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Quantification of Traffic Congestion Based on Vehicular Speed under Heterogeneous Flow Conditions using Fuzzy Inference Model

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Abstract: ***Traffic congestion is a condition on transport networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. In simple words, "the ability of a vehicle to move forward in a traffic state" defines congestion. Traffic congestion has become a serious problem in the urban districts. In heterogeneous flow like India, congestion impacts the movement of people both in perception and in reality that leads to consumption of time, energy and also leads to the pollution. In order to save precious human life, eliminate road accidents and the essence factor called time, it is essential to ensure a proper measure for traffic congestion. Earlier there were several attempts made to develop different approaches for congestion analysis. At present the congestion levels of ten different road stretches of Visakhapatnam city within the Central Business District (CBD) area. The main aim of this study is to introduce a versatile fuzzy logic traffic flow model that is capable of making optimal traffic prediction to identify the congestion levels of the city by considering the factors like vehicle volume, average speed and road speed limits by using MATLAB and to generate the desired congestion index of the specified study stretches. This study lays the foundation for traffic congestion prediction, early warning & proactive alleviation of traffic congestion.***

Keywords: ***Level of Service, MATLAB, Membership Functions, Fuzzy Logic, Linguistic Variables.***

I. INTRODUCTION

Urban traffic congestion has become a critical problem that not

Only affects the people's daily lives, but also restricts the stable

development of society and economy. In our country like India which have mixed traffic conditions, congestion can't be totally eliminated but it could be stabilized to some extent by taking proper enforcement and mitigative measures therefore traffic congestion has become a serious issue that is found in every cities.

Irregular planning, intolerable road capacity, private transit encouragement, tremendous growth of vehicles are the main source of traffic congestion. Countries like China, Singapore, London and US has introduced a concept called "congestion charging" to control congestion. Our country is making some flexible policies to implement the same initially in some of the metro cities. Figure.1 shows how the heterogeneous flow impact congestion.

At present, urban areas creates complex problems in daily life with traffic. Congestion phenomenon cannot be terminated only by constructing bridges, motorways or increasing road capacity alone, but also by providing proper channelization. It is necessary to build technology system for transportation management which is used for control of the traffic phenomenon.

Figure.1 Heterogeneous Flow

Traffic control systems have direct influence on traffic problems which helps to improve traffic flow and reduce Traffic congestion. At present, there is no unified and fixed evaluation measure for evaluating traffic operation conditions. In fact, there are various evaluation measures in different regions [5].In 1985, Highway Capacity Manual (HCM) first suggested to use the level of service as an evaluation index of road performance. The level of service was defined into six grades in the United States, and three grades in Japan.

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In China, Ministry of Public Security selected the average travel speed of a city road as the evaluation indicator to describe conditions of road traffic [9]. Levinson and Lomax developed a Congestion Index that indicated in differences in actual versus desired travel times for different types of roadways. A Delay Rate Index (DRI) concept was derived on the basis of LOS, speed, delay rate, and other relationships indicated in HCM of 1985 and 1994 [12]. Washington State Transportation Department published the congestion report in 2006, in which the congestion evaluation index was defined as the average peak travel time [10].Yan and Liu conducted a study based on Speed Performance Index for Beijing Expressway network where the author took different road segments for study and evaluated Road segment congestion index and Road network congestion index with the developed speed index [2]. M. Vaziri *et. al* developed congestion indices with a limited sampling Speed and flow rate information. The congestion indices were associated, in simple and logical models, with variables of travel speed, travel rate, delay rate, travel rate ratio and delay ratio respectively. To calibrate the congestion index models, specific congestion levels were assessed by the index values under free and capacity flow conditions. Index models were developed for comparison based on the US Highway Capacity Manual, speed and flow rate information [6]. Hamad *et. al* developed a fuzzy inference model with inputs of travel speed, free-flow speed, and the proportion of very low speed in the total travel time. The process was demonstrated using real-world data. The results were compared with those of the Highway Capacity Manual [8]. Aathira K Das has developed Congestion Modeling under Mixed Traffic Conditions by using MATLAB. Here the author considered six km stretch dividing it into three segments of 2km each for feasibility of the study [1]. Surendra R and Parbat developed congestion modeling on urban road network using fuzzy inference system to obtain an output Parameter Congestion Index [3]

