same time.
2. To specify the type of follower $f(x)$(convex or concave) we resort to the Hessian matrix for this function:

$$H_N(x) = \begin{bmatrix} \frac{\partial^2 f}{\partial x_1^2} & \frac{\partial^2 f}{\partial x_1 \partial x_2} \\ \frac{\partial^2 f}{\partial x_2 \partial x_1} & \frac{\partial^2 f}{\partial x_2^2} \end{bmatrix}$$

$$H_N(x) = \begin{bmatrix} \{4, 6{,}8\} & 2 \\ 2 & 2 \end{bmatrix}$$

The matrix is symmetric and the main diagonal elements are also positive.
Major basic minor determinants are positive because:

$$|\{4, 6{,}8\}| > 0$$

$$\begin{vmatrix} \{4, 6{,}8\} & 2 \\ 2 & 2 \end{vmatrix} = \{8, 12{,}16\} - 4 = \{4, 8{,}12\} > 0$$

Hence the Hessian matrix of the function$f_N(x)$Positive knowledge, that is, the function is convex. From the above, the Vector of the solution that we obtained is a minor limit of the value neutrosophic to follow him:

$$f_N^*(x_1^*, x_2^*) = \{3.1, 3.55, 3.24\}$$

3. Conclusions

In the previous study, we presented an important technique for solving neutrosophic nonlinear models constrained by equal constraints. Through the study, we found that there is a difference in the values of the optimal solution when using the technique and the data are traditional values and using them and the data are neutrosophic values, since the goal of solving examples problems is to find the maximum value that expresses profit or profitability and the smallest value that expresses the amount of loss or cost for a follower of a goal within certain constraints, and since mathematical models are built using data collected on the case under study, and these data are values that represent the current reality of the work environment, and any change in the surrounding conditions leads to a change in the results of the solution, which may cause unexpected losses whose nature is determined by the type of issue under study, it may be human, material, or otherwise, so we focus on the need to use neutrosophic values when collecting data for any realistic issue, values that take into account the worst conditions to the best, as we focus on necessity reformulation of many other techniques for solving nonlinear models using neutrosophic concepts such as projection gradients and vibration–Newton's method–Fibonacci Search.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

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

Ethical approval

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

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Neutrosophic Decision Making Model for Investment Portfolios Selection and Optimizing based on Wide Variety of Investment Opportunities and Many Criteria in Market

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Abstract: Investment portfolio selection is a difficult subject due to the presence of competing factors. Choosing a portfolio for one's investments is a major choice that may have far-reaching effects on one's financial well-being. Risk tolerance, time horizon, investing objectives, asset allocation, and investment selection are only a few of the factors that will be studied in this article. The Stable Preference Ordering Towards Ideal Solution (SPOTIS) technique is the basis for our proposed integrated multi-criteria decision-making (MCDM) model. This paper used the single-valued neutrosophic set as a framework to deal with uncertain data. The purpose of the suggested SPOTIS–Neutrosophic model is to choose the most promising investment possibilities by considering several financial variables. Because of the wide variety of investment opportunities and the many elements (political unpredictability, news, economic circumstances, etc.) that may affect the market, investors often worry about selecting and optimizing their investment portfolios.

Keywords: Decision making; Neutrosophic Set; Investment; Portfolio Section.

1. Introduction

The contemporary portfolio theory was proposed by Markowitz in the 1950s. The goal of this theory is to generate a desired return while limiting exposure to risk via the strategic allocation of a portfolio's resources. The mean-variance approach takes into account the covariance among pairs of assets in addition to the risk-return connection [1, 2].

While the mean-variance approach has gained widespread acceptance, other writers have explored the use of extra variables in portfolio construction by testing out different approaches that consider the large variety of investment opportunities that make up a portfolio and the many criteria that might be taken into consideration. The focus of these research efforts is on improving portfolio optimization and generating returns that are higher than the market reference. Multi-criteria decision-making (MCDM) techniques, which employ various parameters to rank or arrange options according to a mathematical basis for decision-making assistance, are a significant development in investment portfolio choice. In this study, we applied the Stable Preference Ordering Towards Ideal Solution (SPOTIS) method with the single-valued neutrosophic method [3, 4].

When making decisions in a complex setting, fuzzy numbers may be a useful aid. When Zadeh first created fuzzy sets (FSs), he set a precedent for their use in resolving ambiguous problems. Since FSs only store membership levels, they cannot be used to resolve more involved decision issues. Intuitionistic Fuzzy Sets (IFSs) were described by Atanassov, and they are ungraded since they include both membership and non-membership degrees [5, 6].

