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Application of fuzzy logic to manage traffic flows in cities

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Abstract. The relevance of the study was driven by the need to improve the efficiency of urban traffic flow regulation in order to enhance the environmental situation, reduce congestion, and stimulate economic development. Modern traffic control methods based on fixed traffic light schedules are unable to adapt to atypical and unpredictable road situations. The aim of this study was to develop a traffic flow management model based on fuzzy logic methods. The research methodology involved the construction of a fuzzy inference model that transforms input parameters (traffic intensity, waiting time, accident data) into linguistic variables and automates decision-making processes for traffic light settings. Simulation modelling of the system's operation under various traffic and weather conditions was carried out using the developed model. An adaptive traffic flow control system was developed that can respond in real time to changes in road conditions. It was established that implementing the proposed model reduces the average vehicle waiting time by 25%, decreases the number of vehicles stopping at intersections by 7%, and increases the number of vehicles passing through intersections by 6%. The efficiency of the proposed system was analysed in comparison with standard traffic light control methods. The potential for expanding the model's functionality was evaluated, particularly to incorporate additional input parameters such as prioritisation of public transport, pedestrians, and emergency services. The practical value of this study lies in the possibility of applying its results by professionals in urban planning, intelligent transportation systems, and traffic logistics to optimise the operation of traffic signal systems in urban areas

Keywords: intelligent regulation; adaptive control; fuzzy inference algorithms; urban mobility; traffic signal automation; linguistic variable

INTRODUCTION

Every year, cities face a significant increase in the number of vehicles, leading to increased traffic flows and road congestion. Traffic congestion was a critical issue that needed to be addressed to improve the economic prosperity of any country. Traditional traffic management mechanisms, such as fixed-time traffic light systems, are insufficient to solve the growing problem of heavy congestion due to the increase in the number of vehicles on the roads. The specificity of this problem was that traffic flow management was very often associated with unclear or not fully defined circumstances. Traffic management was closely related to parameters such as time, day, season, weather and unpredictable circumstances. By controlling traffic lights, it was

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possible to create conditions for the best throughput capacity at intersections.

The article by P. Michailidis *et al.* (2025) considered the approach to traffic management using Reinforcement Learning (RL) as a promising, data-driven solution. RL allows the system to independently learn optimal actions in real time based on rewards for achieving certain goals, such as reducing congestion or waiting times. The article presented a comprehensive characterisation of reinforcement learning technologies in the context of traffic light control, with a detailed classification of methods by type of RL algorithms, agent architecture (in particular multi-agent approaches), reward system design, baseline methods for comparison, road network types, and simulation platforms. The authors systematised modern approaches, outlining the key technical differences between them and how they are implemented.

In their work, N. Kumar *et al.* (2021) noted that traditional traffic light control systems based on fixed time intervals or time of day are often ineffective in dynamic traffic conditions, especially during accidents, traffic jams, or other atypical situations. To solve these problems, the authors proposed using fuzzy logic-based systems that allow for adaptive responses to changes in traffic conditions. Fuzzy logic makes it possible to formalise subjective assessments of the state of an intersection, such as "high traffic density" or "reduced visibility due to weather conditions," using linguistic variables and fuzzy sets. The advantages of such systems lie in their ability to quickly adapt to changes in traffic flows, which provides more effective regulation compared to traditional methods. At the same time, as in previous studies, the authors pointed out the disadvantages: the need for careful tuning of fuzzy models and training of personnel for their implementation and maintenance. Unlike classical systems, which are standardised and do not require additional configuration, fuzzy logic-based systems require integration with motion sensors and software, which can complicate their implementation in urban environments.

The application of fuzzy logic in the process of managing traffic flows in cities has been published in several scientific works. The article by M.S. Bhatia & A. Aggarwal (2020) presented a traffic light timing control system that adapts to real traffic based on three parameters: queue length, vehicle arrival rate, and peak hour intensity. The authors implemented a fuzzy controller that allows the green phase time to be flexibly changed to 28 seconds instead of a fixed 60 seconds. Compared to traditional systems, the new approach provided an improvement of 6-47% depending on the traffic situation. In a study by Y. Bi *et al.* (2024), an intelligent traffic light control system based on second-order fuzzy logic and reinforcement learning algorithms was proposed. The developed approach made it possible to effectively reduce delays and queue lengths in traffic flow by adapting to dynamic changes in traffic intensity. The authors emphasised the advantages of using second-order fuzzy logic to handle uncertainties in input data and improve real-time decision-making.