II. STUDY AREA

"The City of Destiny", Visakhapatnam is situated in the state of Andhra Pradesh,. It is the second largest city in the state with an area of 550sq.km. Visakhapatnam popularly known as the second Capital of Andhra Pradesh which is also one of the fastest developing city in India. At present there is a in the city. Due to increase in urban population Visakhapatnam was considered as the study area. Data collection was mainly focused on the Central Business District (CBD) due to the tremendous increase of vehicles. Figure.2 shows the map of the study area Visakhapatnam city. Some of the mid-block areas considered are Maddilapalem, Gajuwaka, Dabagardens, Gopalapatnam, Duvvada, Kancharapalem, Marripalem, Dwarakanagar, Akkayapalem and Old Gajuwaka.

A videographic survey of one hour is captured at each stretch during the peak hour of that particular locality. A 50m stretch is taken at each study area and is to be ensured that the study stretch is gradient free .care should be taken that it is not so closer to an intersection to generate accurate vehicle average speeds. To collect data at that particular locality regarding vehicle volume and the class of vehicle using that particular Roadway facility.

Figure.2. Study Area

III. DEVELOPMENT OF FUZZY INFERENCE SYSTEM (FIS) FOR CONGESTION

A. Fuzzy Logic

The term fuzzy logic was introduced by Lotfi Zadeh in 1965. It is a form which purely depends on degree of freedom in which truth of variables may be any real number between 0 and 1 *i.e* it can't be expressed as true or false exactly, but says it as partially true. The Membership Functions (MF) are the integrated functions which constitute the body of the Fuzzy System model. It should be noted that the Membership Function defines the Fuzzy set having a range of values in the horizontal axis. However the only constraint for a Membership Function is in the vertical axis that must be scaled between 0 and 1.

Fuzzy Inference System (FIS) is a process which purely depends upon human based knowledge by framing some of the rules in the Fuzzy Inference Engine (FIE). One of the main advantage of this system is that it doesn't promote any error as this is entirely based on human sense. Initially the process of model consists of aggregating the three input data, designing the output variable, framing the rules based on IF-THEN condition and then finally determining the Congestion Index (CI)

B. Input Parameters

Congestion in road traffic is affected by multiple factors such as Vehicular Volume, Vehicular Average Speed, Road Speed Limit. All the above three parameters combine together to represent the congestion levels within the constraints of rule base.

The three inputs and one output with respect to their linguistic variables and membership functions are tabulated as shown below:

Table.1 Inputs and Membership Functions

S.No.	Input variable	Fuzzy sets	Membership function type
1	Vehicular Volume	Too Low	trimf
		Low	trimf
		Moderate	trimf
		High	trapmf
		Very High	trimf
2	Vehicular Average Speed	Too Low	trapmf
		Low	trimf
		Moderate	trimf
		High	trimf
3	Road Speed Limit	Low	trapmf
		Moderate	trimf
		High	trimf
			trapmf

C. *Output Parameters*

The linguistic variables of the output parameter with respect to the inputs is given in Table.2 as below:

Table.2 Outputs and Membership Functions

S.No.	Output variable	Fuzzy sets	Membership function type
1.	Congestion Index	Low	trimf
		Moderate	trapmf
		High	trapmf
		Very High	trimf

The graphs of the Input and Output parameters that are designed and executed are shown in Results

D. Rule Base of the Model

The inference mechanism in the fuzzy logic controller resembles the human reasoning process. This is where fuzzy logic technology is associated with artificial intelligence. The rules are entirely based on human knowledge and hence it leads to perfect reasoning.

The rules can be defined based on our inputs provided by using IF-THEN condition. The part of the rule following IF is called the antecedent, and the part following THEN is called the consequent. The task of combining three inputs and deriving a natural language based congestion measure is performed using a fuzzy rule which are manually designed as follows

1. IF (Vehicular Volume is too high) AND (Vehicular Average Speed is too low) AND (Road Speed Limit is low), THEN (Congestion Index is very high)
2. IF (Vehicular Volume is too high) AND (Vehicular Average Speed is low) AND (Road Speed Limit is low), THEN (Congestion Index is high)
3. IF (Vehicular Volume is high) AND (Vehicular Average Speed is moderate) AND (Road Speed Limit is moderate), THEN (Congestion Index is moderate)

Where too high, high, moderate, low and too low each represent the degree of congestion as defined in Figures 1, 2, 3, and 4..

