Data Analysis Application for Variable Message Signs Using Fuzzy Logic in Kuala Lumpur

Arash Moradkhani Roshandeh, Othman Che Puan., and Majid Joshani

***Abstract*—** Intelligent Transportation Systems, which apply advanced technologies to surface transportation systems, are widely viewed as the solution to the transportation problems that our society faces. One of the fundamental requirements of an intelligent road vehicle is to assist the driver in finding their anticipated destination in the most economical, reliable and safe way. The use of variable message signs (VMS) is generally considered to be a powerful tool to influence route choice so as to increase safety and comfort during driving and improve network performance and to make optimum use of available capacity. Saving motorists travel time is most important parameter which should be mentioned. Fuzzy logic is powerful problem solving methodology with a myriad of applications in embedded control and information processing. The main advantages of using fuzzy logic system are the simplicity of the approach .This study attempts to simulate and design a fuzzy logic controller with archived traffic data for VMS in Kuala Lumpur to optimize the system performance and understand how the system is going to behave for the entire range of values in the input space.

***Keywords*—** Fuzzy Controller, Fuzzy Logic, Intelligent Transportation Systems, Rule Viewer, Variable Message Signs

I. INTRODUCTION

Intelligent Transportation Systems (ITS) are systems utilizing multidisciplinary technologies to improve all kinds of transportation. One of the most important related technologies is computer science. Computers are used in the automotive industry to perform certain guidance actions, attempting to minimize injuries and to prevent collisions [1].

Intelligent Transportation Systems, which apply advanced technologies to surface transportation systems, are widely viewed as the solution to the transportation problems that our society faces. In many areas, a steadily increasing demand for mobility is confronting economic, social, and physical constraints on transportation infrastructure. These constraints include reduced funding for transportation projects, social and environmental concerns about infrastructure expansion, and, in urbanized areas, a lack of physical space to devote to such projects. ITS applications, in which technology is used to increase the operating efficiency and capacity of transportation infrastructure, can supplement or even replace infrastructure development, providing more effective mobility solutions at less of a cost to society [2]. Urban traffic control is a major area in which ITS can be applied. At the local level, traffic signals and Variable Message Signs are designed to manage vehicle conflicts, allocating time among the conflicting traffic streams which must share the use of the road. The logic by which the signal controller allocates usage of the intersection can range from basic fixed-time methods to intelligent strategies that detect and respond to traffic conditions in real time.

Intelligent Transportation Systems (or ITS) use real-time, travel-related information to integrate all components of a traditional transportation system (roads, transit, traffic control devices, vehicles and drivers) into an interconnected network. Intelligent Transportation Systems use advanced technologies in electronics, information processing, and communications to gather, process and distribute information necessary to maintain and increase the efficiency and safety of the functioning system.

In recent years the existing road network is no longer able to cope the growing traffic demand in many regions all over the world. Since the construction of new roads is often socially untenable, there is a seek to use the existing infrastructure more efficiently. A possibility to improve the capacity of the freeway network is to control the traffic using Variable Message Signs (VMS) [3].

One of the fundamental requirements of an intelligent road vehicle is to assist the driver in finding their anticipated destination in the most economical, reliable and safe way. Dynamic Route Guidance systems are likely to emerge in a variety of forms over the coming years and offer the potential for improved efficiency both to individual guided drivers and to the network as a whole [4].

With the increasing concern on traffic congestion in most of

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metropolitan cities, Advanced Traffic Management and Traveler Information Systems are conducted as a possible solution to solve traffic problem. The acronym VMS stands for Variable Message Sign. It is a sign for the purpose of displaying one of a number of messages that may be changed or switched on or off as required [5].

The use of variable message signs (VMS) is generally considered to be a powerful tool to influence route choice so as to increase safety and comfort during driving and improve network performance and to make optimum use of available capacity. Some of metropolitan cities installed VMS on arterial street and freeways to guiding drivers to make choice when there is some unexpected events on the road segment. In general, the function of VMS can be concluded into 3 categories: lane control, speed control and prescription. It not only provides driver information to avoid unexpected events, but also alternative route for driver to make choice [6].

A Variable Message Sign is a device used to convey information to motorists about events that might affect their travel experience and safety. Such signs warn of traffic congestion, accidents, incidents, roadwork zones, or speed limits on a specific highway segment. In urban areas VMS are used within parking guidance and Information systems to guide drivers to available car parking spaces. They may also ask vehicles to take alternative routes, limit travel speed, warn of duration and location of the incidents or just inform of the traffic conditions [7].

Basically, Fuzzy Logic (FL) is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human−like way of thinking in the programming of computers [8].

In the transportation area we are used to properties which cannot be dealt with satisfactorily on a simple “yes” or “no” basis. Fuzzy sets were introduced by Professor Lotfi Zadeh [9] in 1965 to represent/ manipulate data and information possessing nonstatistical uncertainties. The first real application to a control system was proposed by E. H. Mamdani [10]. Fuzzy sets serve as a means of representing and manipulating data that are not precise, but rather fuzzy [11].

