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A Review of Different Traffic Light Controllers Using Fuzzy Approach

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ABSTRACT

Now a days, the traffic movement on the road is increasing due to increase in population which leads to traffic jam and traffic jam creates many problems in our daily life such as wastage of money & time, growing pollution, delay in services and increase the chances of accidents. Since these traffic problems are based on ambiguity, uncertainty & impression and Fuzzy logic is used to solve the problems based on ambiguity, uncertainty and impression, therefore Fuzzy logic is used to reduce traffic congestion.

Keywords: Triangular Membership Function (TMF), Fuzzy Logic, FIS Tool of MATLAB, Traffic Light Controller/Traffic Signal Controller (TLC/TSC)

I. INTRODUCTION

Today, the road traffic congestion is a huge problem in the world which can be seen everywhere. This problem arises due to high number of vehicles moving on the road. Some other reasons of traffic congestions are large red-light delays, insufficient capacity of roads, insufficient traffic management, incomplete information of traffic, road accidents etc. The traffic congestion is based on ambiguity, impression & uncertainty and these parameters may be dealt with fuzzy logic. Therefore, Fuzzy logic proposed by Zadeh [1] can be used to solve this type of traffic problems. Moreover, this problem can be characterized by Linguistic variables proposed by Zadeh [2]. In 2022, Kumar D, Tripathi J.P. and Shukla R.K. [3] proposed a paper in which they discussed many parts of fuzzy set theory like fuzzy logic, Triangular fuzzy number, Trapezoidal fuzzy number, Linguistic variables etc. The birth and revolution of fuzzy logic is initiated by Zadeh, Lotfi A [4] in 1990. Kumar D and Tripathi J.P. [5] introduced a paper in which they talk about the role of fuzzification & defuzzification in TLC. J.P. Tripathi et al [6,7] is presented a FLC to manage the traffic jam at the road junction. R.R. Yager [8] deals the extension principle focused on interval-valued level sets and Fuzzy sets. H. Bustince et al [9] got interval fuzzy sets from matrices. So, fuzzy set theory is the best proposal to solve road traffic problems. Since, traffic problem

is a real-world problem. So, fuzzy logic is more beneficial to solve road traffic problems. Most of researchers are used to fuzzy inference system tool in MATLAB to solved the road traffic problem. In 2023, Tripathi J.P, Kumar D & Singh U.P. [10] proposed a review paper in which they discuss the different types of recent traffic light controllers using fuzzy logic. They used Fuzzy Inference System (FIS) tool in MATLAB.

II. RELATED WORK

In 1868, the first traffic controller was installed in London and the first electric traffic signal controllers was installed in 1914. Thus, the development of traffic signal controllers was very helpful to control traffic systems. Further, the implementation of traffic monitor system to extend the time by identifying traffic flow using IOT is prepared by Shahk. et al [11]. In this system, Sensors are used to identify traffic flow and it is better flexible than fixed time controllers. K. Tan et al. [12] gives an intelligent TLC is built by fuzzy rules. Software has been grown on the basis of this technology. M. Jha et al. [13] presented a traffic controller and introduced a traffic model using MATLAB. Shoaib Kamran et al [14] introduced a traffic signal based on GPS data which tracks the traffic patterns and performs properly according to vehicle behavior. M.H. Malhi et al [15] proposed a system based on vision for managing traffic. This system is just like a controller in which single output is observed. The fuzzy logic traffic controller is intended by using Mamdani FIS of MATLAB. This design consists of 3-stages, named the green phase stage, the next phase stage, and the switching stage. This system is also working for an emergency vehicle case in traffic management.

At present, traffic signals are widely used to managed traffic jams. Generally, there are three lights used in traffic indicators, first, the red light is indicated for stopping the arriving vehicles, second, the green light is indicated for passing the vehicles and third, the yellow light is indicated for two purposes, one to indicate that we should slow our vehicles and prepare to stop for the red light and second to indicate that we have ready to move. Dharmendra Kumar & J.P. Tripathi [16] proposed a TLC for smart cities using fuzzy logic in which four inputs and two outputs have been taken. This controller works on the basis of 225 fuzzy if- then rules which is capable for any situation and weather condition.

III. COMPARATIVE STUDY

S.Mohanaselvi proposed a fuzzy traffic signal control system for an isolated 4-Lane traffic junction. They use the fuzzy logic controller to perform traffic signal.

They took three fuzzy input variables, which are no. of vehicles, queuing vehicles and fog in the FLSC(Fuzzy Logic Signal Controller) and selected three linguistic variables Less(L), Medium(M) and High(H) for each input variable. They also selected three linguistic variables Short(S), Medium(M) and Long(L) for the output green light duration and constructed 27 fuzzy rules. After making fuzzy rules, they simulated using Mamdani Fuzzy Inference system in MATLAB and got the output for predicted traffic.

