

A Review paper on Traffic Signal Control Based on fuzzy Set Theory

Sandhya Parihar¹, Mr. M.K. Trivedi²

^{1,2} Department of Civil Engineering

^{1,2} Madhav Institute of Technology and science, Gwalior M.P. 474005

Abstract- Now a days the quantity of personal vehicles is increasing quickly. As result the traffic jam is increasing and turning into a large problem in big cities. Because of traffic congestion several big problems are developing such as pollution, wastage of time, money, accidents etc. Traffic congestion occurred very often within the modern times that have an effect on the lifestyle and introduce such a lot of issues and challenges. To resolve all of these issues traffic light management is a best result. Fuzzy set approach are widely useful to several applications and it will easily handle uncertainty, difficulty and imprecision in various systems. The difficulties in traffic management System are primarily defined by the inaccurate, ambiguous and uncertain parameters. Because of these types of parameters in fuzzy logic technique is best suitable approach for traffic signal management. The Working procedure of fuzzy logic based controller is better for two Way Street based on extension of green light time. After that fuzzy logic controller was designed for two way junction without turns, single junction with all movements, and multiple junction etc. improved performance of fuzzy logic depends traffic signal management in comparison of traditional traffic signal control management the study in this field. Fuzzy logic approach will absolutely assist in transportation management structure in upcoming times.

Keywords- traffic signal control, fuzzy logic.

I. INTRODUCTION

In large urban areas vehicular travel increases day by day throughout the world, with the increasing use of automobiles in cities traffic congestion occurred. So there are needs for optimizing traffic control techniques to better hold this increasing requirement. Therefore the transportation arrangement will take on to develop intelligent traffic controls have to be engaged to manage road traffic jamming problems. Fuzzy controllers are generally employed in a lot of consumer products and industrial applications successfully over the past 2 years. Traffic jamming can be intense problem in several modern cities all over the world. Traffic congestion has been causing several critical issues and challenges within the major and most colonized cities. To travel to completely different locations within the town is turning into more difficult for the travelers in traffic. Due to these jamming issues, citizens lose

time, miss opportunities, and get irritated. Traffic jamming directly impacts the businesses. as a result of traffic congestions there's a loss in productivity from staff opportunities are missing, delivery gets delayed, and thereby the prices goes on increasing. To solve these issues problems, we have to create new facilities and infrastructure.

II. TRAFFIC SIGNAL CONTROL

The basic function of traffic light control system is to start and off the traffic light after a fixed given interval time. An intelligent traffic light observes the existence and nonexistence of vehicles and changes timings of signals according to that. this system also intends to have efficient and safe traffic flow control with reduced waiting time at signal intersection and heavy traffic jams [4]. The traffic jam can be eliminate by increasing the time of green signal on congested way and decreasing the time of red signal on non congested way. Traffic light control system is a very essential and effective traffic control technique safe and quick travel. TSC systems have undergone for continuous improvement. TSC methods are passed through three stages. First is controlled before time, second is traffic responsive manages and last one is intelligent control [2]. The actual time traffic measurement is commonly available by the use of many advanced sensing and communication technologies. For stable and regular traffic flow fixed signal time control method is suitable. For the traffic study of network TRANSYT is a good example [11]. For getting the real time traffic information from the environment sensing technology is used. Any traffic control strategy can be made easily with the help of current real time traffic data. Some adaptive traffic systems are Split cycle offset optimization technique Sydney coordinated adaptive traffic system, urban traffic optimization by integrated optimization of etc. There are so many factors which affect the traffic control system like traffic infrastructure, travelers, number of vehicles, weather conditions, etc. Each and every factor has its own properties, which make the traffic system large and complicated, which create many problems and challenges for researchers and engineers.