Fuzzy logic is powerful problem solving methodology with a myriad of applications in embedded control and information processing. Fuzzy provides a remarkably simple way to draw definite conclusions from vague, ambiguous or imprecise information. In a sense, fuzzy logic resembles human decision making with its ability to work from approximate data and find precise solutions [12]

Nowadays, fuzzy logic is used to manage a wide range of systems, like cars, aircraft and railways. The main benefit of fuzzy logic is the opportunity to model the ambiguity and the uncertainty of decision-making. Moreover, fuzzy logic has the ability to comprehend linguistic instructions and to generate control strategies based on priori communication. The point in utilizing fuzzy logic in control theory is to model control based on human expert knowledge, rather than to model the process itself.

II. VMS in Different Countries

A comparing study of driver attitudes to VMS in Canada and United Kingdom was reported by Cheng [13]. The drivers in the U.K. were older and had more years of driving experience, whereas the Canadian drivers were more familiar with VMS. The results from questionnaires showed that Canadian drivers regarded VMS as more effective and more useful. Most drivers in both countries preferred to receive traffic information through radio and VMS`s (in the article by Cheng, however, it is not mentioned whether these were selected among other information channels or if this was the answer of an open question). A large proportion of the interviewed drivers would be frustrated if the information on the VMS was inaccurate and 80 % of the drivers would like the displayed message to include the time when it was first posted. Overall, the VMSs were recognized to be “somewhat up-to-date”, slightly more than “somewhat reliable” and more than “somewhat useful”. Canadian drivers, who were more exposed to VMS, found the information more reliable, effective, up-to-date and useful than the British drivers. They also thought that safety slogans were effective means of achieving a safer driving environment. A conclusion from the study was that when more VMS`s are installed in the United Kingdom, driver perception is likely to improve as exposure and experience increase.

In a Finnish investigation [14] the speed limits were varied by VMS, primarily based on weather and road conditions. For stretches of the road without junctions, the speed limit was 100 km/h during normal road conditions, 80 km/h during bad and 70 km/h during really bad road conditions. At junctions, the speed limit was 80 km/h for normal road conditions, 70 km/h for bad and 60 km/h for really bad road conditions. The driver attitudes to this were analyzed through road-side interviews.

Most drivers knew that the signs were variable but older people to a smaller degree. Most of them also knew that the speed limits were controlled according to weather and road conditions, but did not know that the data was collected automatically.

Additionally, 11-16 % thought that the speed limits were also controlled by the prevailing traffic situation. Generally the drivers accepted the dynamic speed limits and trusted that they were correct with respect to the circumstances. Maintaining this trust sets high quality requirements for the operation and control of the system.

In another Finnish study [15] it was stated that drivers accept VMS on the E18 and rely on the system. 96 % of the drivers consider VMS based on real-weather and road condition data to be necessary. Inadequate speed limits, however, increase the mean speed and decrease the time gap between cars. In a field study where VMS replaced the fixed speed limit 80 km/h, 78 % of the drivers considered 80 km/h to be the appropriate speed limit in poor road surface conditions in daylight [16]. 67 % considered the appropriate speed limit in good road surface conditions in the dark to be at most 80 km/h. The most common advantages mentioned were improved traffic flow and increased traffic safety.

VMS showing a minimum headway sign (minimum distance between two cars) decrease the proportion of short headways [17]. This sign in addition to a slippery road condition sign lead to decreased mean speed of cars travelling in free-flow traffic by 1-2 km/h.

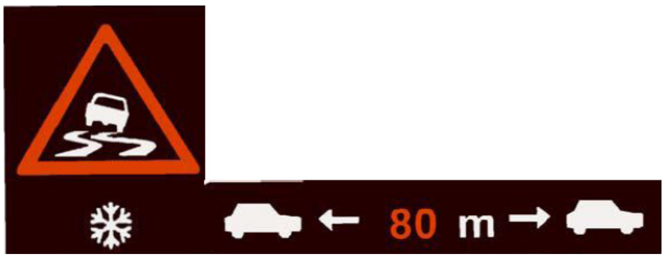

Fig. 1 slippery road condition sign and minimum headway sign

Drivers themselves state that with VMS their attention is being focused on searching for potential hazards, they test the road for slipperiness and are more careful when overtaking. In the winter, weather-controlled speed limits lowered from 100 km/h to 80 km/h decrease the speed by 3.4 km/h. The effectiveness was highest when the adverse conditions were hard to detect. Most drivers accepted lowered speed limits and found variable speed limits valuable. It is concluded that an effective variable message sign may draw attention from other, fixed signs. This leads to recommending slippery road signs only at critical spots, and variable speed limits for longer road sections.

In England, a large test on vehicle-activated signs was carried out, where signs for mandatory speed limit, warning signs for bends and junctions, and safety camera repeater signs were lit up for speeding vehicles [18]. Public opinions were collected in locations where speed limit roundels or junction signs had been installed. The public response on use of vehicle-activated signs was very positive.

Most drivers connected their own speed to the signs being triggered. They thought that exceeding the speed limit triggered the speed limit roundel sign and that the junction sign was triggered to make them slow down or to warn them about a specific hazard.

Dutta et al. [19] report about a driver simulator study carried out in the USA. Variable message signs with text messages presented on two consecutive screens were used and the driver behaviour was studied. The message either was or was not repeated, before it was turned off. If it was repeated, the presentation time of the message was 0,5 s per word, and if it was not repeated, the presentation time was 1 s per word.

Sometimes there was an obstruction leading to out-of-phase message and sometimes not. The participants in the study were told to drive the simulator for 24 trips through underground tunnels, where each tunnel consisted of a five lane roadway. The driver task was to follow the given information to a specific destination. The results show that the miss rate was significantly higher when there was no repetition, compared to when there was a single repetition of the message. The only situation when the difference was not significant was when there was no obstruction present.