They define TMFs for each input and output. The TMFs for the first two inputs i.e., No. of vehicles and Queuing Vehicles are given as;

$$\mu_L(x) = \begin{cases} 0 & ; \quad x < 0 \\ \frac{x}{5} & ; 0 \le x \le 5 \\ \frac{10-x}{5} & ; 5 \le x \le 10 \\ 0 & ; \quad x > 10 \end{cases} \qquad \text{.....(1)}$$

$$\mu_M(x) = \begin{cases} 0 & ; \quad x < 7 \\ \frac{x-7}{9} & ; 7 \le x \le 16 \\ \frac{25-x}{9} & ; 16 \le x \le 25 \\ 0 & ; \quad x > 25 \end{cases} \qquad \text{.....(2)}$$

$$\mu_H(x) = \begin{cases} 0 & ; \quad x < 20 \\ \frac{x-20}{15} & ; 20 \le x \le 35 \\ \frac{50-x}{15} & ; 35 \le x \le 50 \\ 0 & ; \quad x > 50 \end{cases} \qquad \text{.....(3)}$$

The TMFs for the 3rd input i.e., Fog are given as;

$$\mu_L(x) = \begin{cases} 0 & ; \quad x < 1000 \\ \frac{x-1000}{250} & ; 1000 \le x \le 1250 \\ \frac{1500-x}{250} & ; 1250 \le x \le 1500 \\ 0 & ; \quad x > 1500 \end{cases} \qquad \text{.....(4)}$$

$$\mu_M(x) = \begin{cases} 0 & ; \quad x < 400 \\ \frac{x-400}{400} & ; 400 \le x \le 800 \\ \frac{1200-x}{400} & ; 800 \le x \le 1200 \\ 0 & ; \quad x > 1200 \end{cases} \qquad \text{.....(5)}$$

$$\mu_H(x) = \begin{cases} 0 & ; \quad x < 50 \\ \frac{x-50}{225} & ; 50 \le x \le 275 \\ \frac{500-x}{225} & ; 275 \le x \le 500 \\ 0 & ; \quad x > 500 \end{cases} \qquad \text{.....(6)}$$

The TMFs for the output i.e., Green Time Duration are given as below;

$$\mu_L(x) = \begin{cases} 0 & ; \quad x < 0 \\ \frac{x}{5} & ; 0 \le x \le 5 \\ \frac{10-x}{5} & ; 5 \le x \le 10 \\ 0 & ; \quad x > 10 \end{cases} \qquad \text{.....(7)}$$

$$\mu_M(x) = \begin{cases} 0 & ; \quad x < 8 \\ \frac{x-8}{11} & ; 8 \le x \le 19 \\ \frac{30-x}{11} & ; 19 \le x \le 30 \\ 0 & ; \quad x > 30 \end{cases} \qquad \text{.....(8)}$$

$$\mu_H(x) = \begin{cases} 0 & ; \quad x < 25 \\ \frac{x-25}{17.5} & ; \ 25 \le x \le 42.5 \\ \frac{60-x}{17.5} & ; 42.5 \le x \le 60 \\ 0 & ; \quad x > 60 \end{cases} \qquad \text{.....(9)}$$

In the similar way, Vinay Yadav et. al., represented an intelligent TLC in which they took three fuzzy input variables, named as No. of vehicles, Speed of vehicles (in km/h) & Weather condition (in %). In first input, they used four linguistic variables Very Less (VL), Less(L), Medium(M) and High(H). Similarly, in the second input, they used four linguistic variables Very Less (VL), Less(L), Medium(M) & High(H) and in the third input, they used four linguistic variables Very Bad (VB), Bad(B), Average(A) and Good(G) in the fuzzy logic signal controller for each input variable. They also selected four linguistic variables named Very Less (VL), Less(L), Medium(M) and High(H) for the output traffic flow time and constructed 64 fuzzy rules. After making fuzzy rules, they simulated using Mamdani Fuzzy Inference System in MATLAB and got the output for predicted traffic.

