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Pavement Maintenance Treatment Selection Using Fuzzy Logic Inference System

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Abstract*—The safety and convenience of traffic using the road are governed to a large extent by the quality of maintenance. The life of an asset can be preserved and prolonged if adequate maintenance measures are undertaken in proper time. By early detection and repair of defects at initial stages the rapid deterioration of the pavement can be prevented. The function of maintenance is to preserve the pavement in a traffic-worthy condition and to allow the movement of traffic at a requisite speed and safety. This paper presents a approach on pavement treatment selection using fuzzy logic inference system. Two parameters like drop of quality and age of the flexible pavement has been taken into account as input and treatment type as output. The result provides an appropriate and economically viable maintenance strategy.

***Index Terms*- Pavement Maintenance, Fuzzy logic, Fuzzy inference system, Treatments alternative.**

I. INTRODUCTION

Transport infrastructure plays a key role in economic growth and development of the country. The road transport is the oldest and perhaps the most widely adopted mode of transport by the mankind. The road transport witnessed a tremendous growth rate since independence in our country. The length of surfaced roads which was 1.57lakh kilometers (39.35% of total road length)as in year 1950-51 increased to 25.25 lakh kilometers(53.83% of total road length)as in year 2010-11,chart 1of [1]. The growth of road network has not kept pace with the growth in the number of registered vehicles [1].While the number of registered motor vehicles has grown at a compound annual growth rate (CAGR) of 10.6% between 1951 and 2011; the growth in the road network during the same period was 4.2%.Dreadful increase of traffic axle load on pavement cause deterioration of pavement surface along with environmental condition. Poor maintenance of roads costs the country about Rs 35,000 crore annually. Therefore, it is essential to be maintained the road sectors in proper condition to ensure its regular utilization in optimum manner. The maintenance requirements are uninteruptly altering with new needs emerging and advancement in society. There has been a tremendous traffic growth on Indian roads. As it is a well established fact that the road deterioration gets accelerated with increased axle loads and increased in repetition of the same, the requirement of the improved maintenance norms is a prerequisite to ensure a smooth and safe transit of passengers as well as freight in this scenario. However, due to inadequacy of funds as well as internal system, a large scale of dissatisfaction has resulted in especially from the segments like the truckers and the frequent road users. There is a general feeling that roads are not being maintained up to the desired level-of-service. The primary reason for causing dissatisfaction is that the government has been struggling to provide bare minimum funds required to keep the roads open in traffic worthy condition. Another factor of great concern in maintenance is the fact that the majority of the road network system has not been structurally designed to withstand traffic over the 15-20 years design life. The deficiency leads to excessive maintenance costs, which may not in the long run provide a sustainable road network. Therefore the national assets constructed in the road sector needs to be preserved maintenance model is to be developed to prioritise the investment needs and thereby ensure that the available resources are put to optimum use. Roads in our country are maintained mostly by government agencies and the maintenance of the entire road network depends on the funds allotted through yearly budget by the government. Judicious allocation of such public funds not only requires a rational and careful evaluation, but also, prioritization of various road maintenance activities through systematic and scientific approaches. Sandra et al (2001) have used fuzzy approach for priotisation of pavement stretches using fuzzy multi-criteria decision making approach and have included both severity and extent of pavement failure. Expert opinion survey was carried out to generate fuzzy rules.Chassiakos (2006) has presented a fuzzy-based system for pavement maintenance planning. The aim of this paper is to present an approach for pavement maintenance treatment selection corresponding to their drop in quality and age of the pavement.

II. FUZZY INFERENCE SYSTEM

Fuzzy logic is a design methodology that can be used to solve real life problems. Fuzzy sets theory resembles human decision making in its use of approximate information. It was basically used to mathematically represent uncertainty and vagueness and provide tools to deal with the imprecision in many problems. A fuzzy logic technique has the advantage of lower development costs, superior features and better end product performance. The following discussion introduces the four-step fuzzy inference system employed in implementing FL efficiently: Fuzzifier, Fuzzy inference engine, Fuzzy rules and Defuzzifier (Figure 1).

A. Fuzzifier

The function of the fuzzifier is to convert a crisp numerical value from the universe of discourse of the input variable into

a linguistic variable and corresponding level of belief. This step takes the current value of a process state variable and gives levels of belief in input fuzzy sets, in order to make it compatible with the fuzzy set representation of the process state variables in the rule-antecedent. The level of belief is equal to the degree of membership in the qualifying linguistic set which can take any value from the closed interval (0, 1).

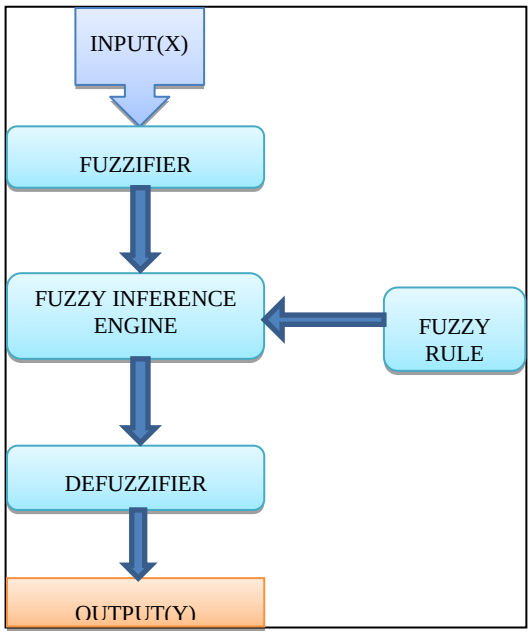
B. Inference Engine

The basic function of the inference engine is to compute level(s) of belief in output fuzzy sets from the levels of belief in the input fuzzy sets. The output is a single belief value for each output fuzzy set. In this stage, the fuzzy operator is applied in order to gain a single number that represents the result of the antecedent for that rule. The inference engine is mainly based on rule.

