IJAER/ September-October 2021 /Volume-10/Issue-2 ISSN: 2278-9677
International Journal of Arts & Education Research

The Future of Fuzzy Logic in the Internet of Things (IoT) and Smart Cities

Wong Chung Tong

B. Tech Electrical Engineering, (Third Year-5th Semester)

Monad University, Hapur, Uttar Pardesh, India

kevinwong08gmail.com

Abstract: The application of fuzzy logic has become a potent instrument for improving decision-making in the intricate and constantly changing contexts of the IoT and intelligent urban communities. The objective of this abstract is to examine the ability of fuzzy logic to handle the intrinsic uncertainties linked to Internet of Things systems. These systems involve the production of large amounts of diverse data by interconnected devices. The application of principles derived from fuzzy logic enables smart cities to enhance urban mobility, boost energy efficiency, and optimize resource management. Moreover, this approach facilitates the generation of flexible judgements in real-time, considering a range of situations and client preferences. The application of fuzzy logic has the potential to greatly influence the advancement of IoT and smart city technologies. The reason for this is the increasing need for urban settings that include both technical sophistication and environmental sustainability.

Key words: Fuzzy Logic, Internet of Things (IoT), Smart Cities, Decision-Making, Resource Optimization, Urban Mobility, Real-Time Systems, Adaptive Systems

1. Introduction

Smart city efforts have been made possible by the proliferation of the Internet of Things, which has altered the traditional role of cities by facilitating the creation of more eco-friendly, efficient, and pleasant cityscapes. By utilizing technology, smart cities are able to improve infrastructure, raise living standards, and combat urban issues like pollution, traffic, and excessive energy usage. An intelligent urban ecosystem composed of networked IoT devices, such as sensors, actuators, smart meters, and linked cars, is essential to this goal because it will allow for the collection and analysis of massive volumes of data. The variety, quantity, and inherent uncertainties of real-world settings make this data a treasure trove of possibilities for improving city services, but it also poses new obstacles. Fast, accurate decision-making in the face of imperfect, noisy, or otherwise confusing data is a major obstacle for smart cities. This kind of ambiguity is typically too much for conventional decision-making systems that use strict logic or binary categories. True or false is the binary system's way of classifying circumstances, but in reality, things are rarely black and white. Fuzzy logic, on the other hand, provides a more versatile method of decision-making since variables in it might mean more than simply "yes" or "no." Fuzzy logic enables more nuanced solutions to complicated urban circumstances by handling degrees of truth, which accommodate uncertainty. In intelligent traffic management systems, for example, a lot of variables, like the time of day, the weather, and unforeseen events, can affect the amount of traffic on the roads. Fuzzy logic allows computers to act more naturally when interpreting data, rather than rigidly categorizing variables as either "moderate" or "heavy" with little room for nuance. Improved traffic flow and shorter commute times are the results of this capability's capacity to optimize traffic lights, public transportation timetables, and navigation routes. Using fuzzy logic has the potential to revolutionize smart city management in several crucial areas, including traffic, trash disposal, public safety, and energy usage. By using fuzzy logic into smart grids, energy managers can better respond to changing demand and environmental factors by determining the optimal times to store, distribute, or preserve energy. Similarly, smart sensors and fuzzy logic can optimize garbage collection routes in waste management by modifying schedules according to real-time bin fill levels, reducing operational expenses and wasted trips.

Fuzzy logic's flexibility is also essential for smart city applications that aim to provide individualized service. Fuzzy logic-based systems, for instance, can accommodate occupant comfort choices that do not neatly fit into "on/off" or "hot/cold" categories when it comes to smart home or office lighting, heating, or cooling. More accurate and responsive control means better energy efficiency and happier users. Future developments in the IoT are likely to see fuzzy logic play an increasingly important role in smart cities, allowing for the resolution of some of the most serious problems that cities face. Smart cities will thrive in the future when they are able to adapt to changing circumstances and make judgements based on real-time analysis of complicated and confusing data, rather than static algorithms developed for perfect settings. Future IoT smart cities will be shaped in large part by fuzzy logic, which provides a link between the real world's unpredictability and digital systems' ordered nature. Last but not least, smarter, more responsive urban infrastructures will be developed with the help of fuzzy logic in response to the rising demand for sustainable and efficient city administration brought about by more city-dwelling populations. Not only will fuzzy logic improve city operations, but it will also make cities more adaptable and people-centered by allowing rational decision-making even when faced with ambiguity. With its capacity to adapt to and understand the intricacies of contemporary city life, fuzzy logic has great promise for the IoT and smart cities of the future.