When looking at lane change distances, drivers changed lanes later when there was no repetition compared to when there was a repetition. When there was no obstruction, drivers changed lanes later than when there was an obstruction (significant). It was also noted that the sequencing of the messages had an impact of the driver performance when it comes to lane change distances. It was revealed that the lane change distance was shorter for out-of-sequence messages than it was for in-sequence messages. This was thought to be because of the nature of the message in the second phase, for instance “2 RT LANES CLOSED”.

III. Statement of the Problem

Variable Message Signs systems have a significant impact on roadway efficiency, with benefits such as time saving. VMS is an electronic message sign strategically placed along the road network with alternative roads to provide information and recommendations for drivers on traffic conditions. VMS allows operators in Traffic Control Centre to activate or upload new messages via software [20], [21].

In many cases, VMS was design to improve flow at localised points in the network such as heavily congested roads, or to make travellers aware of nonrecurring congestion such as special events or incidents [22].


VMS ID: V052
Location: Jalan Tun Razak (towards Jalan Ampang/ city center)
Fig. 2 VMS placement

Saving motorists travel time is most important parameter which should be mentioned. Fuzzy logic is an approach trying to mimic human thinking by using computer algorithms. In practice, the measured values are first transformed into fuzzy sets. These sets describe measured values by intuitive truth-values such as “high” density or “medium” number of vehicles.

Indeed, fuzzy control has proven to be successful in problems where exact mathematical modelling is hard or impossible but an experienced human operator can control process. In general, fuzzy control is found to be superior in complex problems with multi-objective decisions.

IV. Research Objective

Classical mathematics adopts a binary attitude toward subjects; for example, a variable either has a specific value or it does not. From this point of view, an answer to a question is either true or false; there is no compromising position. In reality, however, there are some phenomena where it is more suitable to adopt a continuum of answers between two extremes. This attitude toward understanding phenomena is described by the term fuzzy logic, as presented by Asgar Zadeh in 1965 [23].

Variable Message Signs (VMS) have been used on highways to provide information on traffic conditions such as congestions, weather, and work zones to road users in real-time. Even though VMS plays vital roles in Intelligent Transportation System (ITS) such as dynamic route guidance. However, when VMS are implemented along highways, their presence or messages that appear on the VMS affects traffic operations to a certain extent.

In any measurement or control action the uncertainty raises a fundamental obstacle. The precision of the measurements and the performance of the control process can be improved if we dispose of more knowledge about the system [24].

During the past decade, fuzzy logic control has emerged as one of the most active and fruitful research areas in the application of fuzzy set theory, fuzzy logic and fuzzy reasoning.

Intelligent control is performed with the help of Fuzzy Logic as a tool. Fuzzy Logic enables the development of rule-based behavior. The knowledge of an expert can be coded in the form a rule-base, and used in decision making. The main advantage of Fuzzy Logic is that it can be tuned and adapted if necessary, thus enhancing the degree of freedom of control.

It is also a non-linear structure, and this is especially useful in a complex system such as a Variable Message Sign.

Fuzzy logic is an effective paradigm to handle imprecision. It can be used to take fuzzy or imprecise observations for inputs and yet arrive at crisp and precise values for outputs. Also, the Fuzzy Inference System (FIS) is a simple and commonsensical way to build systems without using complex analytical equations. In this study, fuzzy logic will be employed to capture a categories identified during clustering into a Fuzzy Inference System (FIS).

This study attempts to simulate and design a fuzzy logic controller with archived traffic data for VMS in Kuala Lumpur to optimize the system performance and understand how the system is going to behave for the entire range of values in the input space.

V. Network Description

The study was conducted at one of the most important freeways, MRR1 network, in Kuala Lumpur. MRR1 combines 6 roads known as “Jalan Sg Besi, Jalan Yew, Jalan Tun razak, Lebuhraya Mahameru, Jalan Damansara and Jalan Istana”. Fig. 3 illustrates the network of this study.

VI. The Connection between Variable Message Sign and Fuzzy Logic System

In general, fuzzy logic control involves three main steps: fuzzification to convert the quantitative inputs into natural language variables, rule evaluation to implement the control heuristics, and defuzzification to map the qualitative rule outcomes to a numerical output.

Fuzzification involves the conversion of the input/output signals into a number of fuzzy represented values (fuzzy sets). It can choose an appropriate membership function to represent each Fuzzy Set and also label the Fuzzy Sets appropriately such that they reflect the problem to be solved.