Among Ukrainian authors, the work of V. Gandrybida *et al.* (2024) was considered, which examined modern methods of automated traffic control based on fuzzy logic, which allow processing incomplete or inaccurate information – a characteristic feature of dynamic road conditions. The authors evaluated the prospects and challenges of introducing fuzzy logic into transport system management to improve road traffic efficiency and safety. Particular attention was paid to integration with intelligent transport systems, artificial intelligence and Internet of Things technologies. The article by V. Shevchenko (2023) presents the priorities for the development of a network of local traffic light objects in Ukrainian cities. The author analysed modern traffic light control methods, in particular adaptive and coordinated control, and compared their effectiveness. It was found that the combined use of both approaches provides significantly better results than the use of each separately. This indicates the feasibility of coordinating traffic lights as a priority direction for the development of traffic management systems in cities.

The article by A. Agrahari *et al.* (2024) provides a comprehensive review of adaptive traffic light control systems based on artificial intelligence. The authors classified the approaches according to the number of intersections and the methods used, in particular fuzzy logic, metaheuristic algorithms, dynamic programming, reinforcement learning, and hybrid models. The analysis showed that such systems can significantly reduce traffic delays, improve traffic efficiency, and reduce harmful emissions. Another approach was demonstrated by M. Li *et al.* (2025), who created a two-stage fuzzy model called FuzzyLight that works in noisy or incomplete data conditions. In real-world experiments, the system improved intersection efficiency by 48%, demonstrating its reliability even in unstable environments. The aim of the study was to improve the process of managing traffic flows in cities by increasing the throughput of a controlled intersection or a single traffic light.

MATERIALS AND METHODS

In this study, the structure of the fuzzy controller shown in Figure 1 was used to better understand the principles of its operation, the relationships between individual blocks, and the methods of processing input and output data in the control process.

A fuzzy control model based on a system of rules that operate with fuzzy logical variables and implement a fuzzy logical inference mechanism for decision making. A fuzzy logic controller describes the control protocol using "if-then" rules. The necessary parameter values are fed into the controller. These are the values that the controller must maintain during its operation. The error value is calculated using an adder, which is usually obtained as the difference between the required value and the output signal. The error is sent to the controller, which calculates the error values of three components: proportional, integral and differential. The generated signal is transmitted to the control element, which directly affects the parameters. In this case, it is the green traffic light signal time. The result of the operation directly affects the values of the controlled parameters. This new value is transmitted back to the input to determine the new error value.

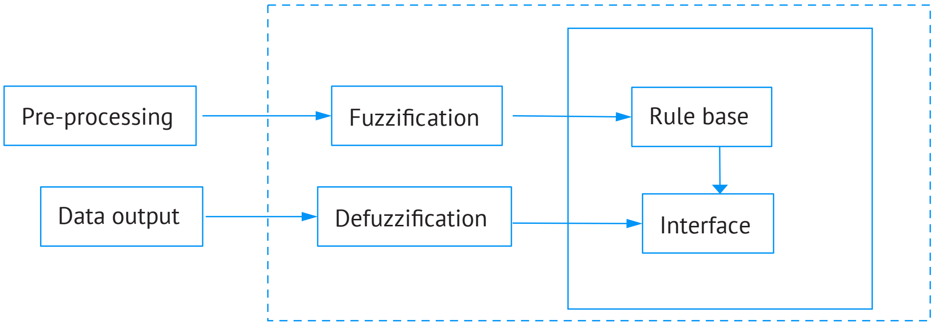


Figure 1. General structure of a fuzzy controller

Source: developed by the authors

As shown in Figure 2, if at a given moment in time the traffic light is green for the north and south sides of the intersection, these will be the sides of passing vehicles, while the west and east sides will be considered the waiting sides, and vice versa. The output fuzzy variable will be the green light duration on the passing sides. Thus, based on current traffic conditions, fuzzy rules can be formulated so that the output of the fuzzy controller increases or does not increase the current green light time. If the current green time is not extended, the traffic light status will immediately change to another status, allowing traffic from the alternative phase to move. During adverse weather conditions, in this case fog, the green signal time will also be increased for safety reasons.