They define TMFs for each input and output. The TMFs for the first input i.e., No. of Vehicles are given as below;

$$\mu_{VL}(x) = \begin{cases} 0 & ; \quad x < 0 \\ \frac{x}{10} & ; \ 0 \le x \le 10 \\ \frac{20-x}{10} & ; 10 \le x \le 20 \\ 0 & ; \quad x > 20 \end{cases} \qquad \text{.....(10)}$$

$$\mu_L(x) = \begin{cases} 0 & ; \quad x < 15 \\ \frac{x-15}{22.5} & ; \ 15 \le x \le 37.5 \\ \frac{60-x}{22.5} & ; 37.5 \le x \le 60 \\ 0 & ; \quad x > 60 \end{cases} \qquad \text{.....(11)}$$

$$\mu_M(x) = \begin{cases} 0 & ; \quad x < 50 \\ \frac{x-50}{30} & ; \ 50 \le x \le 80 \\ \frac{110-x}{30} & ; 80 \le x \le 110 \\ 0 & ; \quad x > 110 \end{cases} \qquad \text{.....(12)}$$

$$\mu_H(x) = \begin{cases} 0 & ; \quad x < 90 \\ \frac{x-90}{30} & ; \ 90 \le x \le 120 \\ \frac{150-x}{30} & ; 120 \le x \le 150 \\ 0 & ; \quad x > 150 \end{cases} \qquad \text{.....(13)}$$

The TMFs for the second input i.e., Speed of Vehicles (in km/h) are given as below;

$$\mu_{VL}(x) = \begin{cases} 0 & ; \quad x < 0 \\ \frac{x}{10} & ; \ 0 \le x \le 10 \\ \frac{20-x}{10} & ; 10 \le x \le 20 \\ 0 & ; \quad x > 20 \end{cases} \qquad \text{.....(14)}$$

$$\mu_{L}(x) = \begin{cases} 0 & ; \quad x < 15 \\ \frac{x-15}{12.5} & ; \ 15 \le x \le 27.5 \\ \frac{40-x}{12.5} & ; 27.5 \le x \le 40 \\ 0 & ; \quad x > 40 \end{cases} \qquad \text{.....(15)}$$

$$\mu_{M}(x) = \begin{cases} 0 & ; \quad x < 30 \\ \frac{x-30}{20} & ; \ 30 \le x \le 50 \\ \frac{70-x}{20} & ; 50 \le x \le 70 \\ 0 & ; \quad x > 70 \end{cases} \qquad \text{.....(16)}$$

$$\mu_{H}(x) = \begin{cases} 0 & ; \quad x < 60 \\ \frac{x-60}{20} & ; \ 60 \le x \le 80 \\ \frac{100-x}{20} & ; 80 \le x \le 100 \\ 0 & ; \quad x > 100 \end{cases} \qquad \text{.....(17)}$$

The TMFs for the third input i.e., Weather Condition (in %) are given as below;

$$\mu_{VL}(x) = \begin{cases} 0 & ; \quad x < 0 \\ \frac{x}{10} & ; \ 0 \le x \le 10 \\ \frac{10-x}{10} & ; 10 \le x \le 20 \\ 0 & ; \quad x > 20 \end{cases} \qquad \text{.....(18)}$$

$$\mu_{L}(x) = \begin{cases} 0 & ; \quad x < 15 \\ \frac{x-15}{17.5} & ; \ 15 \le x \le 32.5 \\ \frac{10-x}{17.5} & ; 32.5 \le x \le 50 \\ 0 & ; \quad x > 50 \end{cases} \qquad \text{.....(19)}$$

$$\mu_{M}(x) = \begin{cases} 0 & ; \quad x < 45 \\ \frac{x-45}{15} & ; \ 45 \le x \le 60 \\ \frac{75-x}{15} & ; 60 \le x \le 75 \\ 0 & ; \quad x > 75 \end{cases} \qquad \text{.....(20)}$$

$$\mu_{H}(x) = \begin{cases} 0 & ; \quad x < 70 \\ \frac{x-70}{15.5} & ; \ 70 \le x \le 85.5 \\ \frac{100-x}{15.5} & ; 85.5 \le x \le 100 \\ 0 & ; \quad x > 100 \end{cases} \qquad \text{.....(21)}$$

The TMFs for the output i.e., Traffic Flow Time are given as below;

$$\mu_{VL}(x) = \begin{cases} 0 & ; \quad x < 0 \\ \frac{x}{1} & ; \ 0 \le x \le 1 \\ \frac{2-x}{1} & ; 1 \le x \le 2 \\ 0 & ; \quad x > 2 \end{cases} \qquad \text{……..(22)}$$

$$\mu_{L}(x) = \begin{cases} 0 & ; \quad x < 1 \\ \frac{x-1}{1} & ; \ 1 \le x \le 2 \\ \frac{3-x}{1} & ; 2 \le x \le 3 \\ 0 & ; \quad x > 3 \end{cases} \qquad \text{……..(23)}$$

$$\mu_{M}(x) = \begin{cases} 0 & ; \quad x < 2 \\ \frac{x-2}{1} & ; \ 2 \le x \le 3 \\ \frac{4-x}{1} & ; 3 \le x \le 4 \\ 0 & ; \quad x > 4 \end{cases} \qquad \text{……..(24)}$$

$$\mu_{H}(x) = \begin{cases} 0 & ; \quad x < 3 \\ \frac{x-3}{1} & ; \ 3 \le x \le 4 \\ \frac{5-x}{1} & ; 4 \le x \le 5 \\ 0 & ; \quad x > 5 \end{cases} \qquad \text{…….(25)}$$