III. APPLICATION OF FUZZY LOGIC IN TRAFFIC ENGINEERING

A key inspiration for the employment of fuzzy sets is that the improved handling of uncertainty. Usually, uncertainty is taken into account undesirable, and one tries to decrease it the maximum amount as probable so as to come to “precise” conclusions. However, the actual world is inexact and unsure. Man’s perception of the actual world is additionally ambiguous and inexact as shows by our natural language. Although the imprecision in linguistic explanations, however, a lot of information can be conveyed linguistically, provided one can contact with the indistinctness [5]. In traffic system some phenomena similar to route selection actions, driving actions, or traffic management result from subjective decisions. The input data which is used to take these decisions are travel cost, travel time, distance and velocity of vehicles, congestion duration, waiting time, etc. several these input data’s are crisp whereas others are ambiguous and represented by the linguistic functions. Therefore in traffic management high variety of issues are explained through elements that are indecisive, indistinct, subjective, and deficient. The traffic engineering study area has a shortage of analytical tools which can easily manage the ambiguity in human awareness and decision making method. Fuzzy approach can be work to deal with such type of issues in the research area of traffic engineering. Several functions are incident discovery, jamming finding modeling route selection actions, management of parking and traffic control.

Functions of fuzzy approach in different areas of traffic management and transportation management are described as follow:

- Some of fuzzy logic based applications in traffic engineering are found in real life. Most of the applications are in developing phase and are applied in a simulated environment which is unrealistic and oversimplified.
- The results of fuzzy logic applications are satisfactory whether in real life environment or in simulated environment.
- The results show that the fuzzy set theory can easily be able to deal with uncertainty, vagueness, and ambiguity in traffic engineering such as car following behavior and route choice.
- Fuzzy logic fuses the data from many different resources which increases the accuracy of the predictions and estimations.
- Generally the fuzzy approaches which have been applied in researches do not efficiently use the fuzzy methodologies.

IV. TRAFFIC SIGNAL CONTROL BASED ON FUZZY LOGIC

Traffic signal management may be pre-timed management or actuated management or adaptive management. The pre-timed controller uses the predefined signal timings collected from older traffic approach pattern and repeat it. Actuated controllers observe the moving and paused traffic on all lanes towards intersection and calculate the signal stage period. Adaptive controllers think about the total intersection and modify signal stage and timings in reply to real time traffic [9]. In adaptive management, artificial intelligence techniques are performing a significant role by adjusting green signal time, cycle length, red signal time, and phase series. The fuzzy logic approach is used in adaptive traffic signal management to explore expert’s knowledge. Fuzzy describes the uncertainty within the surroundings. It is describe about crisp logic during which there are only two values right or false. Fuzzy logic shows definite degree of true or false. Fuzzy theory is first proposed by Zadeh [1978] one of the best features of fuzzy system is the ability to include an expert’s knowledge in their design. Fuzzy theory has been applied in several fields of traffic management system to resolve several issues. It has been function to regulate traffic signal light, vehicles, lifts, home appliances, etc.

The fuzzy logic depends system may be the primary successful effort to implement intelligence in traffic management system. The fuzzy system interprets the input to the output of the system. In system area the linguistic values are divided in fuzzy sets, for instance we will describe traffic flow as low, high and medium. Membership functions show the degree of dependency to every fuzzy set. Rate of input in fuzzy system may belong to above on fuzzy set. The association of numerical values to fuzzy set is called fuzzification and therefore the reverse method is named defuzzification. The most logic of the fuzzy system is defined by if-then rules in the fuzzy inference. The fuzzy system may be imprecise reasoning system thus it can be easily applied to many application fields. A priori professional data of objects are often simply reflected in well designed fuzzy rules so there is no necessity of mathematical models of objects. Fuzzy system is extremely flexible and its modification is not so complex. To attain better results the membership function parameters and their quantified data’s, system operators, fuzzy rules, defuzzification methods and other parameters can be changed for achieving good results.

Yousaf [17] proposed an autonomus traffic light control system based on multiagent approach using fuzzy control. The proposed system can minimize the vehicle waiting time using fuzzy logic controller under the situations

that normally occurred during emergency. This system was implemented on two traffic junctions.

V. LITERATURE SURVEY

In this segment, we discuss about different analysis work in the field of traffic light system. In other words this section concentrates on the employment of fuzzy logic for traffic control.