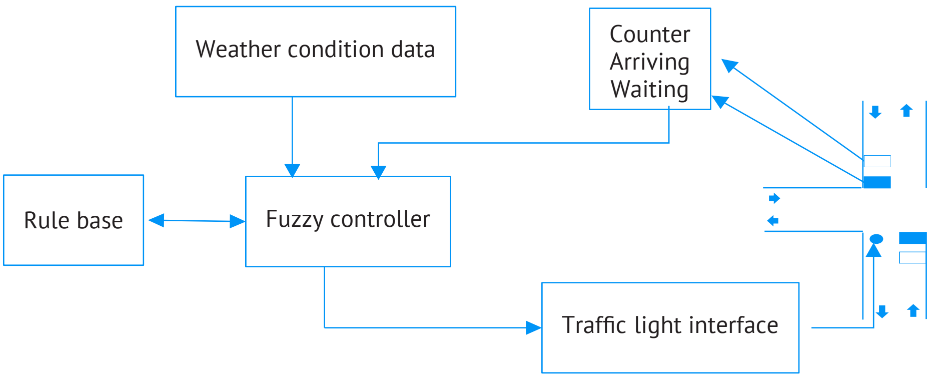


Figure 2. Structure of a traffic light controller based on fuzzy output

Source: developed by the authors

In the proposed fuzzy logic signal controller, three fuzzy input variables are selected, namely: the number of vehicles arriving at the intersection or the number of vehicles passing during the green light (Arriving Vehicles), the number of vehicles waiting in queue at the intersection, or the number of vehicles waiting during the red light (Queuing Vehicles), weather change (Humidity or Fog). The duration of the green light is the output variable, which provides the necessary extension time for the green light on the arrival side. The triangular shape of the membership functions representing fuzzy numbers was chosen because it is often used in many applications due to its computational efficiency. A graphical representation of the membership functions of the input and output variables is shown below. The volumes of arriving and queuing traffic have (Low – L, Medium – M, High – H) vehicles, as well as the weather factor fog has (Low – L, Medium – M, High – H) and the duration of the green time has (Short – S, Medium – M, Long – L).

For input fuzzy variables for arriving vehicles and vehicles in the queue, the x-axis is the number of vehicles; for fog, it is the visibility range in metres, and the y-axis for all input variables varies from 0 to 1. The result of the output fuzzy variable is the duration of the signal, which will be extended in seconds. To implement the fuzzy logic inference module, the scikit-fuzzy package was selected – a set of tools for manipulating fuzzy logic devices in the Python programming language. This package simplifies the creation of fuzzy variables, term formation, rule-based formation, and the fuzzification process.

Based on the formed knowledge base, a three-dimensional surface of the control module solution can be constructed. The graphical representation of the surface of the fuzzy logic inference module solutions is an important tool for analysing the effectiveness of intelligent control systems, in particular systems based on fuzzy logic. Such a surface visualises the relationship between the input linguistic variables and the obtained output values, allowing the researcher to better understand the behaviour of the system in different traffic situations. The decision surface is formed after the construction of the fuzzy logic inference rule base, the phasing of the input data, the application of the logical inference mechanism, and the defuzzification procedure. In a three-dimensional graph, one axis represents the first input variable (e.g., the number of arriving vehicles), the second axis represents another input variable (e.g., fog intensity), and the third axis represents the result – the output variable (the green light duration).

This approach allows for a visual check of the consistency and logic of the rules that have been formed. The researcher can identify potentially illogical or overly abrupt changes in signal control that do not correspond to the expected behaviour of the system. In addition, graphical representation facilitates the optimisation of control rules to achieve better performance, reduce congestion and increase intersection capacity. The SUMO environment was chosen for testing traffic flows. SUMO allows to simulate intermodal transport systems, including road vehicles, public transport and pedestrians. SUMO comes with a bunch of helper tools that do things like route finding, visualisation, network import, and emissions calculation. SUMO can be enhanced with custom models and provides various APIs for remote control of the simulation.

RESULTS AND DISCUSSION

Table 1 presents the developed ranges of values for input and output variables used in the fuzzy traffic light control model. Specifically, the input variables are the number of arriving and waiting vehicles, as well as the fog level (visibility). The output variable is the green light duration. For each variable, numerical ranges and corresponding linguistic evaluations are specified: "low", "medium", "high".