Out of 66 rules, 57 number of rules are executed in this process to get the desired output as shown in the below figure.3.

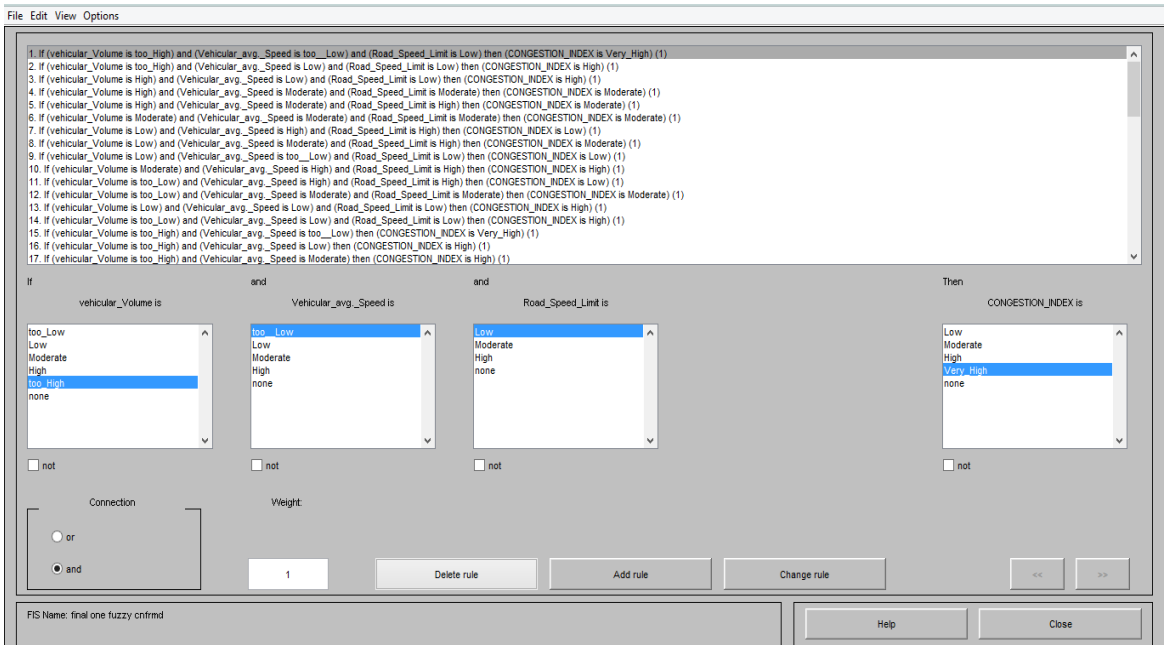

Figure.3 Rule base in FIS

E. Application of Fuzzy Inference System for Generating Congestion Index

The manually tuned Mamdani-type Fuzzy Inference System (FIS) is used to compute and generate the traffic congestion index. Mamdani FIS is the most used tool in developing fuzzy models. Mamdani architecture used in this paper for estimation of road traffic congestion is designed with three inputs, one output parameter and fifty seven fuzzy rules. The manner in which the fuzzy rules are executed is as follows. Once the rules were framed then the Fuzzy Inference Engine is made to run and execute the program that was given to the system in MATLAB.

On entering observational data to the Fuzzy Inference System of ten considered mid-block sections, the system generates the Congestion Indices of study area. The congestion indices are scaled between 0 and 1, where the indices closer to 0 and 1 indicate free flow traffic state and a critical congested state respectively.

The below figures 3 & 4 was generated from the Fuzzy Inference System. In the below figures the vertical numbering of each segment from each input shows the rule that is framed to run the output.