C. Fuzzy Rules

Rules determine the closed-loop behavior of the system. The rules are based on expert opinion, operator experience, and system knowledge. The basic function of the rule base is to represent in a structured way the control policy of an experienced process operator and/or control engineer in the form of a set of production rules such as if (process state) and then (control output).The if-part of such a rule is called the rule-antecedent and is a description of a process state in terms of a logical combination of fuzzy propositions. Moreover, the then-part of the rule is called the rule consequent and is again a description of the control output in terms of a logical combination of fuzzy propositions. These propositions state the linguistic values which the control output variables take whenever the current process state matches (at least to a certain degree) the process state description in the rule-antecedent. The inference process is divided into three phases, application of the fuzzy operator in the antecedent, implication from the antecedent to the consequent and aggregation of the consequents across the rules.

D. Deffuzifier



The function of defuzzifier is to convert the levels of belief in output fuzzy sets to a crisp decision variable of some kind. In practice, the output of the defuzzifier process is a single value from the set. There are several built-in defuzzifier methods. The centre of gravity method is the most commonly used for extracting a crisp value from a fuzzy set.

III. ANALYSIS AND DISCUSSION

Pavement deterioration models are imperative for development of a pavement maintenance management system. These models play a crucial role on aspects of the maintenance and rehabilitation strategies including planning and budgeting. Pavement condition responsive maintenance is very useful for judicious disbursement of maintenance funds. For the Indian conditions, it is suggested that condition responsive maintenance intervention criteria may be adopted [4]. Maintenance alternative selections are based on drop in quality of pavement and pavement age. Drop in quality is defined as the difference of pavement condition index (PCI) corresponding to excellent condition or 100 in the 1-100 scale to the PCI value of desired year. A fuzzy rule-based system was developed to represent the expert knowledge using fuzzy rules 'if-then'. Analysis of adopted parameter was carried out on MATLAB software using Mamdani method.

Table 1: Fuzzy Sets for Treatment Selection

Parameter	Membership function shape	Attribute	Function value range			Universe of discourse
			Left intercept	Value equal 1	Right intercept	
Drop in quality (%)	Triangular	Fail	0	0	10	0-100 %
		Very Poor	0	10	25	
		Poor	10	25	40	
		Fair	25	40	55	
		Good	40	55	70	
		Very Good	55	70	85	
		Excellent	70	85	100	
Age(years)	Triangular	Category 1	0	0	2.5	0-15y ears
		Category 2	0	2.5	4.9	
		Category 3	2.5	4.9	7.5	
		Category	4.9	7.5	10	

		4				
		Category 5	7.5	10	12.5	
		Category 6	10	12.5	15	
		Category 7	12.5	15	15	
Treatment	Triangular	T0	0	0	15.48	0-100
		T1	0.396	16.7	33.3	
		T2	15.48	34.4	51.1	
		T3	33.3	50.66	66.67	
		T4	50.66	66.67	83.33	
		T5	66.67	83.33	100	
		T6	83.33	100	100	

Two input parameter was taken, first is drop in quality of the pavement and second is age of the pavement. One was the output, which is expected treatment of the flexible pavement.Mamdani fuzzy model works under criteria (i) AndMethod='min',(ii)OrMethod='max',(iii)ImpMethod='min',(iv)AggMethod='max',and (v)DefuzzMethod='centroid'.

Thirty five rule bases for treatment selection was applied, some of them are shown in Table 2.Rule bases were prepared based on the taking responses of experts like road engineers and road users.

Table 2: Rule Base for Treatment Selection

If Drop of quality	**and** Age	**then** Treatment
Excellent	Category1	T0
Excellent	Category3	T2
Very Good	Category6	T5
Good	Category1	T2
good	Category7	T6
Fair	Category1	T5
Fair	Category4	T5
Poor	Category2	T6
Poor	Category3	T6

Treatment type T0 represents no need of maintenance required ant T6 represents reconstruction of the pavement surface. Where T1: Thin overlay, T2: Medium overlay,, T3:Thick overlay,T4:Rehabilitation and T5:Reconstruction.

Table 3: Output of Fuzzy Inference System

Pavement Condition	Year of assessment of treatment					
	2^{nd} Yr	5^{th} Yr	8^{th} Yr	10^{th} Yr	12^{th} Yr	15^{th} Yr
Fail	T5	T5	T5	T6	T6	T6
Very poor	T4	T5	T5	T5	T6	T6
Poor	T3	T4	T5	T5	T6	T6
Fair	T3	T4	T4	T5	T5	T6
Good	T2	T2	T3	T3		
Very Good	T1	T2	T3			
Excellent	T0	T1				

The output of the adopted fuzzy model is shown in Table 3.This Table can be used to select the type of treatment corresponding to their drop of quality falls under pavement condition and year of prediction. Empty cell of the table 3 is left blank because it seems that pavement condition will not continue longer. Developed maintenance alternatives will be useful when the pavement performance model is available.

IV. CONCLUSION

This paper presents a fuzzy logic inference system based model for planning of maintenance treatment selection for the black topped pavement surface. Fuzzy inference system procedure has been described in brief. Expert's response was obtained from thirty-five numbers of interviewee but author realize that it would be more for better result. Test results indicate that the developed model can provide a useful tool for selection of maintenance treatment when the parameters under consideration are uncertain.

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