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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.

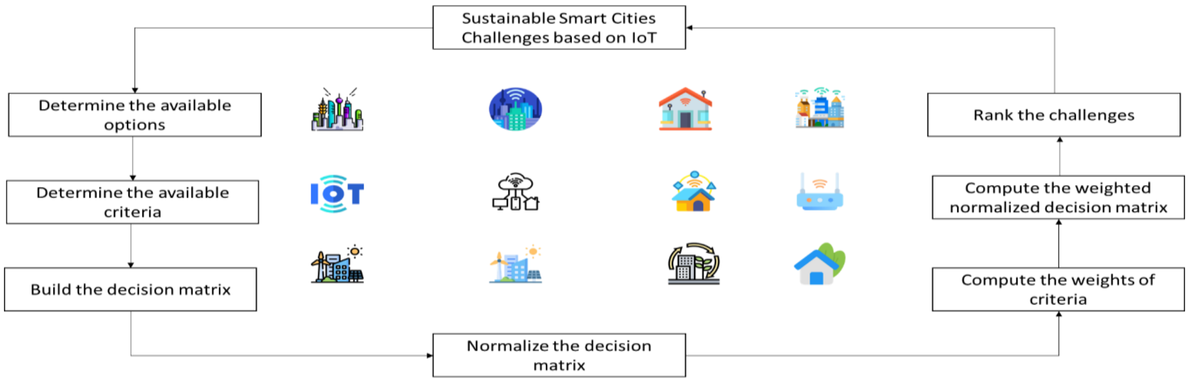

Figure 1. The ranking challenges of sustainable smart cities based on IoT.

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

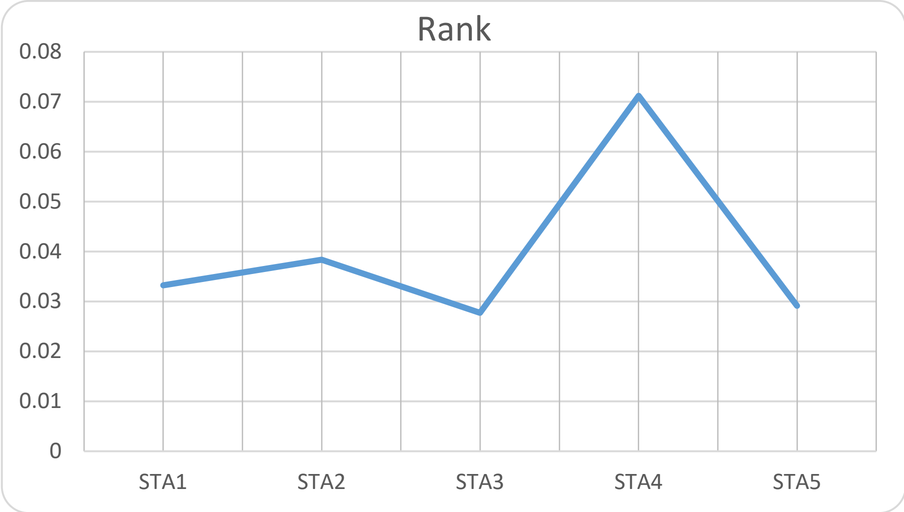

Figure 2. The orders challenges of smart sustainable cities based on IoT.

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.

