

# OPTIMUM METHOD SOLUTION FOR DETERMINING BRAKE DISTANCE DESIGN

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## Abstract

Fuzzy logic is a powerful method for mapping space input into space output. Between space input and output there is a black box for mapping input towards suitable output. Although many ways works with the black box, fuzzy logic will give powerful solution. The purpose of the research is looking for relation parameters between velocity and brake pressure of vehicle model that can be control to determine optimum brake distance of vehicle model by using rules base of fuzzy logic with verbose format. The step of research methodology are: determining space input variable of fuzzy logic i.e. : velocity and brake pressure, using fuzzy operator, using implication function, composing space fuzzy output of brake distance, and then processing of defuzzification. The result of this research has given optimum brake distance of model vehicle. Where as the maximum of velocity = 112 km/h and brake pressure ( $P_{\text{brake}} = 80$  bars will give minimum brake distance = 24.90 meters, if brake pressure  $\leq 22.8$  bars will give maximum braking distance = 52.30 meters. The conclusion is model vehicle with brake pressure 20 bars  $< P_{\text{brake}} < 80$  bars will give brake distance: 24.90 meters  $< S_{\text{brake}} < 52.30$  meters in working velocity.

**Keywords:** Verbose, fuzzy logic, defuzzification

## 1. Introduction

Fuzzy logic is a powerful solution method that was invented by Professor Lotfi A Zadeh. Today, application method with fuzzy logic is not limited only for mathematics but all of knowledge sciences can use this method. Automotive design is one application science that using this solution method. Fuzzy logic solution method can determine the real optimum condition according to output targeted needed. Mostly, fuzzy logic solution methods can solve linear or nonlinear mathematics models in mechanical engineering control system or complex system.

Brake distance is an important parameter needed to design braking system. Braking system hardware is safety device that should considered perfectly by automotive designer, because it can influence sum of human accidental on the streets. If the braking system could be success at high

speed, the vehicle will crashed one to another vehicle. Then, we need to design brake pressure min to hindrance the situation.

The point consideration of this research, if the total weights of vehicle is bigger than other vehicle will cause braking distance increase as effect of mass inertia. So do not ever stop in front of trucks or buses because they need more time to stop according to their weights. Otherwise, vehicle or motor should make a priority for train through railway, because train needs braking distance until 500 meters to stop at emergency condition.

## 2. Theoretical Background

Brake distance design has variation parameter and depend on parameter is influenced to friction coefficient tire and road surface. Otherwise, they could be depend on type of tire and reaction time (mostly, it is assumed that human needs standard

time concentration to operate brake until 1/3 second).

Other factor that we have to consider is brake attitude according to braking process to reach front or back tire stabilization.

Empirical formula for a vehicle on the road can explain according to equation 1, below:

$$d = \frac{V^2}{(254 * f)} \quad (1)$$

d = Braking distance, m

V = Initial speed, km/h

f = Friction coefficient

Empirical formula for up grade stopping distance can be calculated using equation 2, below:

$$d = \frac{V^2}{[254 * (f \pm G)]} \quad (2)$$

G = Percentage up grade/100

For up grade stopping distance condition is lower stopping distance than down grades condition.

Table.1, explain general standard can be applied to practical approximation for braking distance on the road suitable to equation 1.

Table.1. Approximate Stopping Distance As well as type of vehicles and Weight of Load being Carried<sup>(8)</sup>

Speed (mph)	Speed conversion (km/Jam)	Thinking Distance (m)	Braking Distance (m)	Overall Stopping Distance (m)
20	32	6	6	12
30	48	9	14	23
40	64	12	24	36
50	80	15	38	53
60	96	18	55	73
70	112	21	75	96

Approximation according to Mr. Alex Beet, overall stopping distance could be equation 3:

$$\frac{X^2}{20} + X = \text{Overall stopping distance (ft)}, \quad (3)$$

X = Speed (mph),

For example: vehicle average length can be approximate 15 ft, so that overall stopping distance will be 75 ft in working velocity 30 mph.

It shows that there are five cars along space in front of the vehicle reference.

While follow another vehicle, do not ever follow near close, because this condition always cause human accidental because it needs more time to stop at normal condition.

Normally time to stand for brake distance only during 2 second to stop or to hindrance situation.

The impression of the analysis can applied vehicle speed optimization between 32 km/hours - 112 km/hours, it is caused that vehicle normal operation in this working velocity. Meanwhile, normal brake pressure operation between 0-80 bars. Otherwise, membership function could be determined by software modeling to analysis the output target needed.