Comparative Table:

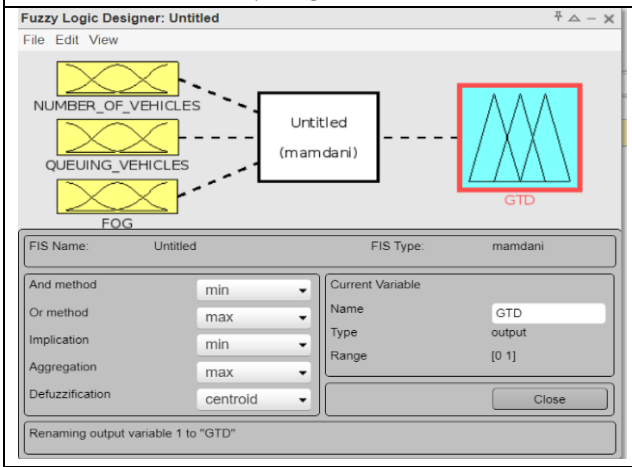
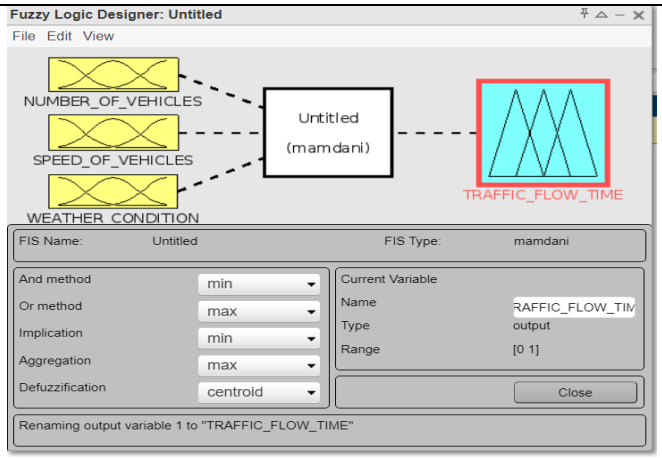
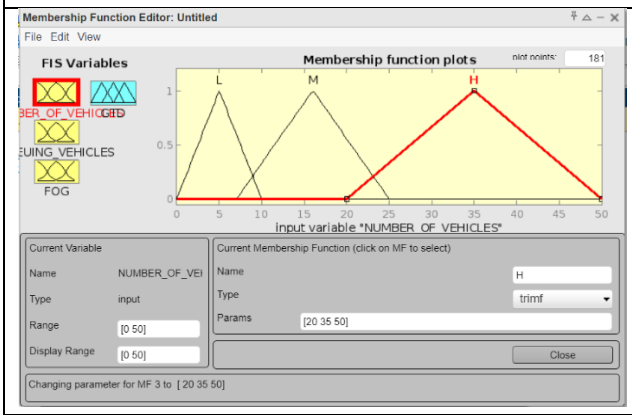
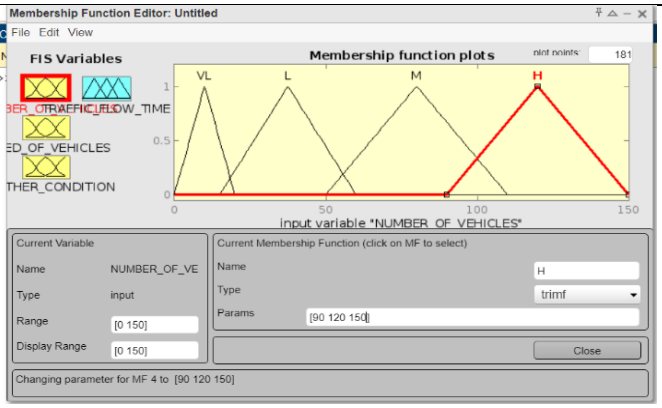
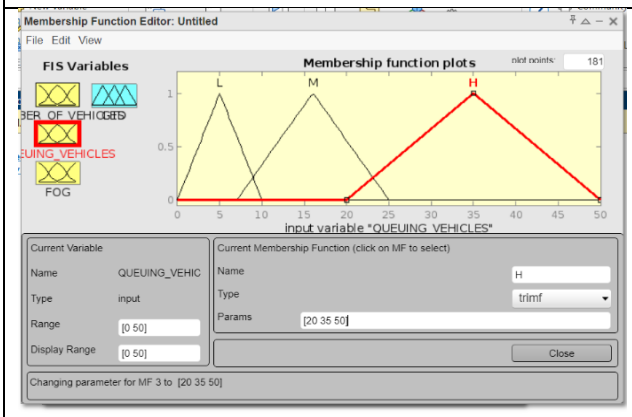
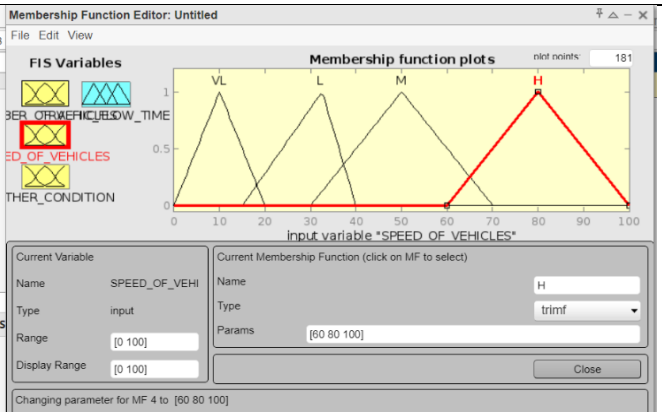
S. Mohanaselvi et al [17]								Vinay Yadav et al [18]							
Inputs						Output		Inputs						Output	
No. of Vehicles		Queuing Vehicles		Fog		Green Time Duration		No. of Vehicles		Speed of Vehicles (In km/h)		Weather Condition (In %)		Traffic Flow Time	
Range	LV	Range	LV	Visual Range (In m)	LV	Time (In sec.)	LV	Range	LV	Range	LV	Range	LV	Range	LV
00-10	L	00-10	L	1000-1500	L	00-10	L	00-20	VL	00-20	VL	00-20	VB	0-2	VL
07-25	M	07-25	M	400-1200	M	08-30	M	15-60	L	15-40	L	15-50	B	1-3	L
20-50	H	20-50	H	50-500	H	25-60	H	50-110	M	30-70	M	45-75	A	2-4	M
								90-150	H	60-100	H	70-100	G	3-5	H