References

1. S. Singh, P. K. Sharma, B. Yoon, M. Shojafar, G. H. Cho, and I.-H. Ra, "Convergence of blockchain and artificial intelligence in IoT network for the sustainable smart city," Sustain. Cities Soc., vol. 63, p. 102364, 2020.
2. F. A. Almalki et al., "Green IoT for eco-friendly and sustainable smart cities: future directions and opportunities," Mob. Networks Appl., pp. 1–25, 2021.
3. B. N. Silva, M. Khan, and K. Han, "Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities," Sustain. cities Soc., vol. 38, pp. 697–713, 2018.
4. E. F. I. Raj, M. Appadurai, S. Darwin, and E. F. I. Rani, "Internet of things (IoT) for sustainable smart cities," in Internet of things, CRC Press, 2022, pp. 163–188.
5. D. Kyriazis, T. Varvarigou, D. White, A. Rossi, and J. Cooper, "Sustainable smart city IoT applications: Heat and electricity management & Eco-conscious cruise control for public transportation," in 2013 IEEE 14th International Symposium on" A World of Wireless, Mobile and Multimedia Networks"(WoWMoM), IEEE, 2013, pp. 1–5.
6. S. Heitlinger, N. Bryan-Kinns, and R. Comber, "The right to the sustainable smart city," in Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, 2019, pp. 1–13.
7. M. A. Ahad, S. Paiva, G. Tripathi, and N. Feroz, "Enabling technologies and sustainable smart cities," Sustain. cities Soc., vol. 61, p. 102301, 2020.
8. A. H. Sodhro, S. Pirbhulal, Z. Luo, and V. H. C. De Albuquerque, "Towards an optimal resource management for IoT based Green and sustainable smart cities," J. Clean. Prod., vol. 220, pp. 1167–1179, 2019.
9. M. U. Farooq and M. Saqlain, "The selection of LASER as surgical instrument in medical using neutrosophic soft set with generalized fuzzy TOPSIS, WSM and WPM along with MATLAB coding," Neutrosophic Sets Syst., vol. 40, no. 1, p. 3, 2021.
10. A. Petrovas, R. Baušys, E. K. Zavadskas, and F. Smarandache, "Generation of creative game scene patterns by the neutrosophic genetic CoCoSo method," Stud. informatics Control, vol. 31, no. 4, pp. 5–11, 2022.
11. Z. Turskis, R. Bausys, F. Smarandache, G. Kazakeviciute-Januskeviciene, and E. K. Zavadskas, "M-generalised q-neutrosophic extension of CoCoSo method," Int. J. Comput. Commun. Control, vol. 17, no. 1, 2022.
12. M. A. Zaher and N. M. Eldakhly, "Integrated Multi-Criteria Decision Making Via Trapezoidal Neutrosophic Sets to Evaluate the Risks of Failure Mode," J. Neutrosophic Fuzzy Syst. Vol, vol. 5, no. 01, pp. 23–29, 2023.
13. S. E. Bibri, "The IoT for smart sustainable cities of the future: An analytical framework for sensor-based big data applications for environmental sustainability," Sustain. cities Soc., vol. 38, pp. 230–253, 2018.
14. S. Nižetić, P. Šolić, D. L.-I. Gonzalez-De, and L. Patrono, "Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future," J. Clean. Prod., vol. 274, p. 122877, 2020.
15. K. L. PRASAD, "Design of Green IoT for Sustainable Smart Cities and Eco-friendly Environment," 2023.
16. S. M. Nagarajan, G. G. Deverajan, P. Chatterjee, W. Alnumay, and V. Muthukumaran, "Integration of IoT based routing process for food supply chain management in sustainable smart cities," Sustain. Cities Soc., vol. 76, p. 103448, 2022.
17. S. Mukherjee, S. Gupta, O. Rawlley, and S. Jain, "Leveraging big data analytics in 5G-enabled IoT and industrial IoT for the development of sustainable smart cities," Trans. Emerg. Telecommun. Technol., vol. 33, no. 12, p. e4618, 2022.
18. P. Mishra, P. Thakur, and G. Singh, "Sustainable Smart City to Society 5.0: State-of-the-Art and Research Challenges," SAIEE Africa Res. J., vol. 113, no. 4, pp. 152–164, 2022.
19. L. Belli et al., "IoT-enabled smart sustainable cities: Challenges and approaches," Smart Cities, vol. 3, no. 3, pp. 1039–1071, 2020.
20. Y. Jararweh, S. Otoum, and I. Al Ridhawi, "Trustworthy and sustainable smart city services at the edge," Sustain. Cities Soc., vol. 62, p. 102394, 2020.
21. S. Gopikumar, S. Raja, Y. H. Robinson, V. Shanmuganathan, H. Chang, and S. Rho, "A method of landfill leachate management using internet of things for sustainable smart city development," Sustain. Cities Soc., vol. 66, p. 102521, 2021.

22. J. Huang, C.-C. Xing, S. Y. Shin, F. Hou, and C.-H. Hsu, "Optimizing M2M communications and quality of services in the IoT for sustainable smart cities," IEEE Trans. Sustain. Comput., vol. 3, no. 1, pp. 4–15, 2017.
23. H. Zahmatkesh and F. Al-Turjman, "Fog computing for sustainable smart cities in the IoT era: Caching techniques and enabling technologies-an overview," Sustain. Cities Soc., vol. 59, p. 102139, 2020.
24. Z. H. Ali and H. A. Ali, "Towards sustainable smart IoT applications architectural elements and design: opportunities, challenges, and open directions," J. Supercomput., vol. 77, pp. 5668–5725, 2021.
25. M. A. Khan and N. S. Alghamdi, "A neutrosophic WPM-based machine learning model for device trust in industrial internet of things," J. Ambient Intell. Humaniz. Comput., vol. 14, no. 4, pp. 3003–3017, 2023.
26. E. Boltürk, A. Karaşan, and C. Kahraman, "Simple additive weighting and weighted product methods using neutrosophic sets," Fuzzy multi-criteria Decis. using neutrosophic sets, pp. 647–676, 2019.

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