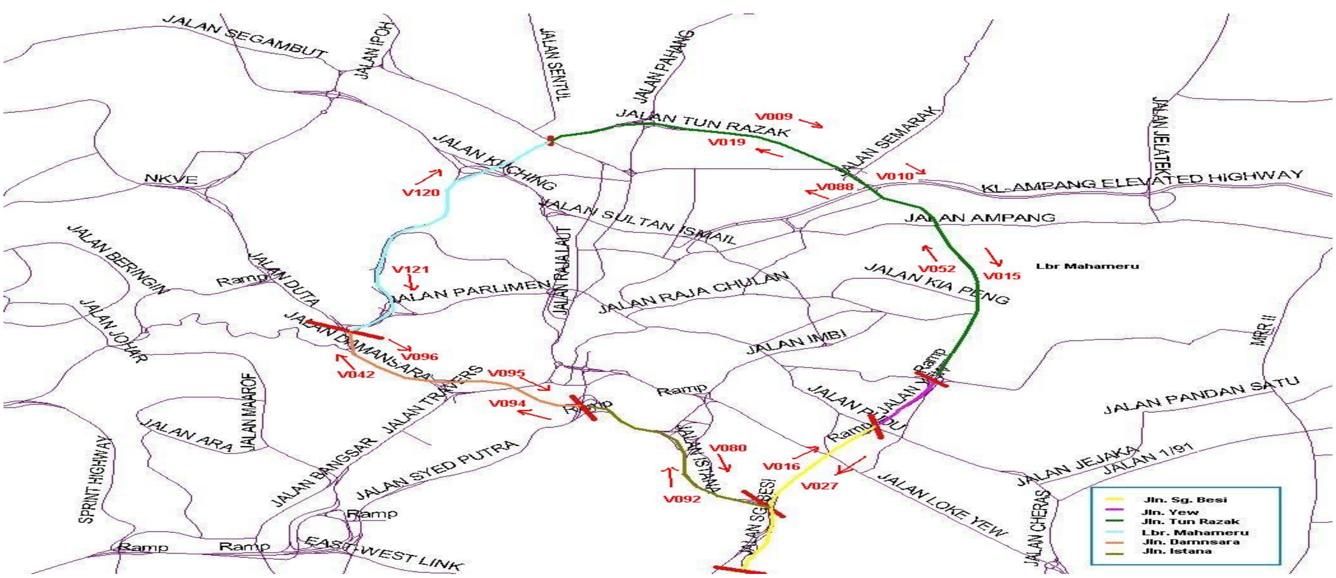

Fig. 3 MRR1 network in Kuala Lumpur

On appropriate Universes of Discourse the fuzzy sets could be set up and adjust / tune the widths and centerpoints of membership functions judiciously.

The fuzzy inference system [25] uses fuzzy equivalents of logical AND, OR and NOT operations to build up fuzzy logic rules. There are several types of fuzzy rules.

The last step of a fuzzy logic system consists in turning the fuzzy variables generated by the fuzzy logic rules into real value again which can then be used to perform some action.

Why fuzzy logic control [26]:

• During the past decade, fuzzy logic control has emerged as one of the most active and fruitful research areas in the application of fuzzy set theory, fuzzy logic and fuzzy reasoning.

• The idea was first proposed by Mamdani and Assilian around 1972.

• Many industrial and consumer product using fuzzy logic technology have been built, especially in Japan.

• In contrast to conventional control techniques, fuzzy logic control is best utilized in complex ill-defined processes that can be controlled by a skilled human operator without much knowledge of their underlying dynamics.

• The basic idea behind fuzzy logic control is to incorporated the expert experience of human operator in the design of a controller in controlling a process whose input-output relationship is described by a collection of fuzzy control rules involving linguistic variables.

• This utilization of linguistic variables, fuzzy control rules, and approximate reasoning provides a means to incorporate human expert experience in designing the controller.

Fig. 4 shows the FLC procedure block diagram of this study.

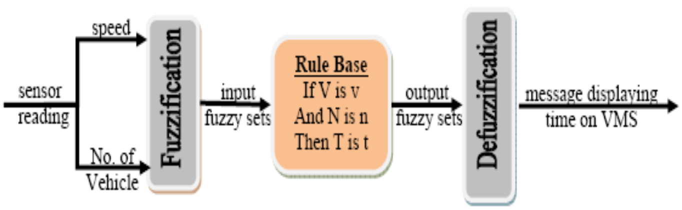

Fig. 4 Fuzzy Logic Controller, block diagram

Fig. 5 and Fig. 6 illustrate distribution of speed and number of vehicles, respectively which are recorded by VMS ID-52 along Jalan Tun Razak in the whole day.

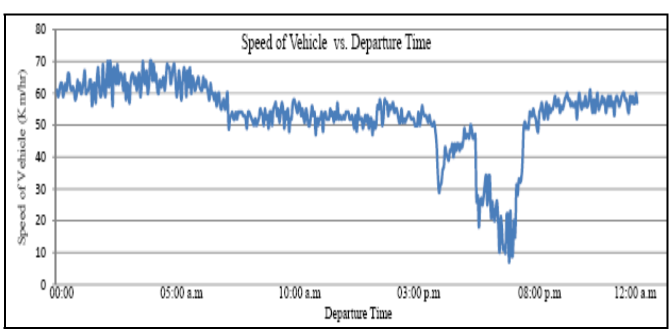

Fig. 5 speed of vehicles vs. departure time

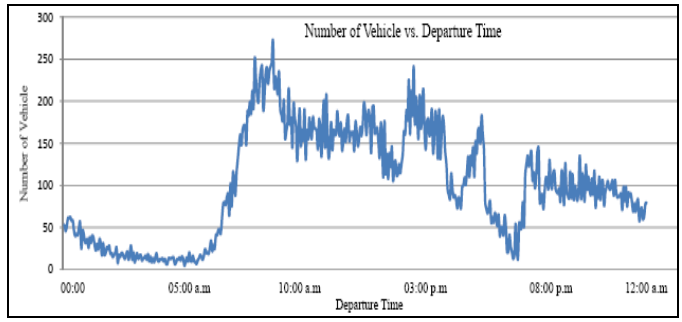

Fig. 6 number of vehicles vs. departure time

The fuzzy variables have to be broken into smaller modules which named quantization. Quantize the input and output variables into several modules which we call fuzzy subsets and assign the appropriate labels. In this study the main archived traffic data by Variable Message Signs are divided into four parts. For more accuracy, they could be divided into more ranges; but the process speed in FLC comes down. Table 1 shows the classification of input data and their fuzzy sets in this study.