Nidhi Sharma et. Al. [2016] in this study a review of traffic signal management which depends on fuzzy logic to improve the traffic signal light control for traffic management and better traffic flow leading to greener environment. The parameters and variables in traffic engineering are based on subjectivity, imprecision, and ambiguity. Fuzzy approach is adequate in dealing with ambiguity, subjectivity, indetermination, and uncertainty present in traffic signal engineering.[1]

Sahar Araghi ET. al. [2015] study about computational intelligence system for controlling traffic signal light timing arrangement to gain quality for best traffic light management. This study supported the area of controlling traffic signal light timing, in exacting studies that describing the function on Q-learning, neural network, and mathematical logic system are presented. As per existing literature, the intelligent ways show the next performance compared to traditional controlling way situations.[2]

Hamed Homaei ET. al. [2015] study regarding new traffic signal controller with the help of fuzzy logic, fuzzy argument has become a substantial intelligent management approach for traffic operation. This study contribution is to present a new fuzzy signal management system for control of a full single intersection involving emergency vehicle preemption. The proposed control system consists fuzzy part selector and fuzzy green phase extender. The primary one specifies following next Green phase and function of green extender controller makes the choice whether not to increase or terminate the current green stage.[3]

K. K. Pandey ET. al. [2015] they study concerning traffic light control signal at Four-way Intersection road as a result of traffic signals are the most appropriate methodology of controlling traffic in busy junction or lane. Traffic management is major trouble of traffic department in busy lane or road within of town in intersection of lane. They try to explain means to sense the traffic and how to handle a huge traffic in four way lane with fuzzy logic.[4]

Roxanne Hawi et. al. [2015] study about techniques for smart traffic control as a result of steady increase within the variety of vehicles on the road has enlarged traffic blocking in most urban cities of the world. The steady increase in variety of vehicles has prompted students to analyze other alternative solutions to traffic blocking. These systems employ actual time information and check out to imitate human way of thinking so prove promising in vehicular traffic light control and management. This study is a review on the motivations behind the emergence of good traffic control system and the different types of these systems in use nowadays for road traffic management.[5]

A. D. Jovanovic ET. al. [2014] study concerning green vehicle routing in urban zone supported neuro-fuzzy approach as a result of Local city authorities are making a significant effort to expand the amount of low-green house gas vehicles reception. So as to optimize the green capacity, a system has been developed to support deciding in urban green vehicle routing. The objective of this research is to propose a green vehicle distribution model in a very public transportation network.[6]

Mojtaba Salehi ET. al. [2014] study regarding traffic lights control system supported fuzzy logic to reducing the traffic jamming in city areas. This study explains a fuzzy logic signal controller for a four-way intersection appropriate for mixed traffic, as well as a high proportion of motorcycles. The planned agent-based approach will offer a most popular answer by minimizing the vehicles' waiting time particularly the emergency vehicles using fuzzy logic management below the situations that normally occur throughout emergencies. The effectiveness of this approach is tested by taking two traffic junctions.[7]

Goran C'irovic ET. Al. [2014] study regarding routing light delivery vehicles in urban areas using neuro-fuzzy model for the routing of light delivery vehicles by supplying operators. The model given takes into account the very fact that supplying operators have a restricted variety of environmentally friendly vehicles (EFV) on the market to them. Once process a route, EFV vehicles and environmentally unfriendly vehicles (EUV) are measured separately. For determination the matter of routing within the model, an adaptative neural network was used that was trained by a simulated hardening algorithm rule.[8]

Mohit Jha [2014] study about design of fuzzy logic traffic controller for isolated intersections with emergency vehicle priority system using MATLAB simulation for controlling flow of traffic in isolated intersections. This controller is based on the waiting time and queue length of vehicles at present

green phase and vehicles queue lengths at the other phases. The controller controls the traffic light timings and phase difference to ascertain sebaceous flow of traffic with least waiting time and queue length.[9]

Javed Alam ET. al. [2014] study regarding development of intelligent traffic signal system supported congestion estimation using fuzzy approach. They illustrate the design and performance of an intelligent traffic light system depends on blocking estimation by fuzzy logic. In an intellectual traffic light system range of vehicles in every lane is measured by sensors. At the end of every stage these numbers are used as inputs to fuzzy controller. Fuzzy controller calculates the length of green light as per the traffic condition. To simulate matters of an isolated traffic junction supported congestion estimation, they use MATLAB. The results obtained show an improvement within the overall outcome of traffic management as compared to the conventional traffic controller, marking great feasibility and reasonably of the current model.[10]