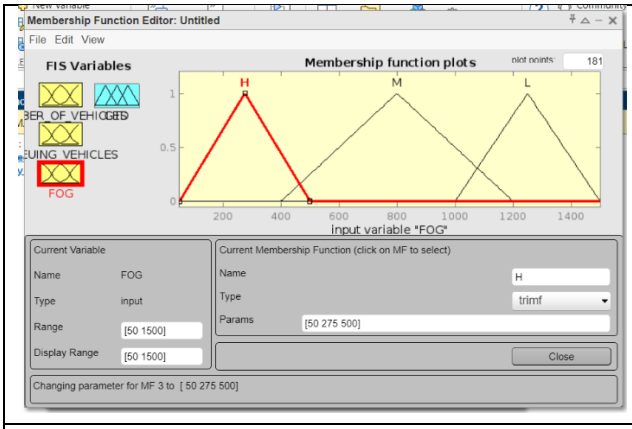
Fuzzy Rules

Inputs				Output
Serial Number	No. of Vehicles	Queuing Vehicles	Fog	GTD
1.	H	L	L	S
2.	H	L	M	M
3.	H	L	H	L
4.	H	M	L	M
5.	H	M	M	M
6.	H	M	H	L
7.	H	H	L	L
8.	H	H	M	L
9.	H	H	H	L
10.	M	L	L	S
11.	M	L	M	M
12.	M	L	H	M
13.	M	M	L	M
14.	M	M	M	M
15.	M	M	H	M
16.	M	H	L	L
17.	M	H	M	L
18.	M	H	H	M
19.	L	L	L	S
20.	L	L	M	M
21.	L	L	H	M
22.	L	M	L	M
23.	L	M	M	L
24.	L	M	H	M
25.	L	H	L	S
26.	L	H	M	M
27.	L	H	H	L