→ Critical congested state generated at Gopalapatnam roadway link as 0.70 ~ 1

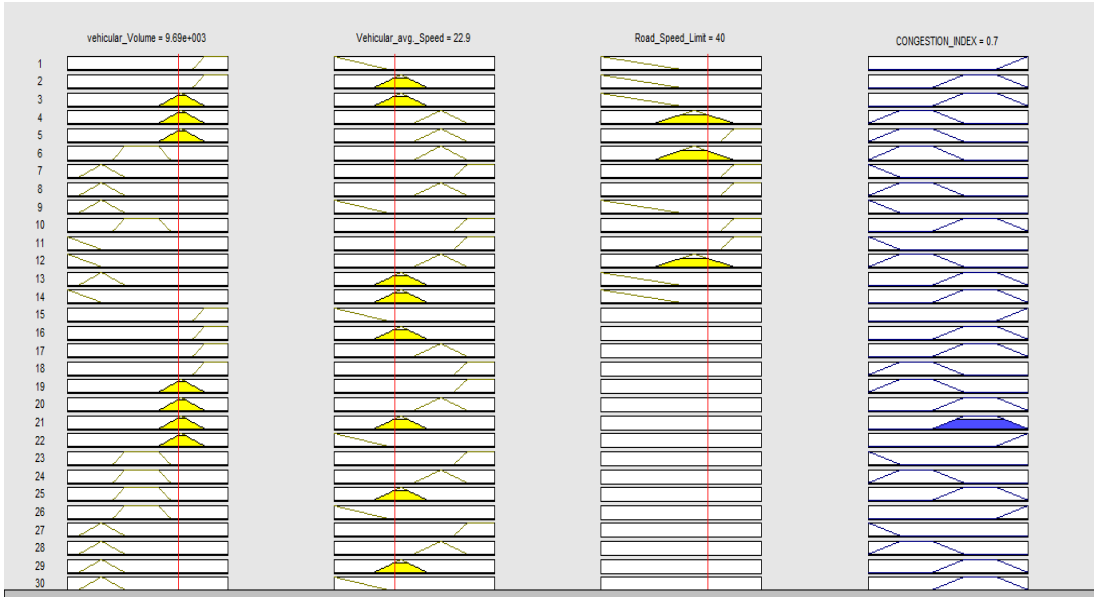

Figure.4 Generated Congestion Index

→ Free traffic flow identified at Kancharapalem roadway link as **0.34** ~ 0.

