Author(s): Almejalli, K. A., Dahal, K. P. and Hossain, M. A.

Title: Intelligent traffic control decision support system.

Publication year: 2007

Book title: Applications of evolutionary computing.

ISBN: 978-3-540-71804-8

Publisher: Springer-Verlag.

Citation: Almejalli, K. A., Dahal, K. P. and Hossain, M. A. (2007) Intelligent traffic control decision support system. In: Applications of evolutionary computing. Proceedings of the EvoWorkshops 2007 (EvoTransLog Workshop), Valencia, Spain, April 11-13, 2007. pp 688-701.

Road Traffic Decision Support System

K Almejalli, K Dahal, and A Hossain, Member IEEE

School of Informatics, University of Bradford, Bradford BD7 1DP, UK
K.A.Al-mejalli; K.P.dahal; M.A.Hossain1{@Bradford.ac.uk}

Abstract— **Road traffic management has long been a complex issue and seems likely to continue to be so. Road traffic laws and policies depend on a large number of factors. Making a correct decision for traffic management can be difficult because decision-makers need to analyze and absorb a large quantity of information. This information can be vague and sometime conflicting in nature. Therefore, there is a need for a better control and a reliable and consistent system to help simplify the traffic decision making process. By incorporating the variables involved in traffic management such as the numbers of accidents, traffic violations, and traffic policemen on duty into an artificial intelligence technique, it is possible to build a traffic decision making system to help decision makers for analysis of traffic laws and policies. This paper proposes a decision support system using fuzzy logic to provide recommendations on whether traffic decision makers should, for example, give priority to increasing the number of traffic policemen on duty, increasing fines, or installing better/more safety devices. Fuzzy Logic allows us to measure imprecise and dynamic factors and to arrive at a reasonable judgment. A case study for Riyadh Region Traffic in Saudi Arabia has been analyzed using the proposed decision making system.**

Index Terms—**Traffic Management, Decision support systems, Fuzzy logic**

I. Introduction

Every year, lots of people die or suffer accidents be cause of factors that could have easily been prevented. The growing number of vehicles, ignorance of safety norms and reckless driving have attributed to the huge number of accidents. For example, in Saudi Arabia, there were 5168 fatalities in 2005 alone. This translates to 14 people died on roads in any given day [1]. The World Health Organization described traffic accidents as the "Epidemic of Civilized Societies". It is sad to note that these people just wanted to go home, visit a friend, or go to their work but encountered something terrible along the way. Although governments have existing traffic policies and continually strive to improve road safety, accidents always seem to happen. This should not mean that this should be accepted as inevitable, but that continued efforts are made to find ways to improve the system and reduce the number of road accidents and loss of lives.

Road traffic management problem has existed for centuries. In the last century there has been unprecedented development in automotive technology, road construction, traffic management and road safety. However, only recently computer-based algorithms are investigated to support the road traffic management. The decisions regarding traffic management to improve the road safety are based on human experience and judgment. Although we can collect statistics regarding traffic accidents, driving violations, and traffic volume, laws and policies, but the related decisions still have to be made by human beings based on the collected information. This information can be vague and sometime conflicting in nature. Many factors involved in formulating traffic management policies/decisions.

Making the correct decision at the right time can be very difficult because decision-makers need to analyze and absorb a large quantity of information. Furthermore, those information are vague and sometime conflicting nature. However, the human brain is capable of evaluating only a very small set of information [2]. There are a number of different dynamic factors involved in formulating the traffic policies. Because of the large number of factors involved, it is sometimes difficult to determine the best policies. For example, increasing the number of traffic policemen would be a waste of resources if accidents occurred infrequently and most drivers obeyed traffic laws. Moreover, even a single wrong decision in this field can cause problems to the traffic administration in that city, or, even to the whole country. Thus, a better control and support system is needed.

In recent years, Fuzzy logic technique has expanded vastly and been applied to many disciplines. It is proven to be a choice for many control system applications [3]. Fuzzy Logic allows us to measure imprecise and dynamic factors and to arrive at a reasonable judgment. It is now widely used in consumer electronics, agriculture, and manufacturing systems. Fuzzy logic has also found its applications in building intelligent decision support systems. For example, in the financial area, INFORM GmbH developed an ASK software tool, one of the first applications based on Fuzzy Logic to analyze creditworthiness assessments for consumer credit [4]. Another example, in the field of agriculture, was the use of a Fuzzy logic decision-making approach to address uncertainties in land suitability analysis processes [5].

Several authors have described decision support systems for traffic management, such as [6-12]. Some of them have used the fuzzy logic technique in their decision process such as [8, 10, 12]. However, all these systems are real time decision support systems, and they do not support the traffic management policies (i.e. long term decisions).