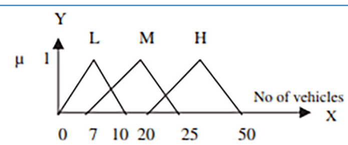
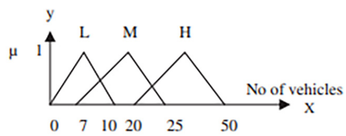
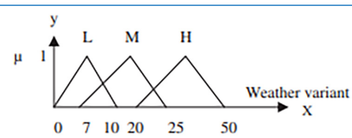
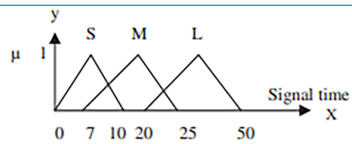
Table 2 is created for the input variables (vehicles and fog), the values are given as the number of cars or visibility in metres, and the membership functions range from 0 to 1. The output variable – the duration of the green signal in seconds.

Table 1. Range of input and output variables

Arriving Vehicles		Queued vehicle		Fog		Green light duration	
Quantity	Linguistic variable	Quantity	Linguistic variable	Visibility (in m.)	Linguistic variable	Duration (in sec.)	Linguistic variable
0-10	Low	0-10	Low	1,000-1,500	Low	0-10	Short
7-25	Medium	7-25	Medium	400-1,200	Medium	8-30	Medium
20-50	High	20-50	High	50-500	High	25-60	Long

Source: developed by the authors

Table 2. Graphical representation of membership functions of linguistic variables

		Functions	Diagram
Input	Arriving Vehicles	Low Medium High	
	Queued vehicle	Low Medium High	
	Fog	Low Medium High	
Output	Green light duration	Short Medium Long	

Source: developed by the authors

Based on three input variables, 27 fuzzy rules were formed, which determine the logic of the system's functioning and allow obtaining the corresponding value of the output variable, as shown in Table 3. A three-dimensional decision surface of the fuzzy control module was created, which visualises the dependence between the input parameters (e.g., the number of vehicles and the fog level) and the output variable – the duration of the green traffic light signal. This graphical representation, shown in Figure 3, allows analysing the logic of the decisions made, identifying possible errors in the system of rules, and improving algorithms to increase the efficiency of traffic management.

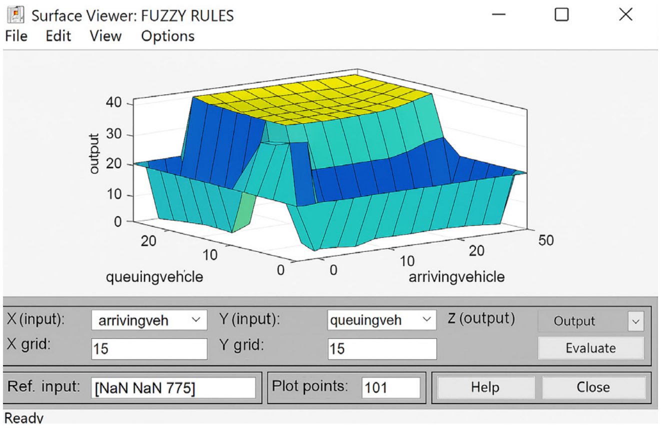


Figure 3. Graphical representation of the decision surface of the fuzzy logic inference module
Source: developed by the authors

Table 3. Knowledge matrix for control by fuzzy logic inference module

Input			**Output**
Arriving Vehicles	Queued vehicle	Fog	Green light duration
H	L	L	S
H	L	M	M
H	L	H	H
H	M	L	M
H	M	M	M
H	M	H	H
H	H	L	H
H	H	M	H
H	H	H	H
M	L	L	S
M	L	M	M
M	L	H	M
M	M	L	M
M	M	M	M
M	M	H	M
M	H	L	H
M	H	M	H
M	H	H	M
L	L	L	S
L	L	M	M
L	L	H	M
L	M	L	M
L	M	M	H
L	M	H	M
L	H	L	S
L	H	M	M
L	H	H	H

Source: developed by the authors

The goals and capabilities of this approach can be significantly expanded, for example, by giving priority to emergency and service vehicles. In addition, green signals can be activated for pedestrians when public transport arrives, which will significantly increase its efficiency. This approach requires a more complex and extensive set of rules, and the computational complexity does not increase with this approach. Thus, without compromising performance, there is the prospect of improving the accuracy and reliability of the model's response and the allocation of resources to several control elements for optimal use.