T. royani ET. al. [2013] study find out solution concerning management of traffic light in isolated intersections by fuzzy neural network and genetic algorithm rule. During this study a fuzzy neural network is applied for real time traffic signal control at associate isolated intersection. The fuzzy neural network has advantages of each fuzzy skilled and simulated neural network. The rules of fuzzy logic controller are developed by following equivalent protocols that an individual's operator would use to manage the time intervals of the traffic light.[11]

Shilpa Mehta et. al. [2013] study concerning traffic control technique employing the Fuzzy Logic based Mamdani Controller. The control technique makes changes within the on and off timings of varied lanes at a traffic junction depending on the particular condition of traffic, in contrast to the standard microcontroller based approach that keeps time slots fixed despite actual state of affairs.[12]

Bilal Ahmed Khan [2013] in this study find out solution regarding an intelligent traffic signal controller is proposed, utilising the fuzzy logic method and image processing technique. A fuzzy logic control has been developed to supply the attribute of intelligence to the system. This study has successfully established an improved traffic controller using fuzzy logic, image processing techniques and microcontroller.[13]

Shailendra Tahilyani et. al. [2012] study about a new genetic algorithm based lane by pass approach for smooth traffic flow on road networks to reduce the traffic congestion in urban

roads. This study introduces a new approach to deal with the traffic congestion on the road networks. A new lane by pass based approach is introduced using genetic algorithms.[14]

L. A. Akanbi et. al. [2012] investigated concerning an intelligent traffic light controller comes with very important personnel movement is given. VIP movement usually cause chaos or within the worst case accident at cross junctions. Traffic capacity, waiting time and siren intensity are the inputs to the system. The fuzzy logic approach in Matlab 7.0 was used to simulate the system. The results obtained from running the simulation on sample traffic knowledge shows that the system was ready to accord the VIP movement its desired main concern at the cross junctions thereby decreasing the chance of VIP movement inflicting accident at the junction.[15]

Sandeep Mehan [2011] study about traffic light controller with fuzzy logic system used at a posh traffic junction. The important time parameters like traffic compactness and line length are achieved by with image processing methods. That the on and off timings for the green, red and orange lights are adjusted as per the particular road conditions.[16]

Yousaf Saeed et al [2011] study about a few multi agent based a mostly autonomous traffic lights system using fuzzy management. This study work presents an application of fuzzy logic for multi-agent based mostly autonomous traffic lights control system using wireless sensors to reduced problems like blocking, misfortune, and speed and traffic abnormality. The planned agent based approach will give a most well liked solution by minimizing the vehicle waiting time particularly the emergency vehicle using fuzzy logic management under things that commonly occur throughout emergency. The effectiveness of this approach is tested by taking two traffic junctions. [17]

Mohammad Hossein Fazel Zarandi [2009] study about fuzzy control system for signal control of an isolated intersection. This new fuzzy signal control system (FSCS) contains fuzzy phase selector and fuzzy green phase extender functions, which located in different levels of this multilevel signal control system. The phase selector is working on the phasing, while the green extender belongs to the green extension level of this multi-level signal control system. The phase selector function concluded the next green phase and green extender controller function makes the decision whether to extend or terminate the current green phase. Simulation is used to evaluate the performance of the proposed FSCS system. The FSCS system is compared with pre timed control system and shows significant improvement over pre timed control strategy.[18]

Loukas Dimitriou ET. Al. [2008] investigate an adaptive hybrid fuzzy rule-based methods (FRBM) approach for the modeling and short-run forecasting of traffic flow in urban arterial networks. Such an approach consists the advantage of correctly addressing data vagueness and uncertainty, and it allows the incorporation of expert's information on limited traffic conditions inside the model arrangement. The model uses univariate and multivariate data structures and uses a Genetic Algorithm rule for the offline and online standardization of the FRBS membership functions in keeping with the prevailing traffic conditions. The results obtained from the online application of the proposed FRBS are originate to over execute those of the offline application and standard applied math techniques, once modeling each univariate and multivariate traffic information like true real Signalized urban arterial corridor.[19]