1.2 Background

Fuzzy logic and the IoTare being used in smart cities to help with managing the complexity and uncertainty that come with city life. However, the data produced by these systems is frequently characterised by ambiguity, inconsistency, and fluctuations, and cities are increasingly utilisingIoT technology to optimise services such as energy usage, public safety, and traffic control. Because of the difficulty in handling such unpredictability by conventional binary logic systems, fuzzy logic emerges as an essential tool. Fuzzy logic, first proposed by LotfiZadeh in 1965, facilitates decision-making according to degrees of truth, which helps systems handle imperfect input better. The initial implementations in fields such as energy management and traffic control proved that adaptive systems are capable of adapting to different urban environments. With the expansion of the IoT, fuzzy logic will play an increasingly important role in smart cities. This will allow for more sustainable urban systems that are able to respond to changes in real-time and make effective use of resources.

1.3 Understanding Fuzzy Logic in IoT and Smart Cities

There is a significant difference between conventional logic and fuzzy logic. Fuzzy logic models data as having varying degrees of truth rather than absolute true or false statements, which makes it possible to account for ambiguity and uncertainty. This is very helpful in smart cities because the data used for input is frequently not perfect, missing information, or affected by a lot of things that don't fit neatly into boxes.

Continual fluctuations in environmental data, such as humidity, air quality, and temperature, make it difficult to use absolute terms like high or low to describe all possible states. More nuanced interpretations, like slightly warm or moderately polluted are possible with fuzzy logic, allowing for more context aware decision-making.

For efficient city administration, this adaptability is vital in applications like as public health monitoring, energy management, and climate control, where exact but flexible responses are required.

The Role of IoT in Smart Cities

Smart cities rely on the IoT to build networks of interconnected devices that can exchange data and communicate in real-time. IoT devices supply decision-makers with raw data from a variety of sources, including smart traffic lights, surveillance systems, air quality sensors, and energy grids. Nevertheless, smart city IoT devices can produce an overwhelming amount of data. The real difficulty comes from trying to find useful insights in such massive amounts of data, most of which is unstructured, so that we can take swift and effective action.By improving the interpretative capacities of IoT systems, fuzzy logic provides a sophisticated answer to this problem. Smart city applications are able to make judgements in real-time, even with inadequate or ambiguous data, by processing it through fuzzy logic frameworks. For instance, utilizing IoT sensors to track traffic flow in conjunction with fuzzy logic algorithms allows for real-time light adjustments, congestion management, and the provision of best driving routes in response to changing circumstances. Fuzzy logic can also help smart grids better balance energy supply and demand by modifying power distribution based on interpretations of consumption patterns that fluctuate.

Fig 1 IoT& Smart City

Applications of Fuzzy Logic in Smart City Functions

Traffic Management: One of the most important concerns in smart city design is traffic management in crowded metropolitan areas. In this domain, fuzzy logic shines, enabling traffic control systems to fine-tune the timing of signals in real-time in response to variables such as traffic density, vehicle speed, weather, and road incidents. Better traffic flow, less congestion, and fewer pollution from idle cars are all results of this.

Energy Optimization: Time of day, weather, and human activity all play a role in the ebb and flow of urban energy usage. In order to maximize the distribution of energy, smart grids that use fuzzy logic can analyses data from various sensors. Accounting for unknown inputs like variable weather conditions, these systems can make decisions such as directing excess energy to storage during periods of low demand or changing power delivery to vital infrastructure during peak hours.

Environmental Monitoring and Public Health: In smart environmental monitoring systems, fuzzy logic is crucial. These systems employ data from internet of things (IoT) sensors to evaluate air quality, water levels, noise pollution, and other variables. Fuzzy logic is useful for real-time interpretation of environmental variables that are not easily categorized, such as when pollution levels reach a certain threshold or when public health warnings are issued due to hazardous conditions, since these variables tend to fluctuate and are not easily categorized.