The results of the study presented in this article demonstrated a significant improvement in the efficiency of traffic flow management using a model based on fuzzy logic. Specifically, the average waiting time was reduced by 25%, the average number of vehicles moving at the intersection increased by 6%, and the number of vehicles stopped at the intersection decreased by 7%. These results demonstrate the effectiveness of the proposed approach, especially in changing weather conditions, such as fog, and variable traffic intensity. A graphical representation of the test results is presented in Figure 4.

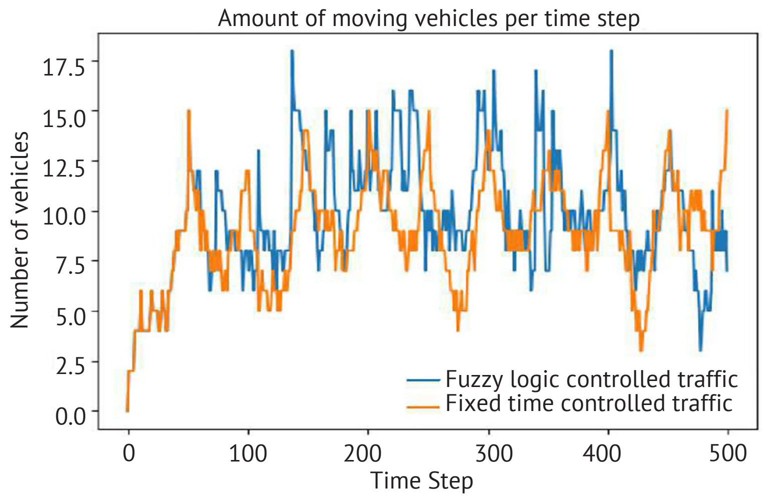


Figure 4. Graphical representation of the results of testing the fuzzy logic inference module in comparison with the classical traffic light control method

Source: developed by the authors

The graph in Figure 4 shows that in most iterations at the intersection that used fuzzy logic to control the green traffic light signal, the number of vehicles that crossed the intersection was greater than at the corresponding intersection that used time-based settings. Comparing these results with other studies, it is worth noting that in the work of M. Li *et al*. (2025), a two-stage traffic light control system called FuzzyLight was proposed, which combined fuzzy logic with compression sensing and reinforcement learning methods. The system showed a 48% improvement in traffic efficiency in real-world conditions at 22 intersections. This demonstrates the potential of integrating fuzzy logic with other artificial intelligence methods to achieve better results.

The study by J. Alam & M.K. Pandney (2013) indicates that there was also the problem of weather conditions, which can be a critical factor in achieving the set goal. The first systems that took weather conditions into account were used in Germany and were implemented on roads with frequent accidents caused by fog or icing. Later, these systems were expanded to detect and control traffic in order to increase road capacity. These traffic control systems use several tracking stations along the road. These stations use magnetic sensors to detect traffic, as well as weather stations that transmit data about the environment, road surface conditions, and the air layer near the ground. A central traffic control computer collects data transmitted from section stations. The control strategy determines the appropriate speed limit for each section. The problem described can be solved using a fuzzy logic mechanism, which allows a completely formal description of the specific value of the number of vehicles and the error value to be converted into a conditional variable. This can be used to form a database of logical rules. This allows to activate rules generated based on the error value and change the error value to the previous one in order to form a conclusion about the optimal behaviour of the system at the next discrete moment in time.

In the context of implementing traffic flow control systems based on fuzzy logic, it is important to compare approaches in related fields of technology. In particular, A. Lazhenko & T. Bila (2020) investigated the effectiveness of a fuzzy controller in domestic refrigeration technology. They found that although the system reduces the duration of the transition process, it also leads to an increase in the amplitude of deviation and the appearance of static error. This result demonstrates that fuzzy systems have certain compromises in accuracy that should be taken into account when adapting them to transport tasks.

Particular attention was paid to the influence of external risk factors related to road conditions. For example, the work of V.A. Tsopa *et al.* (2023) analyses the specifics of assessing the risk of road accidents in freight transport in difficult weather conditions. The authors argue that factors related to fog, ice or reduced visibility are key in the formation of safe traffic algorithms and must be taken into account in control systems. This is consistent with the approach implemented by this model, which adaptively changes the duration of the green signal depending on the weather factor. In addition, the results confirm that fuzzy logic is an effective means of decision-making under conditions of uncertainty. This was also demonstrated in a study by E.N. Allahverdiyev (2023), which proposed the use of fuzzy models for selecting transmitters in gas measurement systems with unstable input parameters. Similar to traffic light control systems, this involves the need to take into account fuzzy criteria and adapt the system to current conditions, which indicates the broad versatility of the fuzzy inference method in technical fields.