Iisakki Kosonen [2003] traffic signal control system supported real-time simulation, multi-agent management scheme, and fuzzy logic is presented. This technique known as HUTSIG is closely associated with the microscopic traffic machine HUTSIM; each are developed by the Helsinki University of Technology. The HUTSIM simulation model is employed each both for off-line analysis of the signal management scheme and for on-line modeling of traffic situations throughout actual management. Indicators are derived from the simulation model as input to the control scheme. Here the choice creating of the agents is predicted on fuzzy logic inference that enables a mixture of various aspects like fluency, economy, surroundings and safety.[20]

Chou, Chih-Hsun et. Al. [2002] investigate about a fuzzy logic primarily based traffic junction signal controller is conferred. So as to design a additional sensible controller, we have simulation an surroundings that meets the traffic things more than ever. This environment is generalized by considering the quantity of consecutive junctions, the quantity of lanes, the extents of vehicles, and also the lengths of streets. Compared with existing studies, the planned fuzzy controller has the subsequent characteristics: completely different input variables, lower conclusion frequency; fewer control policy, and correlating every junction with others.[21]

FENGXIANG QIAO ET. Al. [2002] study about a fuzzy logic depends delay estimation system is proposed, compared with other delay estimation models, and tested through simulation and field studies. The fuzzy logic depends approach is proper suited for intersection studies as it can treat both the complex technical and non technical factors, and can easily adapt to changes in traffic control and the highway surroundings. While only limited study is explained in this study, results from the field experiment and comparison with

other delay estimation models demonstrated strongly the attractiveness of the planned approach.[22]

Wei, Wu, et al [2001] study about a flexible form of a fuzzy logic signal control whose performance can be tuned off-line using a set of parameters which define the fuzzy set membership functions for the input variables. Not only can it be tuned for optimum performance in a particular intersection with four approaches and four-phase signal, but also the criteria by which that performance is measured can be changed to match the prevailing policy objectives. This work additionally shows the feasibility of employing a MOGA to seek out a collection of optimal parameters for a fuzzy system with a variety of possibly conflicting performance measures.[23]

A. Hegyi et. al. [2000] study about a fuzzy decision support system which will be utilized in traffic control centers to supply a restricted list of appropriate mixtures of traffic control measures for a given traffic situation. The system we explain is an element of a bigger traffic decision support system which will assist the operators of traffic control centers once they have to reduce non-recurrent congestion employing a network-wide approach. The kernel of our system is a fuzzy logic base that is constructed using simulated situations. At a later stage this technique are complemented with an adaptive learning feature and with a group of fuzzy rules that incorporate heuristic information of experienced traffic operators.[24]

The summary for evolution of traffic signal control based on fuzzy logic is illustrated in Table. By Nidhi Sharma ET. al.[1].

