<u>THE ANALYSIS OF DRIVING BEHAVIOUR: MANOEUVRING AS A DECISION PROCESS</u>

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1. INTRODUCTION

Driving behaviour can be analysed at different levels:

- choice of destination and means of transportation
- route choice
- manoeuvre selection, for instance overtaking or car following
- vehicle operation

As to manoeuvre selection, a number of aspects can be mentioned such as: the available and minimum space and time needed for carrying out the manoeuvre - depending on traffic, road and vehicle characteristics - and psychological aspects such as the driver's response, perception, information and decision capacities. A simplified scheme of the decisions to be taken on approaching a vehicle ahead is given in Figure 1.

2. MANOEUVRING AS A DECISION PROCES

The following model describes the manoeuvring behaviour from a decision-theoretical point of view. The driver has to decide about overtaking or not using his estimates of the time required to execute the manoeuvre ,

$$R = \frac{\text{distance to lead vehicle}}{\text{own speed - speed of lead vehicle}}$$

and the available time,

$$S = \frac{\text{distance to oncoming vehicle}}{\text{own speed + speed of oncoming vehicle}}$$

In estimating the value of S and R, the driver is assumed to make two types of error. First of all there will be a systematic error which consists of constant underestimation or overestimation of S and R, say C_S and C_R respectivily. C_S and C_R may be different for each driver.

Secondly there will be a normally distributed random error component that influences the estimation of S and R, say e_S and e_R.

The model describes the situation for one driver, estimating one pair of values S and R, under various conditions.

The assumptions that will be made are:

1. The additivity assumption.

For each pair (S,R) it holds that the i-th estimation $\hat{S}_i$ of S and $\hat{R}_i$ of R can be decomposed as follows.

$$\hat{S}_i = S + C_S + e_{S_i}$$

$$\hat{R}_i = R + C_R + e_{R_i}$$

With C_S and C_R the constant error components mentioned above and e_{S_i} and e_{R_i} the random error components of the i-th estimation.

2. Error assumptions.

The usual error assumptions will be made, viz.

$$E\ (e_S) = E\ (e_R) = 0,$$

$$E\ (S, e_S) = E\ (R,\ e_R) = 0$$

and

$$E\ (e_S, e_R) = 0$$

From the assumptions it follows that the mean of the estimates $\hat{D}_i$ of the difference S - R, writing $\hat{D}$ for $\hat{S} - \hat{R}$, is equal to:

$$\mu_{\hat{D}} = S + C_S - R - C_R$$

With regard to the variance of $\hat{D}$ it holds that:

$$\sigma^2_{\hat{D}} = \sigma^2_{e_S} + \sigma^2_{e_R}$$

The probability p of an observed positive difference $\hat{D}_i$ may be computed as follows:

Define : $z_i = \dfrac{\hat{D}_i - \mu_{\hat{D}}}{\sigma_{\hat{D}}}$

If $\hat{S}_i > \hat{R}_i$, which means that $\hat{D}_i$ is positive, then $z_i > -\mu_{\hat{D}}/\sigma_{\hat{D}}$ and as a consequence the wanted value of p is equal to the area under the standard normal curve on the right of the point $z_o = -\mu_{\hat{D}}/\sigma_{\hat{D}}$.

For each $z_i > z_o$ the decision to overtake will be made. In practice, however, it seems unrealistic to assume this without restrictions. The driver will (almost) always be aware of the risk he takes in depending regardlessly on his estimates of S and R.

Therefore he will demand a fair difference between $\hat{S}$ and $\hat{R}$. Thus let us say (to avoid the complications of introducing a new risk variable) that the overtaking manoeuvre takes place if, and only if $\hat{S} - \hat{R} \geqslant L$, where L is some safety constant.

The greater the value of L, the smaller the probability p_L of overtaking, given S and R. We find the probability p_L as the right area at the value $z_L = \dfrac{L - \mu_{\hat{D}}}{\sigma_{\hat{D}}}$

When $S - R > 0$, p_L gives the probability of a correct decision to overtake.

When $(S - R) \leqslant 0$, p_L denotes the probability of an incorrect decisions to overtake.

In Figure 2a the distributions of estimates of R and S are given for specific values of C_R and C_S. Figure 2b shows the corresponding distribution of $\hat{D}$. p_{L_i} represents the (in this case) incorrect

decision to overtake for different values of L.
In the event of such an incorrect decision, the driver may correct his action if he can or there will be a collision.
Speculation about the possibilities of correcting his manoeuvre brings up a new specification removed from the model for reasons of clarity.
For, if we suggest acceleration as a possible correcting action the problem arises what is meant by the time required to overtake. Surely not the minimum time, because in that case the overtaking manoeuvre is planned with full acceleration. This leaves us with the alternatives of eliminating acceleration as a correcting action, or interpreting 'time required to overtake' as the time required for the performance of a manoeuvre as planned by the driver, in which acceleration may be zero or even negative (deceleration).