Smart Buildings and Infrastructure: Smart buildings can benefit from fuzzy logic's ability to optimize HVAC systems, which in turn increases their intelligence. In order to better control indoor environments, it can analyses variables like occupancy levels, weather predictions, and personal preferences. This improves energy efficiency and occupant comfort.

Security and Surveillance: Fuzzy logic is being used more and more by smart city monitoring systems that are enabled by the Internet of Things to identify potential threats. Fuzzy logic enables security systems to evaluate complicated data inputs, such crowd density, movement patterns, and suspicious actions, to determine varied levels of risk rather than providing a binary alarm. Because of this, security and law enforcement organizations receive more precise, context-aware signals, allowing them to react faster to possible dangers.

1.4 Future Prospects: Evolving the Role of Fuzzy Logic in IoT and Smart Cities

Fuzzy logic will play an increasingly important role in smart cities as the Internet of Things (IoT) develops further. Complementing fuzzy logic, developments in machine learning and AI will enable systems to learn from historical data and enhance decision-making processes in an ongoing manner. For instance, hybrid systems that integrate AI and fuzzy logic will have the capability to adjust to new circumstances on their own, optimizing energy use and traffic patterns with even more accuracy. In addition, system development that can scale with the complexity of future cities will rely heavily on fuzzy logic, which is essential for sustainable and adaptable urban management as cities continue to expand. This involves dealing with the greater unpredictability and variability that will come with introducing new infrastructure, services, and technology. When it comes to managing the complexities of city life, fuzzy logic will be crucial in a future where smart cities depend on linked, adaptive systems. To sum up, fuzzy logic has a bright future in the IoT and smart cities. Innovation in smart city technology will be driven by its ability to handle complicated data, uncertainty, and ambiguity. This will make cities more efficient, responsive, and sustainable. Fuzzy logic will definitely continue to play a significant role in facilitating the evolution of smart cities, especially as the demand for intelligent urban solutions increases.

2. Literature Review

In 2024, Roy, Jana, and Mishra published a work. The purpose of this research is to provide smart city emergency vehicle routing systems based on linguistic interval type-2 fuzzy logic. Critical in metropolitan areas where real-time decision-making is important, the authors investigate ways to optimise emergency vehicle routing using IoT-enabled devices. The system is able to improve response times by using fuzzy logic to handle uncertainties, such as unforeseen traffic circumstances. By using soft computing approaches, the system becomes even more capable of handling massive volumes of data from several sources, guaranteeing the selection of the most efficient paths. Fuzzy logic has promise in smart city applications for managing complicated, real-time operations, according to this study.

In a recent publication by Kait, Kaur, Sharma, Ankita, Kumar, and Cheng (2024), For smart city vehicular cloud networks, Kait et al. present a trustworthy routing protocol based on fuzzy logic. Trust and security in data transfer between vehicles and the IoT infrastructure are major challenges that the study tackles. Improved communication reliability and security between vehicles are the results of the authors' use of fuzzy logic to assess the degree of trust between various parts of the infrastructure and individual vehicles. The study adds to the growing body of work on secure IoT frameworks by developing a protocol that can dynamically adjust to trust assessments; these frameworks are becoming more and more important for smart city operations.

A. A. Dasel, S. Kadry, and C. Ming (2024) The use of a context-based fuzzy logic system for the automation of smart home IoT devices is the focus of this article. The difficulties of controlling smart home gadgets, especially those that need to be adjusted to different indoor and outdoor environments, are the main points of discussion among the writers. To account for these differences, smart devices can use fuzzy logic to make better, more context-aware decisions. For instance, climate control systems can modify the air conditioning or heating settings in response to outside conditions and internal activity. An essential part of the larger smart city framework, this work shows how fuzzy logic is key to improving user comfort and energy efficiency in smart homes.

This sentence is a citation for a work by Selvarajan, Manoharan, Iwendi, Al-Shehari, Al-Razgan, and Alfakih (2023). In order to build a safe smart city monitoring system, our research merges the benefits of neuro-fuzzy procedures with blockchain technology. The research demonstrates the ability of neuro-fuzzy systems to handle massive IoT networks in real-time and adapt to changing environmental conditions. Data collected by several Internet of Things (IoT) sensors is further safeguarded by blockchain technology. With these two technologies working together, a solid foundation can be built for tracking vital smart city metrics like pollution, energy consumption, and traffic. For smart city management to be both effective and secure, this work emphasises the need of an interdisciplinary approach.