Membership Function for Vehicle Speed, Brake pressure, and Brake Distance

Fuzzy logic Mamdani's can explain the figures below to control output brake distance and input vehicle speed and brake pressure.

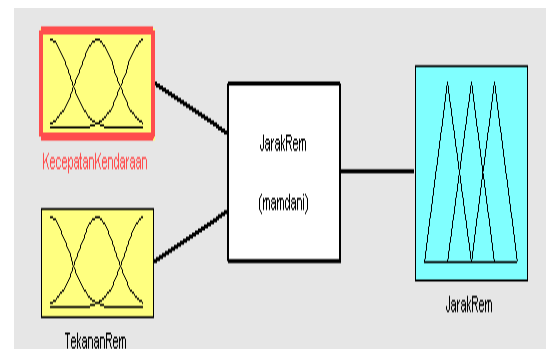
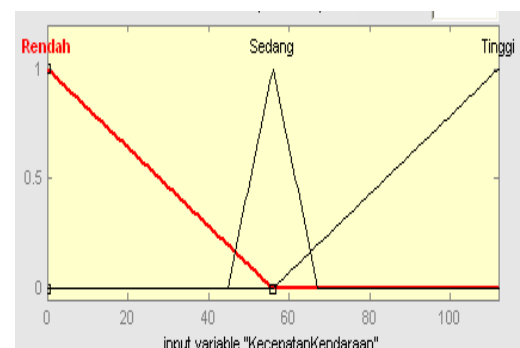


Fig.4. Input-output Fuzzy Logic



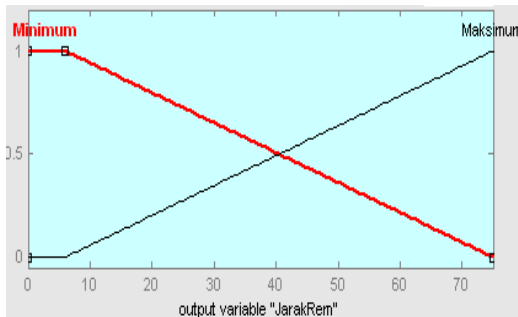
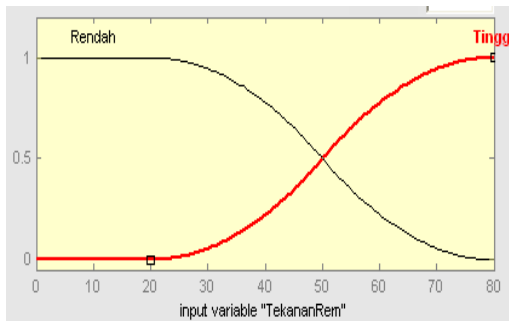


Fig.5. Membership function input-output Fuzzy Logic

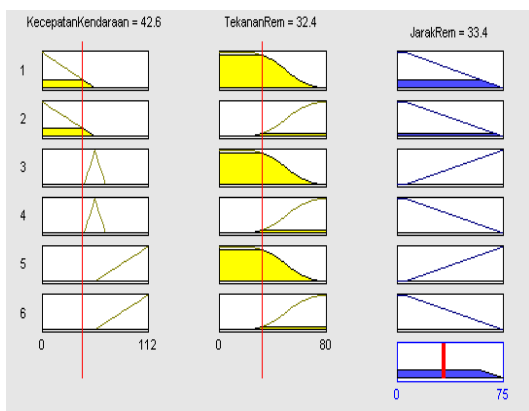


Fig.6. Rule Viewer

Fuzzy logic Mamdani's can be determined vehicle brake distance suitable to format verbose:

1. If vehicle speed is low and brake pressure is low then brake distance is min.
2. If vehicle speed is low and brake pressure is high then brake distance is min.
3. If vehicle speed is medium and brake pressure is low then brake distance is max.
4. If vehicle speed is medium and brake pressure is high then brake distance is min.
5. If vehicle speed is high and brake pressure is low then brake pressure is max.

6. If vehicle speed is high and brake pressure is high then brake pressure is min.

### 3. Research Methodology

Research experimentation to find output targeted can be express by using flowchart procedure figure.7.