Table 1. input data fuzzy sets

	Speed Classification			
Range (Km/hr)	0 – 20	0 – 40	20 – 60	over 40
Type of Membership	Very Slow (VS)	Slow (S)	Medium (M)	High (H)
	Number of Vehicle Classification			
Range	0 – 60	0 – 120	60 – 180	Over 120
Type of Membership	Low (L)	Medium (M)	High (H)	Very High (VH)

It's not too important have a symmetric data in fuzzification. The Fig. 7 and Fig. 8 show smoothly varying lines of speed and number of vehicles. The 25% overlap between ranges is a common method in fuzzification. The membership function in each point, somehow shows the probability of occurrence of the point in discourse of the variable which its shape differ depending upon the characteristics of the machine to be controlled.

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept. The only condition a membership function must really satisfy is that it must vary between 0 and 1. The function itself can be an arbitrary curve whose shape we can define as a function that suits us from the point of view of simplicity, convenience, speed, and efficiency.

The Variable Message Signs are controllable to show any desired message to the motorists in order to diverting the traffic load to the lower traffic paths or any other effects which control the traffic congestion. The traffic load could depend on type of the message shown in the VMS, and time length of displaying such message. Consequently VMS, which is one of the dynamic route guidance tools, would virtually play the role of a traffic light.

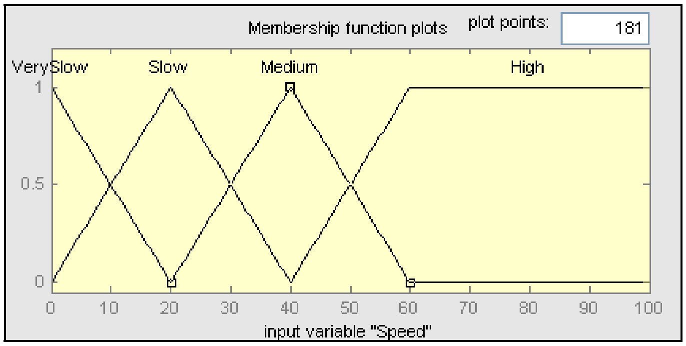

Fig. 7 membership function of speed

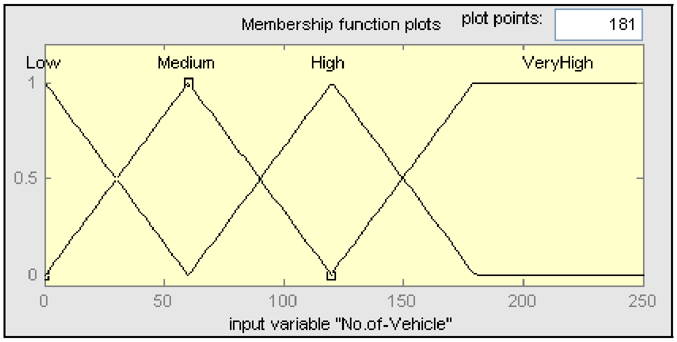

Fig. 8 membership function of number of vehicles

With this difference that the traffic light has only three absolute messages (red for stop; green for move; and yellow for move with caution) where the VMS has many kinds of messages. In this study the output parameter for the fuzzy logic controller is the displaying time length of each kind of messages on VMS which would be extended from 0 minutes to 20 minutes.

Table 2. Output data fuzzy set

Type of Membership	Short (S)	Medium (M)	Long (L)	Very Long (VL)
Degree of Membership(min)	0 - 5	0 - 10	5 - 15	over 10

Fig. 9 is the membership function of message displaying time length on VMS that defines how each point in the output space is mapped to a degree of membership between 0 and 1.

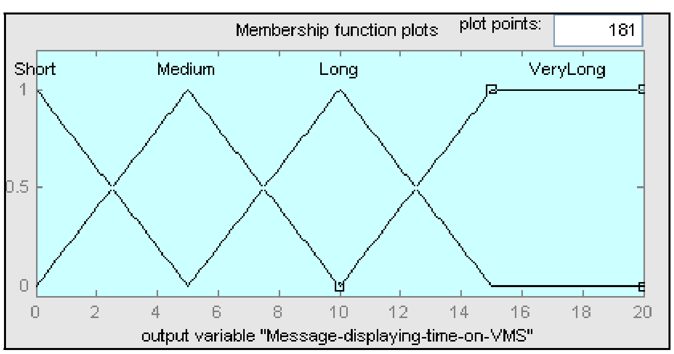

Fig. 9 membership function of message displaying time length on VMS

VII. Fuzzy Logic Controller Design

Fuzzy logic control is a digital control methodology that allows the human description of the physical system and of the required control strategy to be simulated in a reasonably natural way. A fuzzy logic controller can be regarded as a real-time expert system that employs fuzzy logic to manipulate qualitative variables. The fuzzy logic approach makes it possible in many cases to build control systems that are more robust, cost – effective and energy-saving.