This paper aims to propose a system that can improve traffic management policies using Fuzzy Logic. The variables involved in traffic management are dynamic and complex: traffic accidents, traffic violations, available traffic policemen, available traffic cameras, etc. There dynamic variables are fuzzified and used to be analysed with a fuzzy inference system. A fuzzy rules based system is developed using the expert knowledge to generate effective policies. The system priorities the possible traffic policies. The include if a given city should increase the number of traffic policemen on duty, increase fines, impose stricter speed limits, install better safety devices, or provide better education for drivers. The system itself would not decide the policies, but would provide traffic decision makers with better information so they could make better decisions. In order to measure system success, the proposed decision support system has been evaluated in a number of case studies of Riyadh Region Traffic with a set of real data. Overall, a system such as this could help improve traffic flow and increase the safety of drivers and pedestrians.

The paper is organized as follows. The next section presents the designed of the proposed fuzzy logic based traffic decision support system. A case study for Riyadh Region Traffic in Saudi Arabia is discussed in Section 3.

II. The Probosed Decision Support Model

The first and probably most important task in the process of designing a fuzzy logic decision support system is the identification of influencing parameters and to their relation on decision making process. In a traffic decision-making system, the traffic factors contributing primarily to a decision making and the typical traffic decisions are the fuzzy variables. After a discussion with number of personnel who had expert knowledge of road traffic in Riyadh Region Traffic decision-making, five influencing factors and four typical decisions were determined. All these factors and decisions are highlighted below in some detail.

1) Influencing Factors

The first and most important factor is the number of traffic violations, which shows how many times traffic laws have been broken. The number of traffic violations factor is considered as one available assessment criterion simply because of the fact that a large number of traffic violations would suggest that the traffic system was out of control, either because of a shortage of available personnel and equipment such as traffic policemen or traffic cameras, or because that the punishments and fines for having broken the law is not acting as a deterrent to drivers.

The number of traffic accidents is a second important factor influencing the making of most traffic decisions making. It is a fact that reducing the number of traffic accidents is the principal goal of all traffic managements. A 'good' traffic system could be seen as one that has a low rate of traffic accidents.

The following two factors are very similar and so are mentioned together. These are the number of vehicles per traffic policeman on duty and the number of vehicles per traffic camera. The number of vehicles per traffic policeman is calculated by dividing the number of vehicles by the number of traffic policemen on duty, while dividing the number of vehicles by the number of traffic cameras yields the number of vehicles per traffic camera. These two parameters are determined as influencing factors because they are considered as a measure of controlling and monitoring traffic. Thus, to keep the traffic controlled, the number of vehicles per policeman and the number of vehicles per traffic camera should not be high. The values of these two factors in a particular period are based on how many vehicles are used at that period, and also on how many traffic policemen and traffic cameras are available at that period.

The rate of traffic jams is the last and least important factor because it does not directly affect traffic decisions, but is combined with the accident factor. For example, the decision that might be made when the number of accidents is large and the rate of traffic jams is low, is not the same as the decision that might be made when the number of accidents is unchanged but the rate of traffic jams is high, because the high rate of traffic might cause many minor accidents.

2) Typical Decisions:

There are a number of typical decisions made by traffic policy maker based on the identified influencing parameters. Launching a traffic awareness campaign is the first typical decision. The wide concept underpinning traffic awareness campaigns is creating awareness about motorist and pedestrian safety, in order to minimize or prevent traffic accidents. The number of accidents, the number of traffic violations, and the rate of traffic jams are the three factors that influence this decision, but the number of accidents is given a larger weighting.

The second typical decision is increasing punishments or fines. Sometimes, punishments or fines of breaking the law are not acting as a deterrent to drivers. Hence, increasing the punishments or fines is considered as an applicable solution to reduce the number of traffic violations. This decision is influenced by three factors; the first factor is the number of violations, which has a large weighting. The second and third factors are the number of vehicles per traffic policeman and the number of vehicles per traffic camera.