Al-Turjman, F., Kumar, M., and Stephan, T. (2023) are the authors of the article. An eco-friendly and sustainable Internet of Things (IoT) network in a smart city can be built with the help of this study's newly developed neuro-fuzzy dynamic clustering scheme. The major goal is to make Internet of Things devices use less energy while still allowing them to communicate effectively. Based on factors such as energy consumption, communication requirements, and surrounding conditions, the system uses neuro-fuzzy logic to automatically group devices into clusters. The authors prove that this method helps smart cities last longer by increasing the useful life of Internet of Things devices. In order to achieve sustainable urban development over the long run, this study highlights the significance of designing energy-efficient IoT networks.

In 2022, Bhardwaj, Banyal, Sharma, and Al-Numay published a paper. In order to improve smart city plans, Bhardwaj et al. look at the ways in which fog computing and fuzzy logic might collaborate. By distributing computing power closer to the points of data collection, fog computing helps Internet of Things (IoT) devices deal with latency. Fuzzy logic is a powerful tool that these systems can use to make ambiguous decisions in real-time. Tasks like traffic control, environmental monitoring, and allocating resources benefit greatly from this combination. The research shows that fuzzy logic and fog computing can handle the increasing complexity of smart city infrastructures in a scalable way.

In 2022, Hingmire and Bhaladhare An integral part of smart city catastrophe management plans, fuzzy logic is investigated in this research as it pertains to urban flood control systems. Fuzzy logic systems analyse data from

IoT devices that track urban weather, rainfall, and water levels in order to forecast when floods may occur. After that, the system can take precautions like notifying the public or rerouting the water supply. The research shows that fuzzy logic works well with changing and unpredictable situations, thus it could be used to make cities more resistant to natural catastrophes.

Researchers Rejeb, K., Treiblmaier, H., Simske, S., and Zailani, S. (2022) Fuzzy logic plays a key role in enhancing decision-making processes, and this thorough examination focusses on how the IoT and smart city applications meet. Fuzzy logic can be useful in many domains, including energy optimisation, waste management, and traffic control, as the authors point out. They stress the significance of studying how smart city infrastructures can be improved by further integrating fuzzy logic with AI, ML, and other cutting-edge technologies in the future. For a comprehensive grasp of fuzzy logic's effect on smart city IoT systems, this review is invaluable.

In 2022, Raj, Appadurai, Darwin, and Rani published a paper. The Internet of Things (IoT) is the central topic of Raj et al.'s study on smart city sustainability efforts. Fuzzy logic's adaptive decision-making based on real-time data helps optimise resource management, including water and energy usage. Using case examples, the research demonstrates how fuzzy logic can enhance resource allocation and decrease energy consumption. If we want to build sustainable smart cities that don't harm the environment, we need to know how fuzzy logic helps with that. This study fills that gap.

In 2022, Hosseinzadeh, Hemmati, and Rahmani came out with a publication. Focussing on how fuzzy logic might improve clustering performance, this review paper examines clustering approaches in IoT networks for smart cities. When it comes to handling massive IoT systems, clustering is king. It streamlines data routing, reduces energy consumption, and boosts network efficiency. In order to enhance communication between Internet of Things devices in smart cities, the authors examine numerous fuzzy-based clustering techniques. Fuzzy logic's adaptive clustering process management is demonstrated in the research, which guarantees optimal performance regardless of changes in the network.

3. Methodology

This methodology takes a multi-disciplinary approach to investigate potential applications of fuzzy logic in smart cities and the IoT. This approach covers study design, theoretical analysis, and ethical issues. This approach guarantees a thorough comprehension of how fuzzy logic may improve smart cities driven by the Internet of Things and tackle real-life urban problems.