The problem of the inefficiency of traffic lights with planned phase times is solved by using fuzzy logic with fuzzy linguistic variables that are more convenient for human perception. In a study by L.A. Zadeh (1996), a theory of fuzzy sets was proposed as a means of resolving uncertainties in real-life situations, laying the foundation for automated traffic light control based on fuzzy logic. These systems use sensors to count traffic intensity. In a study by V.M. Madrigal Arteaga *et al.* (2022), an adaptive traffic light controller based on fuzzy logic was developed, which uses only traffic intensity data obtained from simple traffic counters. The system showed competitive performance compared to the best existing approaches, reducing technical requirements and computational costs. This confirms the effectiveness of using fuzzy logic even with limited input data.

Z. Fahrunnisa *et al.* (2024) presented an adaptive traffic light control system that uses fuzzy logic based on real-time vehicle detection using video surveillance. The system reduced vehicle waiting times by approximately 21% compared to existing systems. This demonstrates the potential of integrating computer vision with fuzzy logic to improve traffic management. In a study by S. Dasgupta *et al.* (2023), the use of digital twin technology for adaptive traffic light control was proposed. The system showed a reduction in control delays of 1% to 52% depending on the traffic level. This demonstrates the effectiveness of using digital twins in combination with fuzzy logic to improve intersection performance. I. Zrigui *et al.* (2025) proposed an integrated strategy for optimising urban traffic that combines forecasting, adaptive signal control, and distributed communication. The system showed a significant reduction in average waiting times in a realistic urban environment. This highlights the importance of a comprehensive approach to traffic management that takes into account various aspects of urban mobility. Z. Kljaić *et al.* (2021) presented a fuzzy logic-based traffic scheduling algorithm for reduced traffic cases. The system showed a significant reduction in vehicle queue lengths compared to traditional methods. This confirms the effectiveness of using fuzzy logic in conditions of variable traffic intensity.

Y. Inağ & M. Arıkan (2024) developed an intelligent traffic light control system based on fuzzy logic, which showed a 36.5% reduction in waiting time compared to existing systems. This demonstrates the effectiveness of fuzzy logic in real urban conditions. In a study by H. Lin *et al.* (2022) presents an approach to optimising signals at urban intersections that combines fuzzy logic with the differential evolution method, with the aim of reducing transport delays and optimising signal times in adaptive mode. Effective performance on real networks is noted, compared to traditional fixed or adaptive control methods.

The study by M. Teerapun & W. Sumak (2024) proposed a hybrid approach to traffic light control that combines deep learning with reinforcement and fuzzy logic. The model learns to optimise signal phases in real time, taking into account complex road conditions. This approach has improved traffic performance, including reduced waiting times and fewer stops. The results demonstrated the effectiveness of integrating artificial intelligence with fuzzy methods for adaptive urban traffic control. A study using deep learning with reinforcement and fuzzy logic proposed a traffic light control method that showed an 18.46% reduction in average total waiting time compared to traditional methods. This highlights the effectiveness of combining artificial intelligence methods with fuzzy logic to improve traffic management.

Comparing the results of the study with the above-mentioned works, it can be concluded that the use of fuzzy logic in traffic flow management is an effective approach that allows adaptation to changing traffic conditions and improves intersection efficiency. These results, in particular a 25% reduction in average waiting time and a 7% reduction in the number of stops, confirm the effectiveness of the proposed model. Taking into account parameters such as the number of vehicles waiting at the intersection, arriving traffic, and weather conditions (fog) allows the system to adapt to real traffic conditions, which is an important aspect for improving urban mobility.