Intelligent control is performed with the help of Fuzzy Logic as a tool. Fuzzy Logic enables the development of rule-based behavior. The knowledge of an expert can be coded in the form a rule-base, and used in decision making. The main advantage of Fuzzy Logic is that it can be tuned and adapted if necessary, thus enhancing the degree of freedom of control. It is also a non-linear structure, and this is especially useful in a complex system such as Variable Message Signs. In essence a FLC is a natural extension of many of the rule based controllers implemented in many vehicles today.

Fuzzy logic controllers provide a means of converting a linguistic control strategy derived from expert knowledge into an automatic control strategy and uses rule-based logic to easily incorporate operator expertise about a system.

A. Rule Evaluation

After choosing the membership functions, the designer needs to derive the fuzzy control rules. There are normally many rules for each decision. The result of each rule is calculated and resulting fuzzy sets are combined in order to produce a fuzzy membership function reflecting the decision. This phase is called fuzzy interference.

When building fuzzy rule sets, it is possible to exploit expert knowledge on traffic control. The rules are intuitive, making it possible to fine tune the operation without deeper understanding of the traffic controller. Fuzzy reasoning also makes it possible to compare different kind of information (such as waiting times and number of vehicles) without common units, which is difficult in traditional control methods. In addition to this, fuzzy rules also cope reasonably well with inaccuracies in measuring the values used.

In this study the message displaying time ranges on VMS are divided into four parts as shown in Table 2. The rules of the fuzzy controller for each kind of message may be defined as follows:

IF the Speed is (VS) AND Number of vehicles is (L) THEN : Message displaying time =S

IF the Speed is (VS) AND Number of vehicles is (M) THEN : Message displaying time =M

IF the Speed is (VS) AND Number of vehicles is (H) THEN : Message displaying time =L

IF the Speed is (VS) AND Number of vehicles is (VH) THEN : Message displaying time =VL

IF the Speed is (S) AND Number of vehicles is (L) THEN : Message displaying time =S

IF the Speed is (S) AND Number of vehicles is (M) THEN : Message displaying time =M

IF the Speed is (S) AND Number of vehicles is (H) THEN : Message displaying time =L
IF the Speed is (S) AND Number of vehicles is (VH) THEN : Message displaying time =VL
IF the Speed is (M) AND Number of vehicles is (L) THEN : Message displaying time =M
IF the Speed is (M) AND Number of vehicles is (M) THEN : Message displaying time =L
IF the Speed is (M) AND Number of vehicles is (H) THEN : Message displaying time =VL
IF the Speed is (M) AND Number of vehicles is (VH) THEN : Message displaying time =VL
IF the Speed is (H) AND Number of vehicles is (L) THEN : Message displaying time =M
IF the Speed is (H) AND Number of vehicles is (M) THEN : Message displaying time =L
IF the Speed is (H) AND Number of vehicles is (H) THEN : Message displaying time =VL
IF the Speed is (H) AND Number of vehicles is (VH) THEN : Message displaying time =VL
Table below is a summary of rule evaluation of proposed work.

Table 3. fuzzy rules for VMS

No. Veh / Speed	L	M	H	VH
VS	S	M	L	VL
S	S	M	L	VL
M	M	L	VL	VL
H	M	L	VL	VL

To simulate the response of the fuzzy system for the entire range of inputs that the system is configured to work for, the surfview could be shown. surfview is the surface viewer that helps view the input-output surface of the fuzzy system. Fig. 9 shows the surface viewer of proposed work.

Thereafter, the message displaying time on VMS or the response of the Fuzzy Inference System (FIS) to the inputs are plotted against the speed and number of vehicles as a surface. This visualization is very helpful to understand how the system is going to behave for the entire range of values in the input space.

In the plot below the surface viewer shows the message displaying time on VMS surface for two inputs speed and number of vehicles. It is clear that the time for displaying the message increases with increasing the number of vehicles, which sounds very rational.

Upon opening the Surface Viewer, we are presented with a two-dimensional curve that represents the mapping from service quality to Aircond amount. Since this is a two-input one-output case, we can see the entire mapping in one plot.

Two-input one-output systems work well, as they generate three-dimensional plots that MATLAB can adeptly manage. When we move beyond three dimensions overall, we start to encounter trouble displaying the results. Accordingly, the Surface Viewer is equipped with pop-up menus that let us select any two inputs and any one output for plotting.

The Surface Viewer has a special capability that is very helpful in cases with two (or more) inputs and one output: we can actually grab the axes and reposition them to get a different three-dimensional view on the data.

The result of fuzzy interference is a group of fuzzy membership functions. These functions need to be converted into a single output function. There are many rules for this implementation. One is the Max-min Product which is more usual in many applications. Finally this achieved output function needs to be transformed into real value. One of the usual methods is named "centroid" which is calculating the center of gravity of the resulting fuzzy membership function. This procedure is called defuzzification.