TABLE I
THE INFLUENCE FACTORS AND THE TYPICAL DECISIONS

Typical Decisions	Influencing Factors
Launch traffic awareness campaign	Number of traffic accidents
	Number of traffic violations
	Rate of traffic jam
Increase punishment or fine	Number of traffic violations
	Number of vehicles per traffic policeman
	Number of vehicles per traffic camera
Increase the number of traffic policemen	Number of vehicles per traffic policeman
	Number of traffic violations
Increase the number of traffic cameras	Number of vehicles per traffic camera
	Number of traffic violations

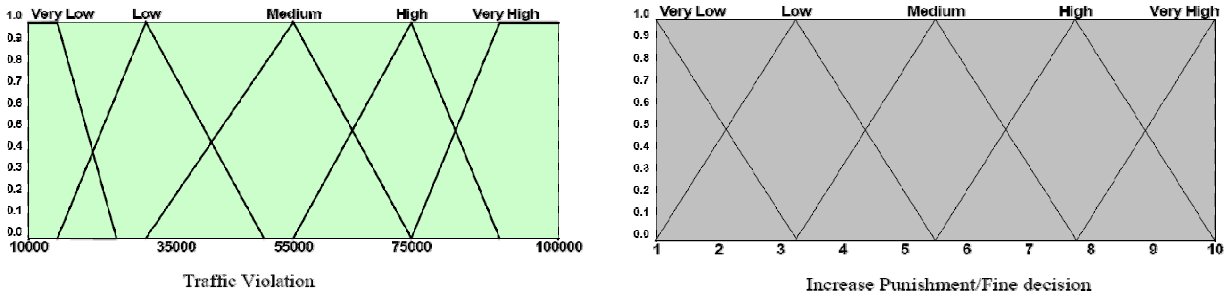


Fig. 1. The Triangle membership for the Traffic Violation factor and the Increase Punishment/Fine decision

The third and fourth typical decisions are increasing the number of traffic policemen on duty and increasing the number of traffic cameras. These two decisions are made to reduce the number of violations, when the number of vehicles per traffic policeman is high or the number of vehicles per traffic camera is high. Table I summarises the relationships between the influence factors and the typical decisions.

TABLE II
LINGUISTIC VARIABLES AND THEIR RANGES FOR TRAFFIC VIOLATION

Linguistic value	Numerical range (per month)
Very Low	[10000 , 25000]
Low	[15000 , 50000]
Medium	[30000 , 75000]
High	[55000 , 90000]
Very High	[75000 , 100000]

3) Fuzzy Logic in Decision Making

After identifying all parameters (input and outputs) needed for building our fuzzy model, fuzzifying those parameters was the next stage. For each of those parameters, appropriate linguistic variables associated with their numerical ranges have been specified using experts' knowledge in the Riyadh traffic administration as well as analysis of traffic data from previous years. For example, Table II shows the linguistic variables and their numerical ranges for the traffic violations factor. Then we have used linear triangular membership functions to design the fuzzy sets for all linguistic variables. Figure 1 shows two examples of fuzzified parameters.

The next step was building the rule-based structure. This was done by breaking the control problem down into a series of IF X AND Y THEN Z rules that define the desired system output response for given system input conditions. A total of 375 *IF-THEN* rules were used to build the rule-based structure for the proposed traffic fuzzy system, all these rules were derived from the experienced traffic decision makers of the Riyadh traffic administration, and an analysis of historical data for a period of six years [13]. Table III shows a selection of these rules.

The final stage of designing our traffic fuzzy logic system was applying an appropriate defuzzification method in order to obtain a 'crisp' value (decision priority) for each decision. The Centroid method was used to calculate the approximate centre of gravity of the distribution for the fuzzy sets. Figure 2 shows the whole structure of the traffic fuzzy inference system, consisting of five inputs parameters that map to four outputs, which have been translated into fuzzy values (fuzzy sets). The fuzzy inference takes place in the rule box (TDSS) that contains all the linguistic control rules. MATLAB fuzzy toolbox has been used to implement the traffic fuzzy system.

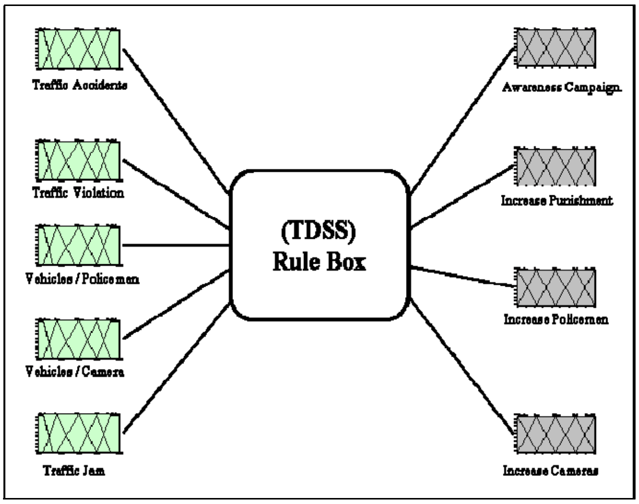


Fig. 2. The structure of the traffic fuzzy inference system

III. CASE STUDIES

In order to evaluate and test the system in terms of the results achieved from it to see whether the system is reliable or not, a number of case studies of Riyadh Region Traffic are studied, which represent a different state in the Riyadh traffic. One interesting case for the summer vacation period is presented below as an example.