Authors	Area of Research
J. Niittymaki (2001)	They studied about fuzzy rule base formulation is done for separate single intersection.
Wu Wei and Yi Zhang et al.(2001)	They investigate about a fuzzy logic based traffic signal controller for an isolated four approaches Intersection. They also use multi objective genetic algorithm (MOGA) to find a set of optimal Parameters for fuzzy controller.
F. Qiao et al.(2002)	They developed a fuzzy logic based delay estimation system which can treat both technical and Nontechnical factors. They simulate the signal controller for over congested Intersections using fuzzy Logic. The controller extends or terminates the green phase for given real time traffic information.
Chih-Hsun and Jen-Chao(2002)	They implemented traffic junction signal controller based on fuzzy logic which accounts number of continuous junctions, number of lanes, length of vehicles and length of roads. It has following properties: different input variables, lesser inference frequency, lesser rules and connecting each Junction with others.
Isiakki Konsen(2003)	Presented a traffic signal control system which was based on multi-agent control scheme, real time traffic simulation, and fuzzy inference system.
JarkkoNiittymaki and Esko Turunen(2003)	They represented a traffic signal control which was based on fuzzy logic based reasoning. In this fuzzy Reasoning was tied to many valued logic frame work.
Zhang, Li, and Prevedouros(2004)	They developed a fuzzy logic controller which worked as an experienced human traffic controller. According to real time traffic information it extended or terminated the green phase based on fuzzy Rule base.
ANA L. C. BAZZAN(2005)	Presented an approach in which traffic signal agents were used. For coordination between the agents a Distributed approach was used.
Lilin al.(2006 Zang et)	They presented a signal control algorithm for traffic signal control which was based on fuzzy logic by Optimizing the phase's order of traffic signal.
Loukas Diitriou et al.(2007)	They developed a hybrid approach based on fuzzy rule base for modeling the urban traffic flow and Short term forecasting of urban traffic flow.
Mohammad Hossaien et al.(2009)	They presented fuzzy signal control system which contained fuzzy phase selector for selecting the Signal phase and fuzzy green phase extender for extending the green phase.
Gokulan, B.P., & Srinivasan, D.(2010)	They developed urban traffic signal control using distributed geometric fuzzy multi-agent which is Based on a geometric type-2 fuzzy inference system.
P. G. Balaji and D. Srinivasan(2010)	They presented a multi agent system which was using the type-2 fuzzy decision module for traffic Signal control in a complex urban road network.
Alper(2011)	They developed traffic simulator based on real time traffic information using fuzzy inference Mechanism by tuning fuzzy parameters.

Abdel Nasser H. Zaied and Woroud Al Othman(2011)	They proposed a fuzzy logic based traffic system for single intersection which considers the two way Intersection.
Mohammad A. Taha (2012)	They presented a system for traffic simulation based on fuzzy logic.
Yunru Biet al(2014)	They proposed type-2 fuzzy logic control method using multi-agent approach for multiple intersection Traffic signal control optimized by differential evolution.

VI. CONCLUSION

In the present time for urban areas the traffic signal management system performed a very important role. Thus there is necessary to develop the traffic signal control for traffic management and better traffic flow leading to greener environment. The parameters and variables in traffic management are based on subjectivity, indistinctness, and vagueness. Fuzzy approach is adequate in dealing with ambiguity, subjectivity, indetermination, and uncertainty present in traffic management. The methods provided by fuzzy logic make sure of safety, efficiency and environmental objectives in developing efficient and effective traffic signal control. The values of initial parameters in traffic light management derived from fuzzy logic are changeable and are also using other conclusion methods for creating superior performance. The fuzzy reason approach in traffic light management proved better result. When the result of fuzzy approach depends on traffic signal management is compared with the conventional traffic light management, it shows better results. The study of fuzzy logic approach in traffic signal control shows that fuzzy logic dependable traffic light management can easily handle the high congestion problem and uneven traffic run on single junction with on multi-junction on road network.

REFERENCES

- [1] Nidhi Sharma, Shashank Sahu, "Review of Traffic Signal Control based on Fuzzy Logic", International Journal of Computer Applications (0975 – 8887) Volume 145 – No.13, July 2016.
- [2] Sahar Araghi, Abbas Khosravi, Douglas Creighton, "A review on computational intelligence methods for controlling traffic signal timing" , Centre for Intelligent Systems Research (CISR), Deakin University 2015.
- [3] Hamed Homaei, S.R. Hejazi, Seyed Ali Mohamad Dehghan, "A New Traffic Light Controller Using Fuzzy Logic for a Full Single Junction Involving Emergency Vehicle Preemption", Journal of Uncertain Systems, Vol.9, No.1, pp.49-61, 2015.
- [4] Kamlesh kumar pandey, Rajat Kumar yadu, Pradeep kumar shukla, Narendra Pradhan, "A Case Study for Traffic Control Signal at Four-Way Intersection Road" , International Journal of Computer Techniques – Volume 2 Issue 4, July - Aug 2015.
- [5] Roxanne Hawi, George Okeyo, Michael Kimwele, "Techniques for Smart Traffic Control: An In-depth", International Journal of Computer Applications Technology and Research Volume 4– Issue 7, 566 - 573, 2015, ISSN: 2319–8656.
- [6] Aleksandar D. Jovanovic', Dragan S. Pamuc'ar, Snez'ana Pejč'ic'-Tarle, "Green vehicle routing in urban zones – A neuro-fuzzy approach", Elsevier 41 (2014) 3189–3203.
- [7] Mojtaba Salehi, Iman Sepahvand, and Mohammad Yarahmadi, " A Traffic Lights Control System Based on Fuzzy Logic", International Journal of u- and e- Service, Science and Technology Vol.7, No.3 (2014), pp.27-34.
- [8] Goran C'irovic', Dragan Pamucar, Darko Boz'anic' "Green logistic vehicle routing problem: Routing light delivery vehicles in urban areas using a neuro-fuzzy model", Elsevier (2014) 4245–4258.
- [9] Mohit Jha, Shailja Shukla, "Design Of Fuzzy Logic Traffic Controller For Isolated Intersections With Emergency Vehicle Priority System Using MATLAB Simulation", 2014.
- [10] Javed Alam, Prof. M.K. pandey, "Development of intelligent traffic system Based on Congestion Estimation using Fuzzy logic" IOSR, e-ISSN: 2278-0661, Vol. 16, Issue 3, 2014.
- [11] T. Royani, J. Haddadnia, and M. Alipoor "Control of Traffic Light in Isolated Intersections Using Fuzzy