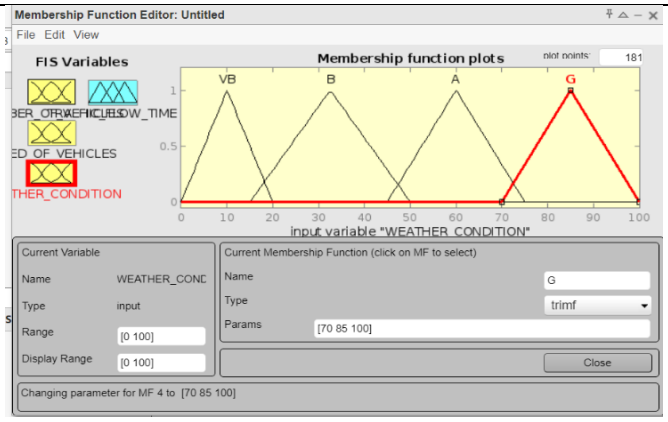
Fuzzy Rule

Inputs				Output
Serial Number	No. of Vehicles	Speed of Vehicles (In km/h)	Weather Condition (In %)	Traffic Flow Time
1.	VL	VL	VB	L
2.	VL	VL	B	L
3.	VL	VL	A	VL
4.	VL	VL	G	VL
5.	VL	L	VB	L
6.	VL	L	B	L
7.	VL	L	A	VL
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…
50.	H	VL	B	H
51.	H	VL	A	H
52.	H	VL	G	M
53.	H	L	VB	H
54.	H	L	B	H
55.	H	L	A	H
56.	H	L	G	H
57.	H	M	VB	H
58.	H	M	B	H
59.	H	M	A	H
60.	H	M	G	H
61.	H	H	VB	H
62.	H	H	B	H
63.	H	H	A	M
64	H	H	G	M

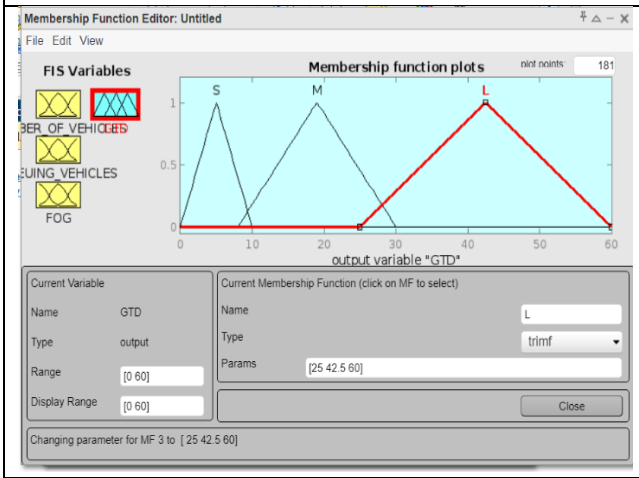
Fuzzy Logic Controller:	Fuzzy Logic Controller:
	
Membership Function of 1st Input (No. of Vehicles)	Membership Function of 1st Input (No. of Vehicles)
	
Membership Function of 2nd Input(Queuing Vehicles)	Membership Function of 2nd Input (Speed of Vehicles)
	
Member Function of 3rd Input(Fog)	Membership Function of 3rd Input(Weather Condition)



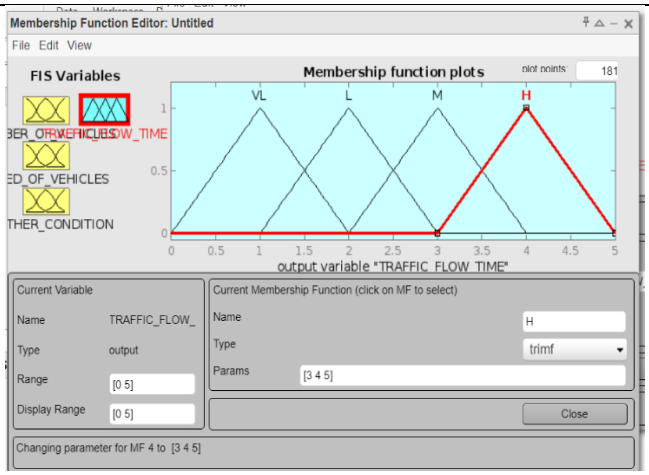
Membership Function of Output(Green Time Duration)



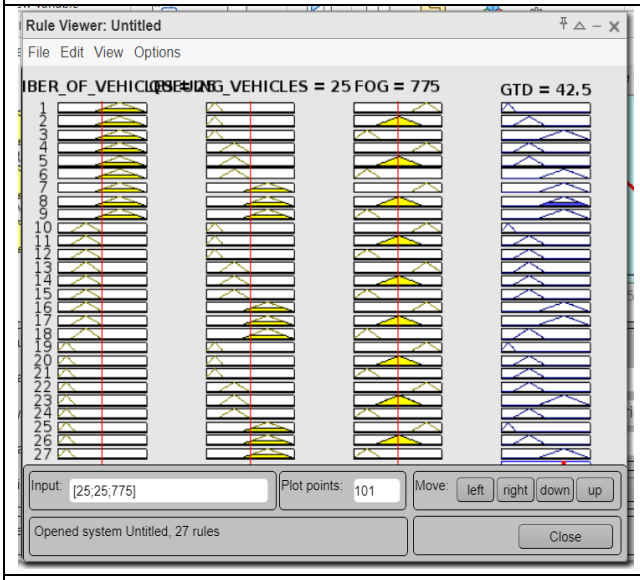
Membership Function of Output(Traffic Flow Time)