In general, in the summer period, the traffic state in Riyadh is smooth and the traffic movement is low, especially in the daytime because most people avoid going out and they prefer to spend more time in air-conditioned places.

Analysing the relevant traffic statistics for six years (1998–2003) [13], the main characteristics of the Riyadh traffic in the summer holiday, can be listed as follows:

TABLE III
SELECTIVE RULES FROM THE RIYADH TRAFFIC RULE-BASED STRUCTURE

IF	***THEN***
Violations is medium AND Jam is low AND Accidents is very high	Launch Traffic Awareness Campaign is High
Violations is high AND Vs/T-Policeman is high AND Vs/T-Camera is high	Increase Punishment/Fine is Medium
Violations is very high AND Vs/T-Policeman is high AND Vs/T-Camera is very low	Increase Num. of T-Policemen is Very High AND Inc Num. of T-Cameras is Low
Violations is very low AND Vs/T-Policeman is high AND Vs/T-Camera is very high	Increase Num. of T-Policemen is Very Low AND Increase Num. of T-Cameras is Very Low

- The number of vehicles on the roads clearly decreases because thousands of families leave Riyadh in this period, which causes a decrease in the number of traffic violations.
- The number of traffic policemen on duty records a slight decrease because of family holidays, where there is no much change in the number of traffic cameras.
- Generally, the summer vacation period has an obvious increase in the number of traffic accidents, because perhaps of the negative effect of the high temperatures on vehicles, like tyres. Drivers may also try to drive fast to avoid the worst effects of the heat.
- The rate of traffic jams in general is low.

Table IV shows the influencing factors for the fuzzy decision making system according to the Riyadh Traffic information for the period (1–31 August 2003).

TABLE IV
INFLUENCING FACTORS

Factor	**Value**
The number of traffic violations	45280
The number of traffic accidents	7012
The number of vehicles per traffic policeman	864
The number of vehicles per traffic cameras	1852
The rate of traffic jam	52

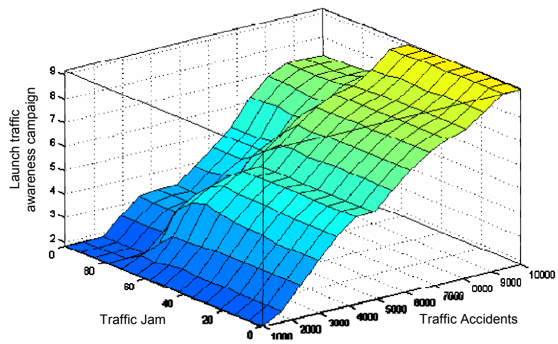
According to the fuzzy set of the traffic accidents factor, the number of traffic accidents in that period belongs to fuzzy set "High". Hence, it can be deduced that there was a need to make a decision to reduce the number of accidents. The following table (Table V) shows how the system analyzed the traffic decision based on the values of these factors.

TABLE V
TYPICAL DECISIONS

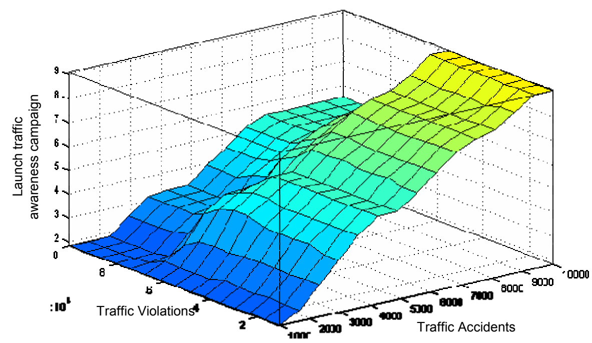
Decision	**Priority**
Launch traffic awareness campaign	7.8 /10
Increase the number of traffic policemen	5.4 /10
Increase the number of traffic cameras	5.0 /10
Increase punishment or fine	3.2 /10

The decision analysis table shows the system strongly supports making the launch traffic awareness campaign decision because the number of traffic accidents was high, whereas the number of traffic violations and the rate of traffic jam were just below medium. On the other hand, although the number of vehicles per traffic policeman was almost high, the system did not support the increase the number of traffic policemen decision because the number of traffic violations in that period was almost low. Therefore the optimal decisions that can be taken in such period is "*Launch Traffic Awareness Campaign*".