Research Design

Fuzzy logic integration into Internet of Things (IoT) systems for smart cities is the focus of this qualitative exploratory study. Case studies of current smart city projects utilizing fuzzy logic for energy efficiency, urban mobility, and traffic management will be examined in the study. The research seeks to demonstrate how fuzzy logic improves decision-making in uncertain contexts by analyzing these case studies for trends and outcomes. To further understand the possibilities and difficulties of using fuzzy logic in actual Internet of Things systems, we will conduct interviews with engineers, urban designers, and specialists in the field. Additionally, many smart city scenarios will be modelled using a simulation-based method. For instance, in order to evaluate the efficacy of fuzzy logic algorithms compared to conventional binary logic systems, we will model traffic flow optimization and energy grid management. Fuzzy logic's impact on smart city decision-making in terms of adaptability and efficiency can be empirically evaluated with the help of these simulations.

Theoretical Analysis

LotfiZadeh's fuzzy logic principles, which stress the management of uncertainty and the processing of partial truth values, provide the theoretical basis for the research. Fuzzy logic's special fit for Internet of Things (IoT) applications will be examined in this study. IoT applications frequently deal with imperfect and inaccurate data collected from a wide variety of linked devices. Urban data uncertainty, resource optimization, and real-time decision-making are some of the important topics that will be covered in the study. Additionally, the theoretical study will look at how smart city systems might benefit from fuzzy logic algorithms combined with AI and machine learning. By combining AI's predictive capability with fuzzy logic's capacity for handling ambiguity, we can learn more about the future of intelligent and autonomous urban systems. This hybrid method will be investigated to better comprehend this potential.

Ethical Considerations

Concerns about privacy, data security, and equity are at the forefront of the ethical issues brought up by fuzzy logic's use in the Internet of Things and smart cities. Worries regarding the processing and storage of personally identifiable information have arisen in response to the massive amounts of data collected by IoT systems from individuals. In order to make sure that data protection rules like the GDPRare followed and that privacy rights are respected during data collection and processing, we will be creating ethical principles. In addition, the study will think about how fuzzy logic systems can lead to biased decisions. It is critical to make sure that decisions made with fuzzy logic are fair and don't impact particular groups more than others, even when fuzzy logic enables more nuanced decisions. This research will look at ways to make smart city systems more open and equitable by reducing the impact of bias in fuzzy logic algorithms. Furthermore, we will discuss the ethical aspects of smart city sustainability. Fuzzy logic has the potential to help make cities greener and more livable for everyone, and this study will look at that possibility. The project aims to help the creation of smart cities that are intelligent, just, and sustainable by ensuring that these systems are technically and ethically sound.

4. Finding & Discussion

Findings

Enhanced Decision-Making Capabilities: Fuzzy logic, when combined with the IoT, allows smart cities to handle the inherent uncertainties and imprecisions in urban data, greatly improving decision-making. Evidence from real-world applications suggests thatfuzzy logic systems, such those employed in energy optimization and traffic management, are better able to adjust to changing circumstances than their binary counterparts. Fuzzy traffic controllers, for instance, have proven themselves capable of dynamically adjusting signal timings and managing fluctuating traffic flows, which in turn reduces congestion and increases traffic efficiency.

Improved Resource Management: Smart city resource management is made more efficient with the help of fuzzy logic algorithms. By analyzing changing consumption patterns and environmental factors, fuzzy logic helps smart grids achieve better supply-and-demand balance in energy management. Fuzzy logic also aids water management in optimizing resource distribution using real-time data from sensors tracking water levels and consumption.

Increased Flexibility and Adaptability: Fuzzy logic's adaptability makes it a good fit for smart city systems, which can deal with a broad variety of situations with different levels of accuracy. This flexibility is on display in smart building climate control, for example, where systems based on fuzzy logic modify HVAC settings according to complex user preferences and environmental data. As a result, indoor spaces become more customized while also reducing energy consumption.

Challenges and Limitations: There are certain obstacles to using fuzzy logic in IoT systems, even if it has many benefits. Fuzzy logic controllers are complex, time-consuming, and resource-intensive to develop and tune, which can be a hurdle. The clarity of the underlying data and the construction of the fuzzy rules determine the quality of the decision-making process; furthermore, fuzzy logic aids in the management of uncertainty but does not eradicate it.

Ethical and Equity Concerns: Concerns about data privacy, security, and equity arise as a result of smart city implementations utilizing fuzzy logic. It is critical to make sure that fuzzy logic systems don't make biased decisions and handle sensitive data properly. To overcome these concerns and establish trust in smart city technology, research emphasizes the requirement of open algorithms and strong privacy safeguards.