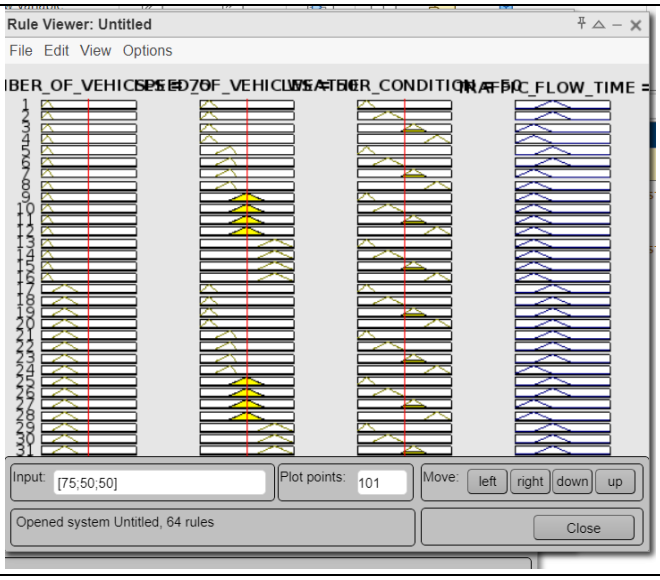
Rule Viewer



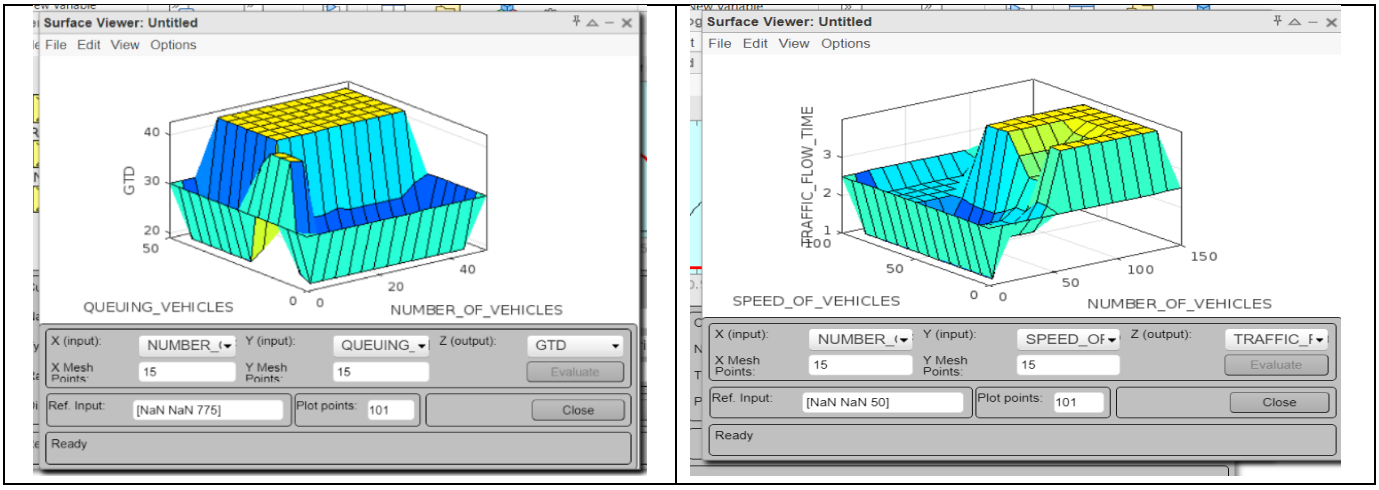
Rule Viewer



Surface Viewer



Surface Viewer



IV. Advantage & Disadvantage

This review paper includes the different approaches for controlling road traffic signals which helps the road traffic safe, secure without any collision. This helps in save driving and also reduces the no. of roads accidents. In foggy weather, the traffic signals are clearly visible at a night or on a rainy day. So, it is very useful in road traffic movement at the crossing. It also reduces air pollution by reducing no. of vehicles proposed in [19]. It is more beneficial and gives the best suitable results.

Now, we discuss the disadvantage of the fuzzy logic controller. The FLC system with sensors is more expensive due to the excessive expensive maintenance of sensors. Sometimes, CCTV cameras are used in traffic control system which is not work in case of shadow overlapping and blockage proposed in [20]. The traffic signals also slow up the traffic by stopping vehicles at crossing the busiest hours and at facilities are not get on time.