Despite expanding FSs' application, IFSs are not very precise when dealing with difficulties involving faulty and inconsistent data. Neutrosophic sets (NSs) were first defined by Smarandache in 1999, and they were inspired by IFSs. Non-conventional unit subintervals are used to define the levels of truth, falsehood, and indeterminacy. Wang et al., who also created the theory of single-valued neutrosophic sets (SVNSs), resolved the three functions to an ordinary unit interval subinterval for implementation simplicity [7, 8].

The SPOTIS technique features a straightforward algorithm that, like several MCDM approaches, calls for a decision matrix with options listed across the top and factors down the side, as well as a vector of weights for the criterion and indications of whether they are financially motivated or not. One of the primary premises of this approach is that you must know the upper and lower limits of each criterion's value to appropriately characterize the decision issue. This ensures that every criterion's value is contained inside the limits of the set [9, 10].

The SPOTIS technique uses a normalized distance to determine how far away each option is from the optimal answer. SPOTIS, like Characteristic Objects Method (COMET), makes use of reference items throughout the choice-making process. Thus, like COMET, SPOTIS is a distance-based technique, where alternatives' liking values are calculated based on the distance to the closest characteristic items and the values of those things [11]–[13]. This paper integrated the neutrosophic set with the SPOTIS method to compute the weights of criteria and rank the alternatives.

2. Portfolio Selection and MCDM

Markowitz established the current portfolio theory in 1952. The traditional mean-variance (MV) structure was an early example of portfolio choice. Portfolio choice is the challenge of allocating scarce resources among competing priorities. It is relevant to our daily lives and has promising future uses in fields like stock market investing, energy research, and portfolio management. Portfolio choice has benefited from a variety of academic studies, including those in the fields of behavioral finance, operational research, and smart optimization technology. When selecting a portfolio, traders often consider several different factors or goals, making the MCDM approach a helpful tool [14]–[17].

In operational research, MCDM is a burgeoning topic with the overarching goal of addressing decision-making issues using numerous criteria, particularly those involving choosing a portfolio. The MCDM structure allows for the consideration of various other critical financial factors, such as the return on investment and net profit margin, in addition to the two primary factors of return and risk [18]–[20]. In addition, MCDM benefits from taking individual investor tastes into account. Using the MCDM for the portfolio choice issue may lead to more accurate simulations. Two primary steps make up choosing a portfolio in the MCDM framework: company financial performance analysis and stock allocation [21]–[24].

Financial institutions, such as those who invest in mutual funds, pension plans, and government bonds, are naturally interested in how well companies are doing financially. The concept of value investing is congruent with this attribute. Firm financial ratios are a common measure of financial success. Investors may get valuable insight into the company's financial status, operational outcomes, and investment worth by perusing the financial statement. The financial achievements of businesses may be accurately described by combining all relevant financial parameters. This follows the multi-criteria decision-making paradigm, which makes the distribution of portfolios simpler [25]–[28].

3. SPOTIS Neutrosophic Decision-Making Model

SPOTIS stands for the recently discovered approach of Stable Preference Ordering Towards an Ideal Solution, which is used for formulating multi-criteria decisions. The primary goal of the presented method was to offer a novel approach that does not suffer from rank reversal (the phenomenon of flipping an order while adjusting the number of choices in the given data). The elaborate technique uses distance measuring and the concept of reference objects. The SPOTIS approach necessitates the declaration of data boundaries, compared to other MCDM methods like TOPSIS and VIKOR, where referent objects are formed from a decision matrix. When comparing ISPs with a linear distribution of variations, using data boundaries to find the ISP with the lowest variant count stops rankings from switching places [29, 30]. The SPOTIS is integrated with the single-valued neutrosophic set in this study as shown in Figure 1.

