Ⅳ-37 A STUDY ON THE FORMULATION OF EXPECTED SPACE IN CAR FOLLOWING

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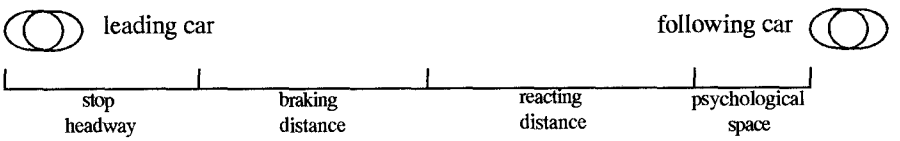
1. INTRODUCTION

The formulation of expected car following space-speed relationship is a key point in study of car following. There are several such formulas existing nowadays which have been developed from statistical data of traffic. But there is no theory to explain why formulas are in that way. So that the formulation usually varies place by place , country by country comes to be a mysterious thing.

In this paper, achievement of the formulation of expected car following space-speed is presented in a psychological way instead of statistic inference. This is an another angle to view the meaning of this expected space. And also this formula is employed to explain some daily traffic phenomena to show how fit it is to the actual situation.

2. FORMULATION DESCRIPTION

From a psychological viewpoint, the space between two following vehicles in a stable congested traffic flow can be classified into 4 items. Please look at the diagram below.



Stopping Headway : the space between two following cars when they are stopped. Average distance is supposed to be 6m.

Braking Distance: the distance covered by a car suddenly braking with V speed. Braking Distance= V*V/2*g*Ubg.(g: gravity ; Ubg: friction factor).

Reacting Distance: the distance covered during a period which is from finding a braking light ahead to braking down his car. Average response time is 0.7 sec. Hence Reacting Distance=0.7*V. (V's unit is m/sec)

Psychological Distance: the distance caused by a driver's safe judgement due to different weather, road conditions. lights etc.. (e.g. when snowing, a driver has to keep an extra distance from ahead car to avoid slipping if he brakes). The Psychological Distance item is omitted in the paper.

The general expression of the formulas in congested flow is:

$$S = \frac{v^2}{2 g u_{bg}} + 0.7v + 6 \ (m) \quad (v\text{'s unit is m/sec})$$

Such classified items of the expected car following space is rational. In general case a sudden brake is the most dangerous situation for a following vehicle driver. However drivers have their own matured experience to keep enough space from ahead car so as to avoid crashing ahead in that case. If there is a sudden braking ahead, the following driver will take such actions or steps: perceiving braking light, reacting to that braking light , braking and stopping the car. Obviously a minimum space is needed to avoid a crash in this course which may be expressed as:

Reacting Distance + Braking Distance + Stop Headway

This space can ensure drivers not too much worry about sudden brake ahead and feel safety . There is no doubt, this minimum space might be defined as the expected car following space.

In the case of free flow, drivers normally feel sure that they will encounter few stop-starts in front. So that a driver chases an ahead car in low speed range without considering the Reacting Distance seriously. That's why the congested flow curve and the free flow curve are not connected and there is a difference between them.(see figure 1 & 2) This difference is about equal to the Reacting Distance at that speed. However when speed is increased over that range, and that speed seems to be not used to a driver, then he probably increase largely the space from ahead in order to get enough time to react. This extra reacting time of course can be regarded as an increment to the Response Distance. The formula is given below in case of free flow:

$$S = \frac{v^2}{2 g u_{bg}} + 0.7v\ (v\text{-}v_{cr}) + 6\ (m) \qquad (v\text{'s unit is m/sec})$$

The item of 0.7*V*(V-Vcr) is the Response Distance. (Vcr is the critical speed .e.g. 46km/hr.) Let's check whether this formula conforms to the real traffic flow.

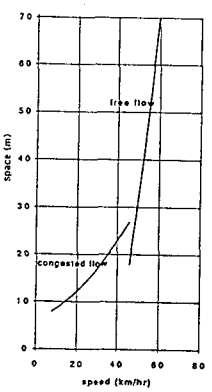


diagram 1. the formulation

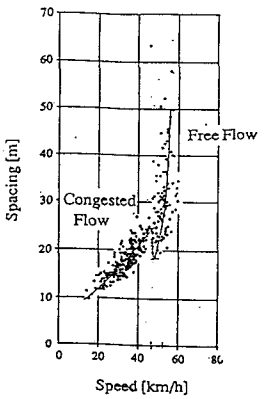


diagram 2. the real traffic flow

From diagrams the expected space-space curve is quite close to the actual one in the congested traffic flow.

3.CASE STUDY

This formula can be used to explain why the slight speed drop in the platoon head generates a shock wave and causes the complete stop in the tail of the platoon. The 0.7 sec reacting time is the key reason. Vehicles in a platoon normally keep the expected spaces from ahead, (the minimum safety space). When ahead vehicle drops its speed slightly, it will be after 0.7 second the following one reacts to this speed drop. This time delay causes the driver to drop his speed as soon as possible with more greater deceleration than his ahead did in order to recover the minimum safety space quickly (the expected space). A greater deceleration is leading to a shorter space for the following vehicle and a shorter space is again resulting in a much greater deceleration of the next following vehicle.

$$S_{k+1} = S_{exp} - \left[0.7v \frac{0.7}{2} (2v - 0.7a_k) \right]$$

S is the space left for the following driver to take braking action. a is deceleration rate. This action happens in order in the platoon . Finally there is a vehicle braking, behind that one all have to stop.

Reference :

Capacity of Sags and Tunnels on Japanese Motorways by Masaki Koshi.
A Study on the Car Following Behavior by Ozaki Haruo