V. Conclusion:

In this paper, we have reviewed different traffic light controllers using fuzzy approaches. This paper consists of recent developed traffic light controllers to remove the traffic jam and reduced waiting time. Here, we compare two types of traffic light controllers in the section of comparative study discussed above. Both traffic light controllers consist of three inputs and one output. The first TLC works according to 27 fuzzy if-then rules while the second TLC works according to 64 fuzzy if – then rules. The FIS tool of MATLAB is used in each type of traffic light controllers. The Triangular membership function is used due to computational efficiency and the centroid method of defuzzification is used.

VI. References:

[1]. Zadeh, Lotfi A. Fuzzy sets. Information and Control, 8(3), 338-353, 1965.

[2]. Zadeh, Lotfi A. The Concept of a Linguistic Variable and its Application to Approximate Reasoning -1. Information Sciences, 8(3), 199-249. 1975.

[3]. Dharmendra Kumar, J.P. Tripathi, R.K. Shukla, "Fuzzy Logic and its Applications in the Road Traffic System", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN: 2395-602X, Print ISSN: 2395-6011, Volime 9 Issue 6, pp. 734-737, November-December 2022.

[4]. Zadeh, L.A., The Birth and Evolution of Fuzzy Logic, Intern. J. of General System, 17(2-3), pp. 95-105, 1990.

[5]. Dharmendra Kumar, J. P. Tripathi and R.K. Shukla, The Role of Fuzzification and Defuzzification in Traffic Light Controller, International Research Journal of Mathematics, Engineering and IT. Vol. 7, Issue 12, 19-27,2022.

[6]. Shukla H.S., Jitesh Pati Tripathi, Traffic Management System Using Fuzzy Logic, Journal of International Academy of Physical Sciences, Vol. 15 No. 2, 189-196,2011.

[7]. Tripathi Jitesh P., Shukla H.S., Management of a Road Traffic Junction Using Fuzzy Lights Controller, Journal of Rajasthan Academy of Physical Sciences (JRAOPS), Vol.11 No. 3,209-222,2012.

[8]. R.R. Yager, "Level sets and the Extension Principle for Interval Valued Fuzzy Sets and its Applications to Uncertainty Measures". Information Sciences, Vol. 178, pp.3565-3576, 2008.

[9]. H. Bustince, E. Barrenechea, M. Pagola, J. Fernandez, "Interval valued Fuzzy sets Constructed from Matrices: Application to edge detection ", Fuzzy Sets and Systems, vol.160, pp. 1819-1840, 2009.

[10]. Tripathi J.P., Kumar D, Singh U.P., A Review of Different Fuzzy Models to Evaluate Vehicular Traffic System. SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology, 15(1), 49-54,2023.

[11]. Shah., Jha, J., Zala, M., & Khetra, N., Importance of Traffic Monitoring System by Density and Flow Control for Indian Road System using LOT. International Journal for Scientific Research & Development, 3(10), 167-170,2015.

[12]. Tan, K., Khaolid, M., & Yusof, R., Intelligent Traffic Lights Control by fuzzy logic. Malaysian Journal of Computer Science, 9(2), 29-35,1996.

[13]. Jha, M., & Shukla, S., Design of Fuzzy Logic Traffic Controller for Isolated Intersections Engineering Research and Application, 4(6), 1-6,2014.

[14]. Shoaib Kamran and Olivier Hass, "A Multilevel Traffic Incidents Detection Approach: Identifying Traffic Patterns and Vehicles Behaviors using Real Time GPS data ", IEEE Intelligent Vehicles Symposium Istanbul, Turky, June 13-15, 912-917,2007.

[15]. M. H. Malhi, M.H. Aslam, Faisal Saeed, Owais Jawed, M.D. Fraz, "Vision Based Intelligent Traffic Management System ", Frontiers of Information Technology, pp. 137-141, 2011.

[16]. Dharmendra Kumar & J.P. Tripathi," Traffic Light Controller for smart cities using fuzzy logic", J. of Ramanujan Society of Mathematics and Mathematical Sciences, Vol. 10, No. 2, pp. 199-212,2023.

[17]. Mohanaselvi, S., & Shanpriya, B., Application of FUZZY Logic to Control Traffic signals. AIP Conference Proceedings 2112, 020045(1-9), 2009.

[18]. Vinay Yadav, Dr. J.P. Tripathi, Dr. Bhawesh Kumar Thakur & Dharmendra Kumar., Traffic Light Controller for Urban Cities Using Fuzzy Approach. IJISAF., 12(2s). 665-670, 2023.

[19]. Ramzanzad, M., & Kanan, H.R., A New Method for Design and Implementation of Intelligent Traffic Control System Based on Fuzzy Logic Using FPGA. 13th Iranian Conference on Fuzzy System (IFSC), 2013.

[20]. Malhi, M.H., Aslam M.H., Saeed F., Javed, O., & Fraz, M., Vision Based Intelligent Traffic Management System. Frontiers of Information Technology, 137-141, 2011.