CONCLUSIONS

As a result of the research, a model for managing traffic flows in cities based on fuzzy logic was developed and implemented. The main aim of the research was to increase the throughput capacity of intersections, which was achieved through the use of a fuzzy logic inference system for adaptive traffic light control. The model identified key fuzzy variables: the number of vehicles waiting at the intersection, arriving traffic, and weather conditions (fog). A corresponding rule base was built to enable real-time decision-making. The model was implemented using the Python programming language and the scikit-fuzzy library. The SUMO traffic simulator was used to verify the correctness of the model. The simulation results showed that the proposed system allows for a significant improvement in traffic performance: the average waiting time for cars was reduced by 25%, the number of vehicles continuing to move without stopping increased by 6%, and the number of those stopping at the intersection decreased by 7%. A comparison with the classic approach (fixed traffic light intervals depending on the time of day) confirmed the higher efficiency of the fuzzy approach. The results of the study confirmed the feasibility of implementing such systems in urban infrastructure, particularly in conditions of variable traffic intensity. In further studies, it is advisable to expand the number of input parameters to include information about the presence of public transport, cyclists and pedestrians, as well as the possibility of priority passage for emergency services. A separate area for future work includes the integration of fuzzy models with Internet of Things sensors and machine learning to improve the system's adaptability to the dynamic environment of megacities.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Agrahari, A., Dhabu, M.M., Deshpande, P.S., Tiwari, A., Baig, M.A., & Sawarkar, A.D. (2024). Artificial intelligence-based adaptive traffic signal control system: A comprehensive review. *Electronics*, 13(19), article number 3875. doi: 10.3390/electronics13193875.

[2] Alam, J., & Pandey, M.K. (2013). Intellegent traffic light control system for isolated intersection using fuzzy logic. In *Proceedings of the conference on advances in communication and control systems (CAC2S 2013)* (pp. 209-215). Dehradun: DIT University. doi: 10.13140/RG.2.1.4854.6406.

[3] Allahverdiyev, E.N. (2023). Selection of transmitters using fuzzy logic for gas metering systems under uncertainty. *Technologies and Engineering*, 2, 42-49. doi: 10.30857/2786-5371.2023.2.1.

[4] Bhatia, M.S., & Aggarwal, A. (2020). Congestion control by reducing wait time at the traffic junction using fuzzy logic controller. *International Journal of Sensors, Wireless Communications and Control*, 10(6), 989-1000. doi: 10.2174/2210327910666200226113614.

[5] Bi, Y., Ding, Q., Du, Y., Liu, D., & Ren, S. (2024). Intelligent traffic control decisionmaking based on type2 fuzzy and reinforcement learning. *Electronics*, 13(19), article number 3894. doi: 10.3390/electronics13193894.

[6] Dasgupta, S., Rahman, M., & Jones, S. (2023). Harnessing digital twin technology for adaptive traffic signal control: Improving signalized intersection performance and user satisfaction. *ArXiv*. doi: 10.48550/arxiv.2309.16673.

[7] Fahrunnisa, Z., Rahmadwati, R., & Setyawan, R.A. (2024). Adaptive traffic light signal control using fuzzy logic based on real-time vehicle detection from video surveillance. *Jurnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)*, 10(2), 235-251. doi: 10.26555/jiteki.v10i2.28712.

[8] Gandrybida, V., Bondarenko, D., & Sevastyanov, V. (2024). Advancements in automated traffic management using fuzzy logic: Prospects and challenges. *Information Technologies and Computer Engineering*, 21(3), 86-95. doi: 10.63341/vitce/3.2024.86.

[9] Inağ, Y., & Arıkan, M. (2024). A fuzzy based intelligent traffic light control (ITLC) method: An implementation in Ankara city. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, 14(1), 98-110. doi: 10.17798/bitlisfen.1388486.

[10] Kljaić, Z., Pavković, D., Mlinarić, T.J., & Nikšić, M. (2021). Scheduling of traffic entities under reduced traffic flow by means of fuzzy logic control. *Promet – Traffic & Transportation*, 33(4), 621-632. doi: 10.7307/ptt.v33i4.3686.

[11] Kumar, N., Rahman, S.S., & Dhakad, N. (2021). Fuzzy inference enabled deep reinforcement learning-based traffic light control for intelligent transportation system. *IEEE Transactions on Intelligent Transportation Systems*, 22(8), 4919-4928. doi: 10.1109/TITS.2020.2984033.

[12] Lazhenko, A., & Bila, T. (2020). Evaluation of motor-compressor energy efficiency using control systems of a household refrigerator. *Technologies and Engineering*, 3, 30-36. doi: 10.30857/1813-6796.2020.3.5.