Discussion

The results highlight fuzzy logic's revolutionary potential for smart city Internet of Things (IoT) system enhancement. Fuzzy logic is a huge step up from the old binary methods since it handles the unpredictability and uncertainty that come with city life. Its enhanced data processing capabilities enable more refined real-time decision-making, which in turn improves resource allocation, energy usage optimization, and traffic management. Smart cities, with their ever-changing conditions and frequently inaccurate data, are ideal environments for fuzzy logic because to their adaptability and flexibility. Fuzzy logic's proven track record of success in fields like energy management and traffic control proves that it can help build smarter, more efficient city systems. Fuzzy logic's incorporation with other new technologies, such as artificial intelligence and machine learning, holds significant potential for the future of smart city technology, opening the door to increasingly autonomous and intelligent methods of city management.

To reach their full potential, however, fuzzy logic systems must first overcome the obstacles that come with their implementation. Some applications may not be able to make use of fuzzy controllers due to the fact that they are sophisticated and require specialized knowledge and resources to create and tune. To further guarantee the responsible and equitable use of smart city technology, it is necessary to meticulously handle the ethical concerns pertaining to data privacy and equity. To sum up, fuzzy logic provides useful tools for handling the complexity of urban surroundings and therefore has a bright future in the creation of smart cities. It will be an important component of the IoT applications of the future because of its capacity to deal with uncertainty and offer adaptive solutions. Continuous improvement of fuzzy logic systems, resolution of implementation issues, and maintenance of ethical standards are necessary for it to realize its full potential. Smart cities of the future will be smarter, more efficient, and more egalitarian thanks to the continuous use of fuzzy logic.

5. Conclusion

To sum up, smart city development has reached a critical juncture with the incorporation of fuzzy logic into the IoT. In today's data-driven and complicated metropolitan environments, fuzzy logic provides a solid foundation for handling uncertainty and unpredictability in real-time decision-making. Better traffic management, energy optimization, and resource allocation are all outcomes of its capacity to analyses data in degrees of truth instead of binary values, which increases the responsiveness and adaptability of smart city systems. The study shows that fuzzy logic is great at dealing with the uncertain and ever-changing data produced by IoT devices because of its flexibility. Urban dwellers' requirements can be better met with the help of smarter, more individualized solutions made possible by fuzzy logic's more sophisticated control and interpretation of varied data inputs. To alleviate traffic, control energy usage, enhance environmental monitoring, and ensure public safety—all of which are complex problems in today's cities—this capability is essential. There are a number of obstacles that must be overcome before fuzzy logic can be effectively used in smart cities. Fuzzy systems require ongoing research and improvement due to their complexity, which is further compounded by ethical concerns surrounding data privacy and justice. For fuzzy logic systems to be widely used and effective, it is crucial that they are both technically sound and ethically accountable. In the future, smart city systems will be even more advanced thanks to the combination of fuzzy logic with new technologies like AI and ML. Fuzzy logic's future in IoT smart cities could be even more innovative and efficient if it takes use of these developments. Future urban management will be heavily influenced by fuzzy logic as cities embrace new technologies. This will help create smarter, more sustainable, and more equitable environments.

Reference

[1] Roy, S., Jana, D. K., & Mishra, A. (2024). Linguistic interval type 2 fuzzy logic-based exigency vehicle routing: IoT system development for smart city applications with soft computing-based optimization. *Franklin Open*, *6*, 100057.

[2] Kait, R., Kaur, S., Sharma, P., Ankita, C., Kumar, T., & Cheng, X. (2024). Fuzzy logic-based trusted routing protocol using vehicular cloud networks for smart cities. *Expert Systems*, e13561.

[3] Ming, C., Kadry, S., &Dasel, A. A. (2024). Automating smart Internet of Things devices in modern homes using context-based fuzzy logic. *Computational Intelligence*, *40*(1), e12370.

[4] Selvarajan, S., Manoharan, H., Iwendi, C., Al-Shehari, T., Al-Razgan, M., &Alfakih, T. (2023). SCBC: Smart city monitoring with blockchain using Internet of Things for and neuro fuzzy procedures. *Mathematical Biosciences and Engineering*, *20*(12), 20828-20851.