- Neural Network and Genetic Algorithm”, International Journal of Computer and Electrical Engineering, Vol. 5, No. 1, February 2013.
- [12] Shilpa Mehta, K. Soundararajan, U Eranna, Bharathi SH, “Intelligent System for Automated Traffic Signal Control Using Fuzzy Mamdani Model”, IJETTCS, Volume 2, Issue 6, 2013.
- [13] Bilal Ahmed Khan; Nai Shyan Lai, “An Intelligent Traffic Controller Based On Fuzzy Logic” 2013.
- [14] Shailendra Tahilyani, Manuj Darbari, Praveen Kumar Shukla, “A New Genetic Algorithm Based Lane-By-Pass Approach for Smooth Traffic Flow on Road Networks”, International Journal of Advanced Research in Artificial Intelligence, Vol. 1, No. 3, 2012.
- [15] L.A. Akanbi, E.A. Olajubu, “A fuzzy based intelligent traffic control system for Managing VIP-induced chaos at road intersection”, IEEE, Vol 5. No. 4, June, 2012.
- [16] Sandeep Mehan, “Introduction of Traffic Light Controller with Fuzzy Control System”, IJECT Vol. 2, Issue 3, Sept. 2011.
- [17] Yousaf Saeed, M. Saleem Khan, Khalid Ahmed, Abdul Salam Mubashar, “A multi agent based autonomous traffic lights control system using fuzzy control” International Journal of Scientific & Engineering Research Volume 2, Issue 6, June-2011.
- [18] M. H. Fazel Zarandi, Shabnam Rezapour, “A fuzzy signal Controller for isolated intersections” ,Journal of Uncertain Systems, Vol.3, No.3, pp.174-182, 2009.
- [19] Loukas Dimitriou, Theodore Tsekeris, Antony Stathopoulos, “Adaptive hybrid fuzzy rule based system approach for modeling and predicting urban traffic flow” ELSEVIER, 2008.
- [20] Issakki Kosonen, “Multi- agent fuzzy signal control based on real-time simulation” ELSEVIER , 2003.
- [21] Chou, Chih-Hsun, and Jen-Chao Teng. "A fuzzy logic controller for traffic junction signals." Information Sciences 143.1 (2002): 73-97.
- [22] Qiao, Fengxiang, et al. "Fuzzy logic based intersection delay estimation." Mathematical and computer modelling 36.11 (2002): 1425-1434.
- [23] Wei, Wu, et al. "Traffic signal control using fuzzy logic and MOGA." Systems, Man, and Cybernetics, 2001 IEEE International Conference on. Vol. 2. IEEE, 2001.
- [24] A. Hegyi, B. De Schutter, S. Hoogendoorn, R. Babuska, H. van Zuylen, “Fuzzy decision support system for traffic control centers” , Proceedings of the European Symposium on Intelligent Techniques (ESIT 2000), Aachen, Germany, pp. 389–395, Sept. 2000.