[13] Li, M., Wang, J., Du, B., Shen, J., & Wu, Q. (2025). FuzzyLight: A robust two-stage fuzzy approach for traffic signal control works in real cities. In *Proceedings of the 31st ACM SIGKDD conference on knowledge discovery and data mining* (pp. 2393-2404). Toronto: Association for Computing Machinery. doi: 10.1145/3690624.3709393.

[14] Lin, H., Han, Y., Cai, W., & Jin, B. (2022). Traffic signal optimization based on fuzzy control and differential evolution algorithm. *IEEE Transactions on Intelligent Transportation Systems*, 24(1), 8555-8566. doi: 10.1109/TITS.2022.3195221.

[15] Madrigal Arteaga, V.M., Pérez Cruz, J.R., Hurtado-Beltrán, A., & Trumpold, J. (2022). Efficient intersection management based on an adaptive fuzzy-logic traffic signal. *Applied Sciences*, 12(12), article number 6024. doi: 10.3390/app12126024.
[16] Michailidis, P., Michailidis, I., Lazaridis, C.R., & Kosmatopoulos, E. (2025). Traffic signal control via reinforcement learning: A review on applications and innovations. *Infrastructures*, 10(5), article number 114. doi: 10.3390/infrastructures10050114.
[17] Shevchenko, V.V. (2023). Justification of the effective direction of development of traffic light control systems with fixed cycle regulation. *Journal of Mechanical Engineering and Transport*, 16(2), 110-119. doi: 10.31649/2413-4503-2022-16-2-110-119.
[18] Teerapun, M., & Sumek, W. (2024). Traffic signal control with state-optimizing deep reinforcement learning and fuzzy logic. *Applied Sciences*, 14(17), article number 7908. doi: 10.3390/app14177908.
[19] Tsopa, V.A., Cheberiachko, S.I., Deriugin, O.V., & Pyshchykova, O.V. (2023). Features of risk assessment of road traffic accidents during cargo transportation under adverse conditions. *Bulletin of Kryvyi Rih National University*, 21(1), 55-62. doi: 10.31721/2306-5451-2023-1-56-86-95.
[20] Zadeh, L.A. (1996). Fuzzy logic = computing with words. *IEEE Transactions on Fuzzy Systems*, 4(2), 103-111. doi: 10.1109/91.493904.
[21] Zrigui, I., Khoulji, S., & Kerkeb, M.L. (2025). Integrated strategy for urban traffic optimization: Prediction, adaptive signal control, and distributed communication via messaging. *ArXiv*. doi: 10.48550/arXiv.2501.02008.

Нечітка модель керування транспортними потоками у містах

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Анотація. Актуальність дослідження зумовлена необхідністю підвищення ефективності регулювання транспортних потоків у містах для поліпшення екологічної ситуації, зменшення заторів та стимулювання економічного розвитку. Сучасні методи керування на основі фіксованих графіків роботи світлофорів не здатні адаптуватися до нестандартних та непередбачуваних ситуацій на дорогах. Метою дослідження була розробка моделі керування транспортними потоками на основі використання методів нечіткої логіки. Методологія дослідження передбачала побудову моделі нечіткого логічного висновку, яка дозволяє трансформувати вхідні параметри (інтенсивність руху, час очікування, аварійні події) в лінгвістичні змінні та автоматизувати процес прийняття рішень щодо налаштувань світлофорів. За допомогою моделі проведено імітаційне моделювання роботи системи в різноманітних дорожніх та погодних умовах. Розроблено адаптивну систему керування транспортними потоками, яка оперативно реагує на зміни дорожньої ситуації в реальному часі. Встановлено, що впровадження запропонованої моделі дозволяє зменшити середній час очікування автомобілів на 25 %, знизити кількість транспортних засобів, що зупиняються на перехресті, на 7 % та підвищити середню кількість транспортних засобів, які проїжджають через перехрестя, на 6 %. Проаналізовано ефективність розробленої системи в порівнянні зі стандартними методами керування світлофорами. Оцінено перспективи розширення функціональності моделі для врахування додаткових вхідних параметрів, зокрема надання пріоритету громадському транспорту, пішоходам та екстреним службам. Практична цінність дослідження полягає в можливості застосування результатів фахівцями з міського планування, інтелектуальних транспортних систем та транспортної логістики для оптимізації роботи світлофорних об'єктів у містах

Ключові слова: інтелектуальне регулювання; адаптивне керування; алгоритми нечіткого виведення; міська мобільність; автоматизація світлофорів; лінгвістична змінна