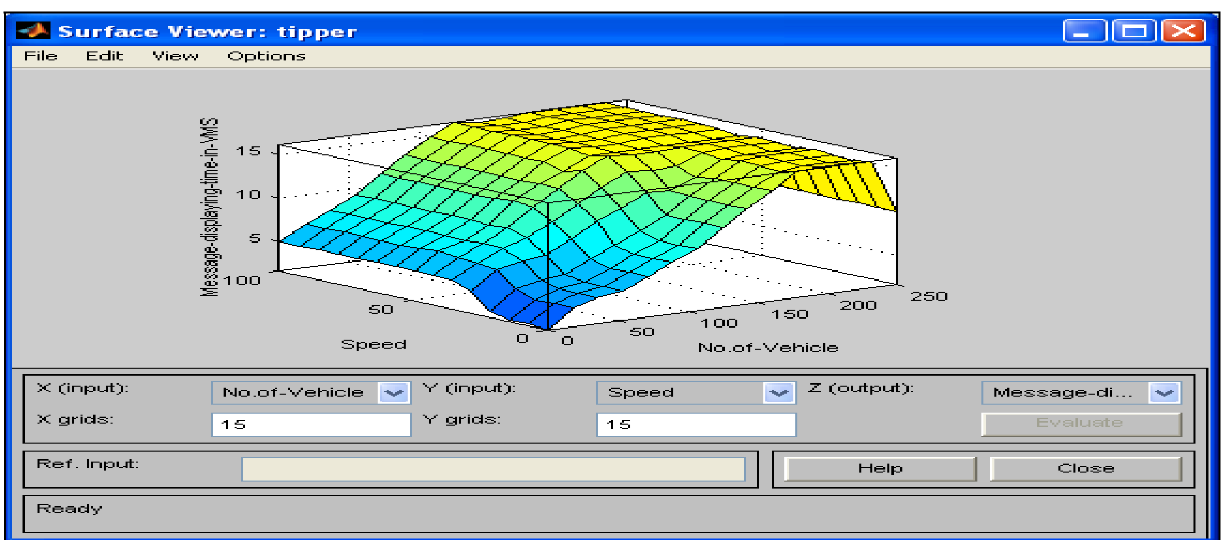

Fig. 9 input – output surface viewer

To view the entire implication process from beginning to end, ruleview, could be used. ruleview is the graphical simulator for simulating the FIS response for specific values of speed and number of vehicles which are the input variables of this study. To understand the message displaying time length on VMS, with a specific number of vehicles in the given speed, the ruleview could be helpful.

In the Fig. 10 by moving around the line indices that correspond to the speed and number of vehicles the system readjust and new output achieve. Fig. 11 shows the summary of results from graphical simulator, ruleview, in speeds which are more common than others.

The Rule Viewer and the Surface Viewer are used for looking at, as opposed to editing, the FIS. They are strictly read-only tools. The Rule Viewer is a MATLAB based display of the fuzzy inference diagram. Used as a diagnostic, it can show (for example) which rules are active, or how individual membership function shapes are influencing the results. The Surface Viewer is used to display the dependency of one of the outputs on any one or two of the inputs — that is, it generates and plots an output surface map for the system.

The Rule Viewer displays a roadmap of the whole fuzzy inference process. it is based on the fuzzy inference diagram .

The Rule Viewer allows you to interpret the entire fuzzy inference process at once.

The Rule Viewer also shows how the shape of certain membership functions influences the overall result. Since it plots every part of every rule, it can become unwieldy for particularly large systems, but, for a relatively small number of inputs and outputs, it performs well (depending on how much screen space you devote to it) with up to 30 rules and as many as 6 or 7 variables.

The Rule Viewer shows one calculation at a time and in great detail. In this sense, it presents a sort of micro view of the fuzzy inference system.

In the Fig. 11 the message displaying time length on VMS varies between almost 4 to 16 minutes. With the increasing number of vehicles on the road the VMS message stays for a longer time for safety and traffic congestion control or any other surveillance effects. At around 130 numbers of vehicles it remains almost constant. It can be seen that there is not a significant difference in the results with changing the speed of vehicles.