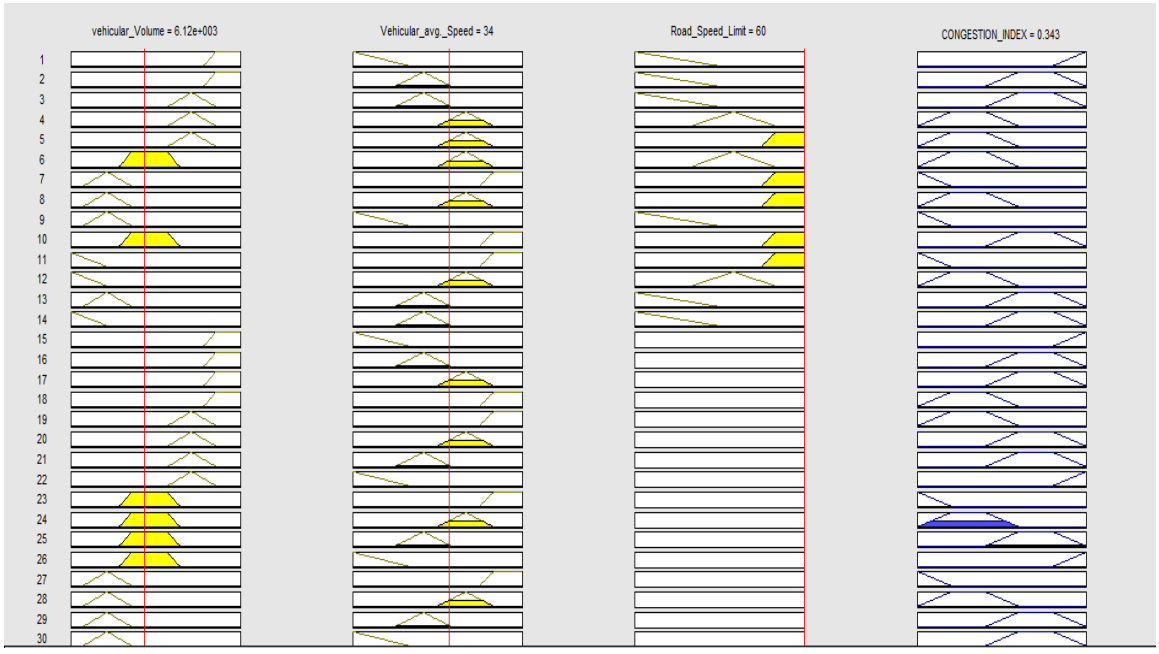

Figure.5 Generated Congestion Index

The conclusion derived is a number between 0 and 1 as stated earlier. This value carries the information about the current situation in terms of congestion index. It is a continuous measure for each and every point of Vehicle Volume, Vehicular Average Speed, Road Speed Limit. Output shows the corresponding congestion measure for that each and every point according to the rules framed. It is to be noticed that limited number of inputs should be taken in FIS system as the rule base becomes complex in deriving the accurate results.

IV. RESULTS AND CONCLUSION

The proposed fuzzy congestion model is applied to a real-world road network of the study area. The necessary data is collected focusing mainly around the Central Business District (CBD) area which generate more number of trip times based on the requirement. The obtained Congestion Index on the major roads of the city should be studied carefully and some mitigate measures are to be taken up in the congestion prone area. By looking at this we can say that the Kancharapalem roadway link possess free flow state whereas Gopalapatnam roadway link generates higher congestion effect and some remedial measures have to be taken by anticipating future trends. Below table.3 shows how all the Congestion Indices of the study network are varying

Table.3 Generated Congestion Indices

S.No.	Roadway Link	Vehicle Volume(per hr)	Vehicle Average Speed(kmph)	Road Speed Limit (kms)	Obtained CONGESTION INDEX
1	Maddilapalem	12887	32.01	60	0.62
2	Kancharapalem	6115	*34.05*	*60*	*0.34*
3	Akkayyapalem	4499	20.71	40	0.49
4	Daba Gardens	6582	23.82	40	0.52
5	Gajuwaka	5611	26.7	60	0.48
6	Gopalapatnam	9688	*22.94*	*40*	*0.7*
7	Old Gajuwaka	5557	26.22	40	0.51
8	Duvvada	5545	21.71	60	0.47
9	Marripalem	5420	33.12	40	0.39
10	Dwarakanagar	3868	29.32	40	0.55

Below are the figures of the developed Input and Output parameter graphs in Fuzzy Inference System (FIS) in order to generate the Congestion Index (CI) by Fuzzy Inference Engine (FIE) as above.

The input parameters developed are Vehicle Volume, Vehicle Average Speed and Road Speed Limit. The graphs are as follows:

A. *Vehicular Volume:*

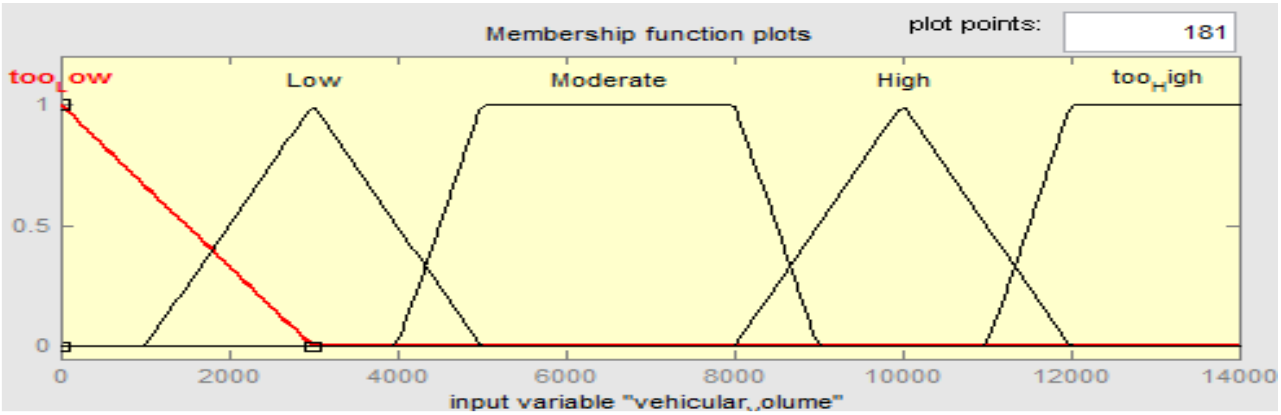

Figure.6 Vehicular Volume

B. Vehicular Average Speed

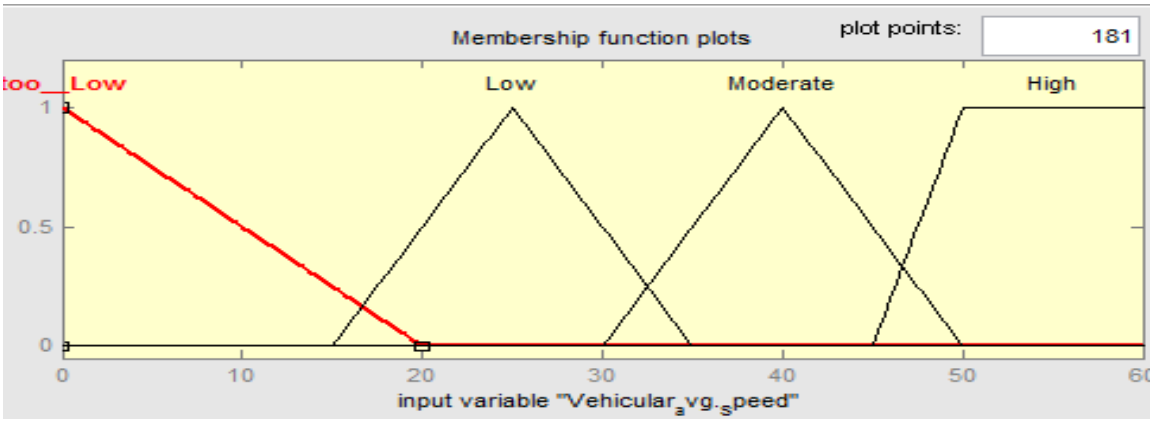

Figure.7 Vehicular Average Speed

C. Road Speed Limit

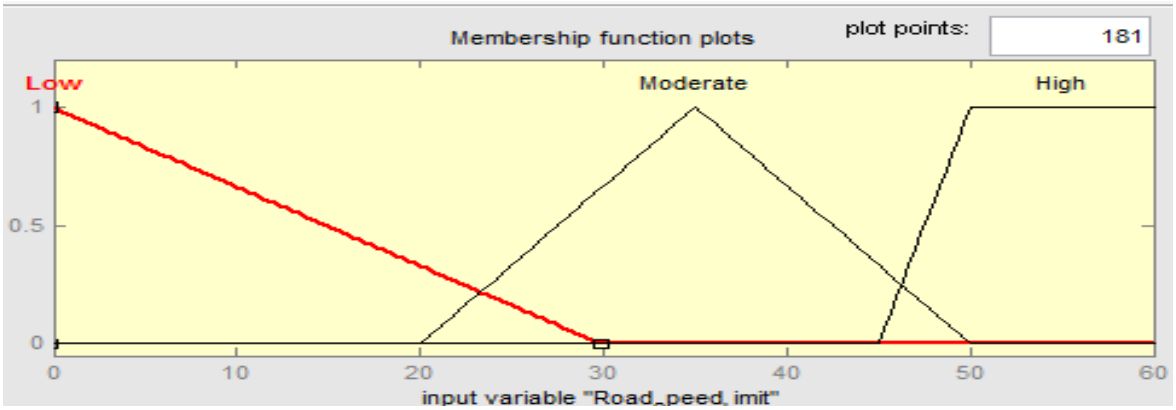

Figure.8 Road Speed Limit

The desired output parameter developed is the Congestion Index. The graph developed is as shown below:

D. Congestion Index

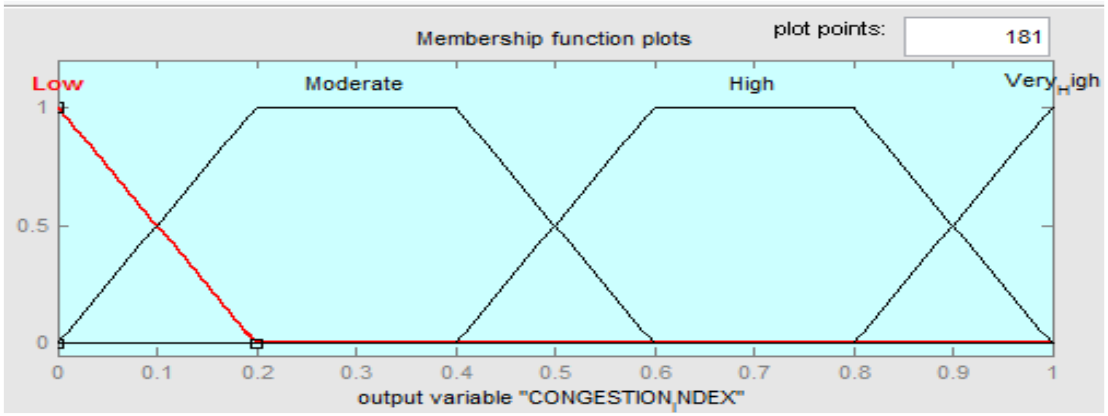

Figure.9 Congestion Index

Observation shows that study stretch running of vehicular volume of nearly 10000 vehicles per hour is said to be in a maximum congested state. It is also noticed that the same stretch where the maximum congestion is generated in Bus Rapid Transit System (BRTS). Here it is observed that the travelers were not using the BRTS roadway facility in a proper manner *i.e* the traffic regulations were not at all followed by the travelers and all type of vehicle travelers themselves tend to use this BRTS facility in a mixed way. No proper guidelines were even followed by the traffic department to regulate the roadway facility meant only for the buses. Certain enforcement measures and initiatives are to be taken up by the traffic department leading to the proper usage of this BRTS facility so that the congestion rate occurred as above can be reduced and excellent results like reduction in travel time, vehicle maintenance cost, lower consumption of fuels can be occurred.

Also by proper usage of this BRTS facility, there is a great chance of the travelers to change their route choice behavior. This further makes the public to use this path as the travel time and also fare is low rather than using their own vehicles at risk which costs more in all aspects. This eventually leads to the encouragement of public transit.

REFERENCE

1. Aathira K Das et al. (2016) "Traffic congestion modeling under mixed traffic conditions through fuzzy logic approach." in Global Research and Development Journals.
2. Feifei He et al. (2016). "A traffic congestion assessment method for urban road networks based on speed performance index." Procedia Engineering, 137, 425-433.
3. Kukadapwar et al. (2015) "Modeling of traffic congestion on urban road network using fuzzy inference system."
4. N.P. Padhy et al. (2015). *Soft Computing: With MATLAB Programming*. Oxford University Press.
5. M.Vaziri et al. (2007). "Modeling Highway Congestion Index for a Developing Country: The Iran Experience." ScientiaIranica, 14(1), 1-10.
6. R.Narayanan et al. (2003). "Quantification of congestion using Fuzzy Logic and Network Analysis using GIS." In *Map India Conference*.
7. K.Hamad and S.Kikuchi (2002). "Developing a measure of traffic congestion: fuzzy inference approach." Transportation Research Record: Journal of the Transportation Research Board, (1802), 77-85.
8. Manual, H. C. (2000). Transportation research board. *National Research Council, Washington, DC, 113.*
9. Ministry of Public Security., 2000. Urban Traffic Management Evaluation Indicators System (printed in 2012).
10. B.Krause et al. (1996). " Intelligent highway by fuzzy logic: Congestion detection and traffic control on multi-lane roads with variable road signs." In *Fuzzy Systems, 1996., Proceedings of the Fifth IEEE International Conference on* (Vol. 3, pp. 1832-1837). IEEE.
11. H.Levinson and T.Lomax (1996). "Developing a travel time congestion index." Transportation Research Record: Journal of the Transportation Research Board, (1564), 1-10.
12. Goldstein et al. (1991). *U.S. Patent No. 5,029,164*. Washington, DC: U.S. Patent and Trademark Office
13. F.B Lin(1989). "Applications of 1985 Highway Capacity Manual for Estimating Delays at Signalized Intersections." *Transportation Research Record*, (1225).
14. Rothenberg, M.J.(1985) "Urban congestion in the United States-what does the future hold," ITE Journal, 55(7), pp. 22-39.