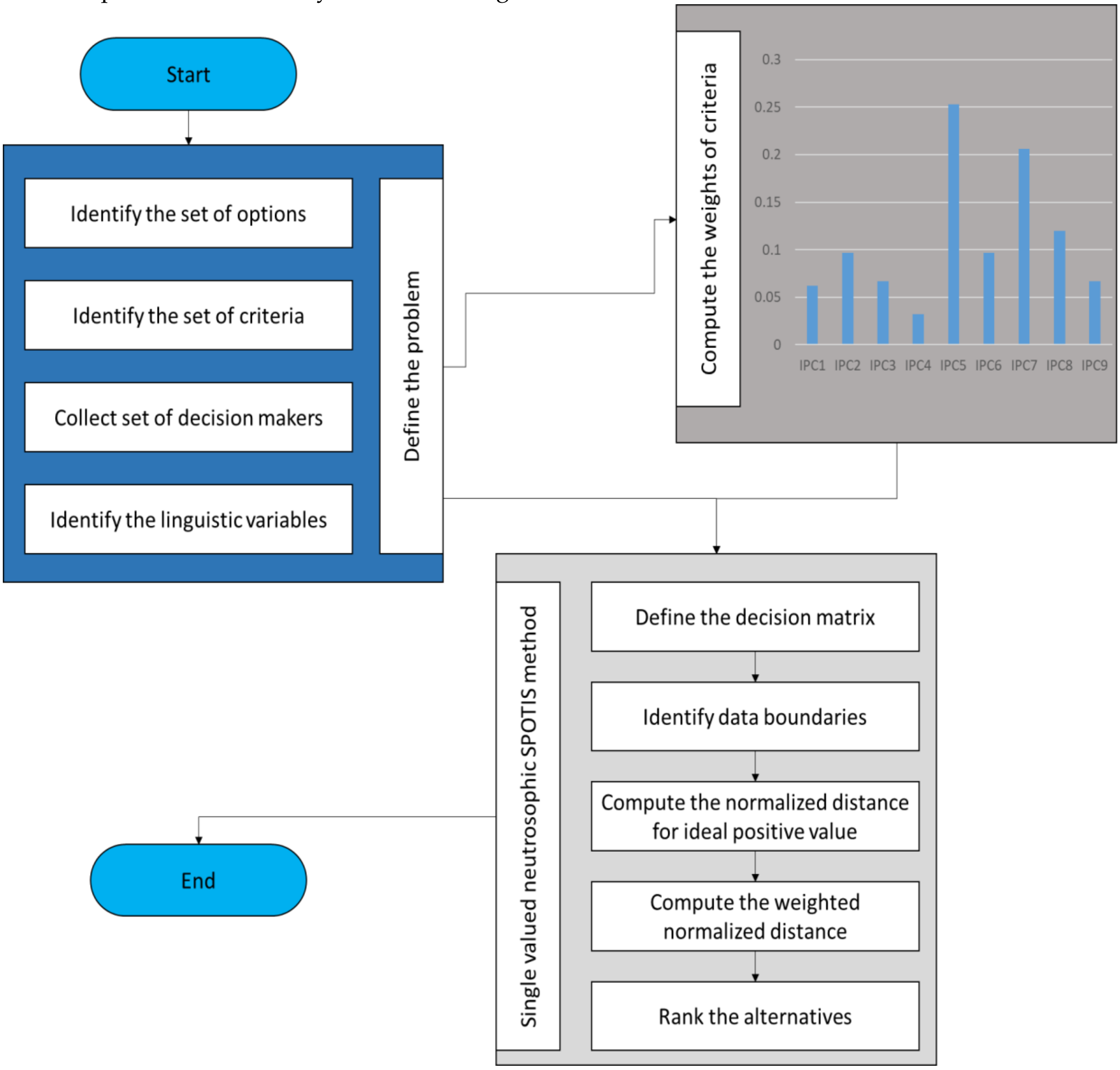

Figure 1. Single valued neutrosophic SPOTIS Methodology.

Step 1. Define the decision matrix. The decision matrix between criteria and alternatives is built by the decision-makers and experts.

Setp 2. Identify data boundaries. The ideal positive value for positive and negative criteria is identified as:

$$f_j^* = f_j^{max} \quad (1)$$

$$f_j^* = f_j^{min} \quad (2)$$

Where $j = 1,2, \dots n; i = 1,2, \dots m$ refer to the criteria and alternatives.

Step 3. Compute the normalized distance for the ideal positive value.

$$t_{ij}(X_i, f_j^*) = \frac{|f_{ij} - f_j^*|}{|f_j^{max} - f_j^{min}|} \quad (3)$$

Step 4. Compute the weighted normalized distance

$$t_{ij}(X_i, f^*) = \sum_{j=1}^{N} w_j t_{ij}\left(X_i, f_j^*\right) \quad (4)$$

Step 5. Rank the alternatives. The alternatives are ranked based on the lowest value of $t_{ij}(X_i, f^*)$.

4. Application in Investment Portfolio Selection

A person or organization's investment portfolio consists of the many securities it owns, such as stocks, bonds, mutual funds, and other debt and equity instruments. A portfolio of investments is assembled for the dual purposes of spreading out financial exposure and, hopefully, yielding a profit. Investment portfolio advantages consist of:

Management of risk and mitigation of the negative effects of market volatility may be achieved by diversification among diverse types of assets. Possibility of profit Capital appreciation, dividends, and interest all contribute to the ROI potential of a diversified investment portfolio. Investing portfolios are adaptable because their holdings may be changed when market circumstances and personal priorities shift. Effective tax planning allows investors to reduce their tax bill and boost their after-tax earnings.