Figure 3 illustrates two 3D plots of the selected period (1–31 August 2003). Figure 3(a) shows how the "Launch traffic awareness campaign" decision is affected by the factors: Number of traffic accidents and the rate of traffic jam, whereas the figure 3(b) shows how the "Launch traffic awareness campaign" decision is affected by the factors: Number of traffic accidents and the number of traffic violations.



(a)



(b)

Fig. 3. : 3D plots of the period of (1st – 31st August 2003)

As a result, it is clear from studying the case studies of Riyadh Region Traffic that the proposed fuzzy-based decision support system provides traffic decision makers with better information at right time so they could make better decisions.

IV. Conclusion and future work

Making the correct decision at the right time has been a major problem in road traffic managements, because decision-makers need to analyze and absorb a large quantity of information in a short time. The information can be vague and sometime conflicting in nature. This paper presented a fuzzy based decision support system to assist road traffic management. All parameters of the problem that was required to build the system have been defined and modelled using fuzzy sets. The traffic rules for the fuzzy inference system were extracted from traffic experts and historical data. In order to test and evaluate the proposed system, it has been demonstrated for a case study of Riyadh Region Traffic.

The proposed system has shown that Fuzzy logic based approach has a considerable potential to be used in the development of a road traffic management system to support decision-takers.

Currently, we have demonstrated the technical feasibility of the system with the limited influencing variables/ factors which directly affect traffic decisions. In the next stage, all factors that may influence the traffic decision-making process such as road safety, drivers' behaviours, etc., should be taken into consideration. Moreover, the proposed fuzzy model can be developed to assist traffic management to improve the real time decision support systems by using historical data about the traffic problems and the control scenarios used to solve these problems. By using such information, it is possible to evaluate and improve the real time traffic management systems and generate effective long term policies such as extending the road network, adding lanes, creating alternative new freeway connection, and create new traffic controls.

References

[1] Ministry of Transport,"Traffic Safety," [Online document], 2006, [cited 2006 July 26], Available HTTP: http://www.mot.gov.sa/L_Security_sign.asp.

[2] D. Keshav, H. Zabeer, and M. A. Hossain, "Loan Risk Analyzer based on Fuzzy Logic," in *Proceedings of the 2005 IEEE International Conference on e-Technology, e-Commerce and e-Service*: IEEE Computer Society, 2005.

[3] T. J. Ross, *Fuzzy Logic With Engineering Applications: Instructor's Manual*: McGraw-Hill Education - Europe - Release date, 1995.

[4] P. C. Treleaven and S. Goonatilake, *Intelligent systems for finance and business*. Chichester: Wiley, 1995.

[5] T. N. Prakash, "Land Suitability Analysis for Agricultural Crops: A Fuzzy Multicriteria Decision Making Approach," December, 2003.

[6] S. G. Ritchie, "A knowledge-based decision support architecture for advanced traffic management," *Transportation Research Part A: General*, vol. 24, pp. 27, 1990.

[7] H. Zhang and S. G. Ritchie, "Real-Time Decision-Support System for Freeway Management and Control," *Journal of Computing in Civil Engineering*, vol. 8, pp. 35-51, 1994.

[8] A. Hegyi, B. De Schutter, S. Hoogendoorn, R. Babuska, H. van Zuylen, and H. Schuurman, "A fuzzy decision support system for traffic control centers," *Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE*, pp. 358-363, 2001.

[9] K. G. Zografos, K. N. Androutsopoulos, and G. M. Vasilakis, "A real-time decision support system for roadway network incident response logistics," *Transportation Research Part C: Emerging Technologies*, vol. 10, pp. 1, 2002.

[10] B. De Schutter, S. P. Hoogendoorn, H. Schuurman, and S. Stramigioli, "A multi-agent case-based traffic control scenario evaluation system," *Intelligent Transportation Systems, 2003. Proceedings. 2003 IEEE*, vol. 1, pp. 678-683, 2003.

[11] S. Ossowski, J. Z. Hernandez, M.-V. Belmonte, A. Fernandez, A. Garcia-Serrano, J.-L. Perez-de-la-Cruz, J.-M. Serrano, and F. Triguero, "Decision support for traffic management based on organisational and communicative multiagent abstractions," *Transportation Research Part C: Emerging Technologies*, vol. 13, pp. 272, 2005.

[12] C. Quek, M. Pasquier, and B. B. S. Lim, "POP-TRAFFIC: a novel fuzzy neural approach to road traffic analysis and prediction," *Intelligent Transportation Systems, IEEE Transactions on*, vol. 7, pp. 133, 2006.

[13] Studies-and-Census-department, "Traffic Census," Riyadh-Region-Traffic, 1998 – 2003.