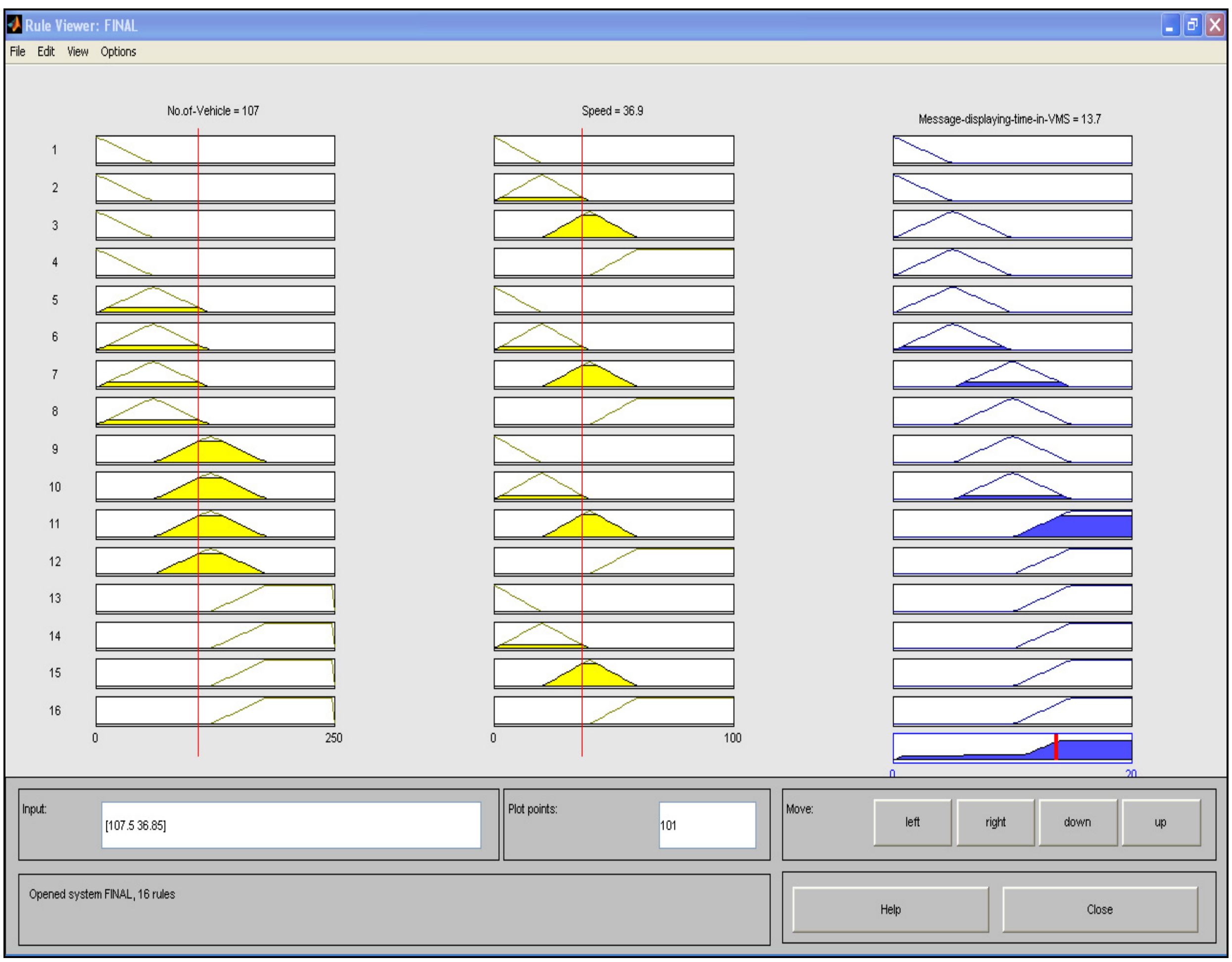

Fig. 10 rule viewer of the system

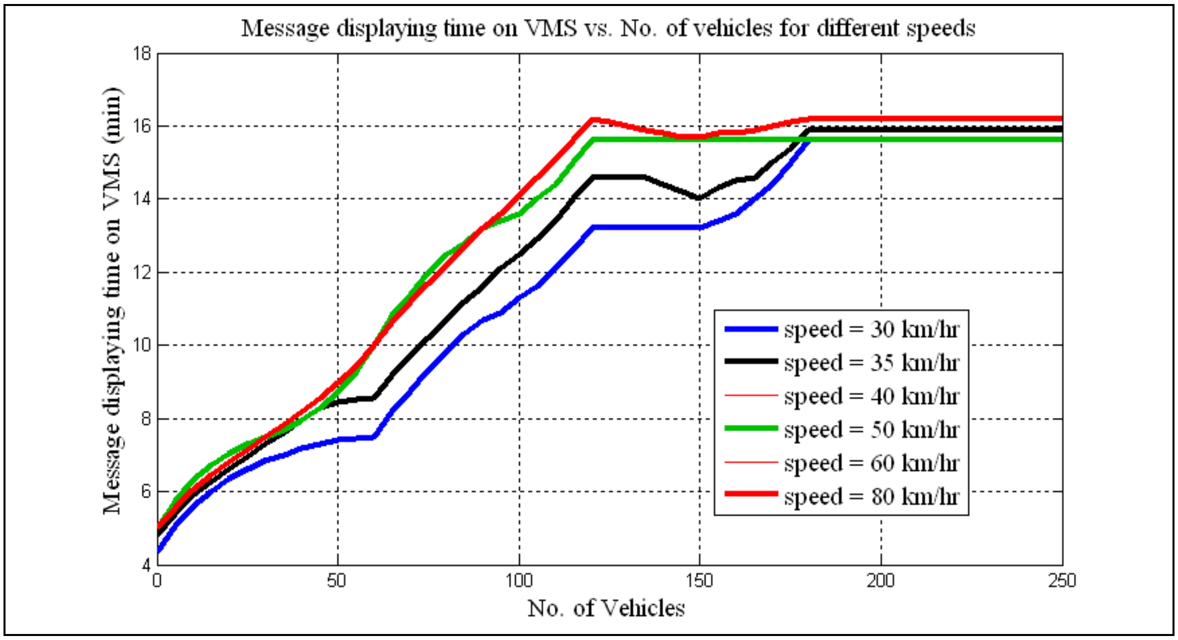

Fig. 11 summary of rule viewer simulation

VIII. Conclusion

The main advantages of using fuzzy logic system are the simplicity of the approach [25]. Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems and complex industrial processes, as well as for traffic congestion control, as well as for other expert systems and applications. It is an effective technique for modeling and simulation the main traffic data in VMS message `s programming. In this study it was found that fuzzy logic gives more benefits for traffic control. Fuzzy logic, simply put, transforms vague concepts such as “very slow”, “slow”, “medium” and “high” into the mathematical form which is then used by Variable Message Signs in performing problem solving actions. This allows VMS to perform jobs better than before which sounds very rational.

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