Investment portfolio nine criteria include:

When putting up a portfolio, it is important to consider the investor's risk tolerance.

When deciding which assets to include in a portfolio, it is important to consider the investor's time horizon.

Portfolio construction should consider the investor's investing objectives, such as income creation or capital appreciation.

Diversification and risk management goals may be accomplished by careful planning of an investment portfolio's asset allocation among several asset classes including stocks, bonds, and cash. Assets, like stocks or mutual funds, should be chosen after careful consideration of their past performance, current management, and associated costs. Volatility and market value are also criteria of the portfolio.

We used nine criteria and ten alternatives in this paper. The experts evaluated the criteria and alternatives to build the decision matrix. Then we replace their opinions by using single-valued neutrosophic numbers. Then compute the normalization decision matrix by using Eq. (3) as shown in Table 1. Then compute the weights of the criteria by using the average method. Then multiply the weights of criteria by the normalization decision matrix to obtain the weighted normalized decision matrix as shown in Table 2. Then rank the alternatives by the distance of the ideal positive value as shown in Table 2. Alternative one is the best and alternative two is the worst.

Table 1. The normalized distance for the ideal positive value.

	IPC_1	IPC_2	IPC_3	IPC_4	IPC_5	IPC_6	IPC_7	IPC_8	IPC_9
IPA_1	0.846768	0.817056	0.844603	0.999181	0	0	0.999733	0	0.950372
IPA_2	0.847985	1	0.844603	0.664393	1	1	0.999966	0.995493	1
IPA_3	0.668109	0	1	0.545703	0.818306	0.849624	0.99991	1	0
IPA_4	0.009467	0.09216	0.710558	0.844611	1	1	0	0.904011	0.997767
IPA_5	0.820936	0.541953	0.844603	0.818554	0.818306	1	0.999966	0.89635	0.950372
IPA_6	1	1	0.829181	0.845839	0.375683	1	0.999966	0.89635	0.997767
IPA_7	0.668109	0.97249	0.836062	0	0.375683	0.75188	0.999966	0.995493	0.957816
IPA_8	0	0.817056	0	0.222374	0.554645	0	1	0.995493	1
IPA_9	0	0.969739	0.844603	1	0.699454	0.834586	0.999826	0.995493	1
IPA_{10}	0.144712	0.149931	0.132859	0.364256	0.553279	0	0.999966	0.995493	0.679901

Table 2. The weighted normalized distance for the ideal positive value.

	IPC_1	IPC_2	IPC_3	IPC_4	IPC_5	IPC_6	IPC_7	IPC_8	IPC_9	Rank Score
IPA_1	0.052452	0.078834	0.056537	0.032292	0	0	0.206252	0	0.063617	0.489984
IPA_2	0.052528	0.096486	0.056537	0.021472	0.253112	0.096486	0.2063	0.118931	0.066939	0.96879
IPA_3	0.041386	0	0.066939	0.017636	0.207123	0.081977	0.206288	0.11947	0	0.740818
IPA_4	0.000586	0.008892	0.047564	0.027297	0.253112	0.096486	0	0.108002	0.066789	0.608727
IPA_5	0.050852	0.052291	0.056537	0.026455	0.207123	0.096486	0.2063	0.107087	0.063617	0.866746
IPA_6	0.061944	0.096486	0.055504	0.027336	0.09509	0.096486	0.2063	0.107087	0.066789	0.813022
IPA_7	0.041386	0.093831	0.055965	0	0.09509	0.072546	0.2063	0.118931	0.064115	0.748163
IPA_8	0	0.078834	0	0.007187	0.140387	0	0.206307	0.118931	0.066939	0.618585
IPA_9	0	0.093566	0.056537	0.032319	0.17704	0.080526	0.206271	0.118931	0.066939	0.832128
IPA_{10}	0.008964	0.014466	0.008893	0.011772	0.140041	0	0.2063	0.118931	0.045512	0.55488

5. Conclusion

Choosing an investing portfolio is an involved procedure that must take many factors into account. Investors may create a balanced and diversified portfolio that meets their specific requirements and goals by considering their risk tolerance, time horizon, investing goals, asset allocation, and investment selection. A well-diversified investment portfolio may help you reach your long-term financial goals by reducing your risk exposure, increasing your earnings potential, giving you more options, and reducing your tax liability. Investors should frequently evaluate their holdings and update better suit their current situation and long-term objectives. This paper analysis the criteria of investment portfolio selection and rank the alternatives based on the MCDM methodology. The paper used the SPOTIS MCDM methodology to rank the alternatives. The SPOTIS method is integrated with the single-valued neutrosophic set to rank the alternatives.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

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

Ethical approval

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

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