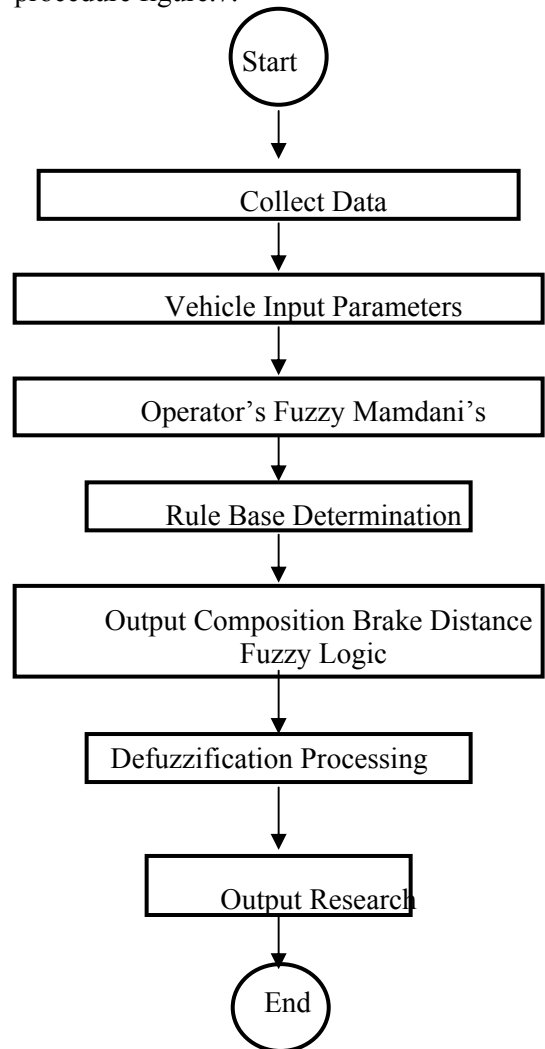


Fig.7. Research Procedure

### 4.Results Discussion

Output results by using fuzzy logic can be got 3D Parameter relationship input and output parameters braking distance in working velocity, i.e.

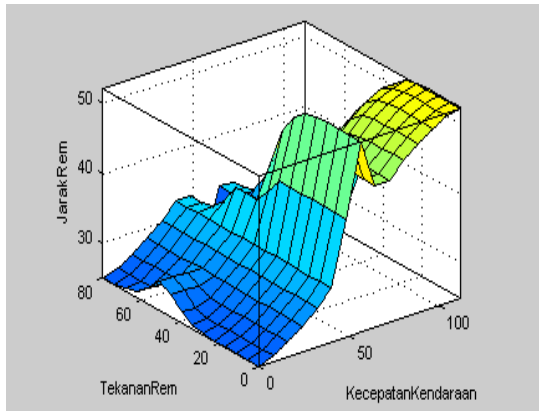


Fig.8. 3D Parameter relationship Vehicle Speed, Brake Pressure and Brake Distance

By using software ruler viewer, it can displayed input and output simulation to readability about responds surface above (fig.8).

Table.2. Optimization Results by Using Fuzzy Logic Rule

Vehicle Speed (Km/Jam)	Brake Pressure Input	Brake distance Optimization Using Fuzzy Logic
32	20 bar	30,50 m
	40 bar	30,50 m
	60 bar	30,50 m
	80 bar	30,50 m
48	20 bar	41,90 m
	40 bar	39,50 m
	60 bar	35,90 m
	80 bar	32,60 m
64	20 bar	45,30 m
	40 bar	39,50 m
	60 bar	35,90 m
	80 bar	32,60 m
80	20 bar	47,40 m
	40 bar	42,70 m
	60 bar	33,10 m
	80 bar	30,50 m
96	20 bar	50,70 m
	40 bar	46,90 m
	60 bar	29,00 m
	80 bar	27,00 m
112	20 bar	52,30 m
	40 bar	47,50 m
	60 bar	28,30 m
	80 bar	24,90 m

## Conclusions

Results analysis by using fuzzy logic controller can be determined some conclusions.

1. Braking distance from a vehicle can show us working velocity and brake pressure as input system.
2. Table.2 can explain to us that max velocity 112 km/hours and brake pressure 80 bars will give minimum of brake distance design, meanwhile brake pressure 20 bars will give max brake distance design.
3. By using fuzzy logic rule we can get interface for ECU (Electronic Control Unit) to converse language program with assembler language.
4. PID Controller can be prepared to set parameters stabilization.
5. Design of brake pressure vehicle should be attention to the result of this research include brake pressure design or operation brake pressure of the vehicle.

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