[5] Chithaluru, P., Al-Turjman, F., Kumar, M., & Stephan, T. (2023). Energy-balanced neuro-fuzzy dynamic clustering scheme for green & sustainable IoT based smart cities. *Sustainable Cities and Society*, *90*, 104366.

[6] Bhardwaj, K. K., Banyal, S., Sharma, D. K., & Al-Numay, W. (2022). Internet of Things based smart city design using fog computing and fuzzy logic. *Sustainable Cities and Society*, *79*, 103712.

[7] Hingmire, A. M., &Bhaladhare, P. R. (2022). Urban flood control system using fuzzy logic and Internet of Things (IoT) for smart city. *NeuroQuantology*, *20*(19), 115.

[8] Rejeb, A., Rejeb, K., Simske, S., Treiblmaier, H., &Zailani, S. (2022). The big picture on the Internet of Things and the smart city: A review of what we know and what we need to know. *Internet of Things*, *19*, 100565.

[9] Raj, E. F. I., Appadurai, M., Darwin, S., & Rani, E. F. I. (2022). Internet of Things (IoT) for sustainable smart cities. In *Internet of Things* (pp. 163-188). CRC Press.

[10] Hosseinzadeh, M., Hemmati, A., &Rahmani, A. M. (2022). Clustering for smart cities in the Internet of Things: A review. *Cluster Computing*, *25*(6), 4097-4127.

[11] de Oliveira, G. G., Iano, Y., Vaz, G. C., Negrete, P. D. M., Negrete, J. C. M., &Chuma, E. L. (2021, December). Intelligent mobility: A proposal for modeling traffic lights using fuzzy logic and IoT for

smart cities. In *International Conference on Soft Computing and its Engineering Applications* (pp. 302-311). Springer International Publishing.
[12] Ashraf, S. (2021). A proactive role of IoT devices in building smart cities. *Internet of Things and Cyber-Physical Systems*, *1*, 8-13.
[13] Al Kindhi, B., &Pratama, I. S. (2021, April). Fuzzy logic and IoT for smart city lighting maintenance management. In *2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT)* (pp. 369-373). IEEE.
[14] Zhang, C. (2020). Design and application of fog computing and Internet of Things service platform for smart city. *Future Generation Computer Systems*, *112*, 630-640.
[15] Rout, R. R., Vemireddy, S., Raul, S. K., &Somayajulu, D. V. (2020). Fuzzy logic-based emergency vehicle routing: An IoT system development for smart city applications. *Computers & Electrical Engineering*, *88*, 106839.
[16] Abbate, T., Cesaroni, F., Cinici, M. C., &Villari, M. (2019). Business models for developing smart cities: A fuzzy set qualitative comparative analysis of an IoT platform. *Technological Forecasting and Social Change*, *142*, 183-193.
[17] Kumar Kashyap, P., Kumar, S., Dohare, U., Kumar, V., &Kharel, R. (2019). Green computing in sensors-enabled Internet of Things: Neuro-fuzzy logic-based load balancing. *Electronics*, *8*(4), 384.
[18] Khan, A., & Abbas, S. (2018). Intelligent transportation system for smart cities using fuzzy logic. *Lahore Garrison University Research Journal of Computer Science and Information Technology*, *2*(2), 64-79.
[19] Iqbal, K., Khan, M. A., Abbas, S., Hasan, Z., & Fatima, A. (2018). Intelligent transportation system (ITS) for smart cities using Mamdani fuzzy inference system. *International Journal of Advanced Computer Science and Applications*, *9*(2).
[20] Meana-Llorián, D., García, C. G., G-bustelo, B. C. P., Lovelle, J. M. C., & Garcia-Fernandez, N. (2017). IoFClime: The fuzzy logic and the Internet of Things to control indoor temperature regarding the outdoor ambient conditions. *Future Generation Computer Systems*, *76*, 275-284.
[21] https://external-content.duckduckgo.com/iu/?u=https%3A%2F%2Fwww.datasciencecentral.com%2Fwp-content%2Fuploads%2F2022%2F08%2FIoT-and-Smart-city.jpg&f=1&nofb=1&ipt=a4e1151b070a0b96fd8fd9b3672baf45aeb9442c8865b0568bb218c7a16ec7bf&ipo=images