3. UNCERTAINTY AND PERCEPTION

The preceding section mentions two types of error.
In the first place there is assumed to be a constant error in estimating S and R, secondly there is a random error component. Because there is knowledge of results in driving, it is possible to improve the manoeuvring behaviour by reducing both types of error. The driver may conclude that in executing the manoeuvre there appears to be always more space available than he did predict, or just the opposite. This may lead him to correct his estimates in the future. As a result the constant errors will become less important.

Furthermore, the driver may become aware of correlations between external factors and what he expects to be random error.
This is possible if the random error component is supposed to consist of error due to factors whose outcome have unpredictable effects on the estimates of S and R, and error due to restrictions of the perceptual organs.
If the minimum manoeuvring space needed is inferred from, say, acceleration capability as a function of speed, the driver may learn that such factors as wind force or road gradient are correlated with the fluctuations in his estimates.
He may then conclude that what seemed to be unpredictable is partly predictable and then refine his estimates.
The integration of more factors in the process of perception makes the decision task more and more complicated. This may effect the observation period and the number of observations.

Both kinds of error reduction may result in more fluent and more efficient or safe driving because of the increase in discriminability and the resulting decrease in uncertainty.

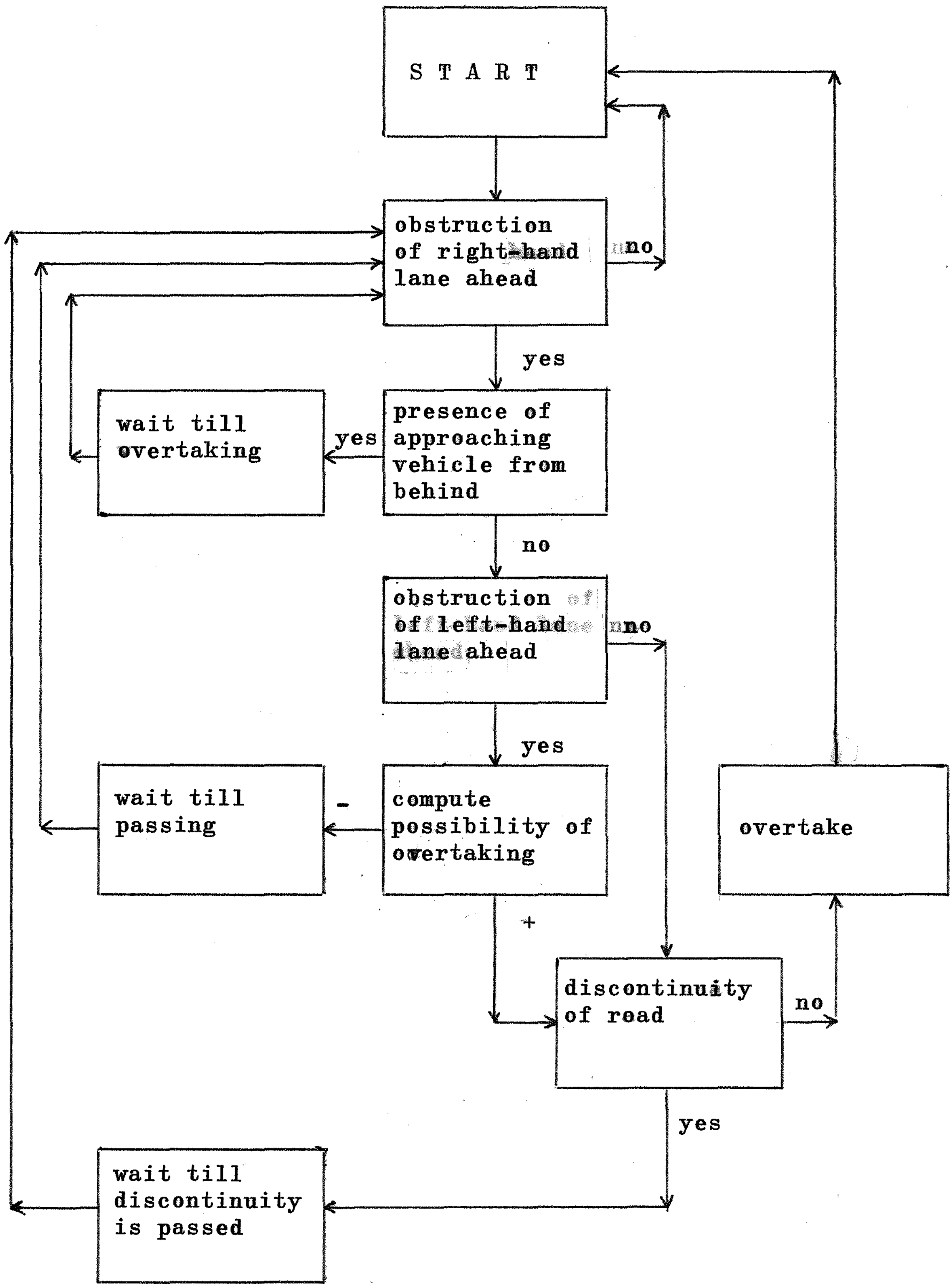

Fig. 1. Decision scheme approaching a vehicle ahead, for right-hand driving.

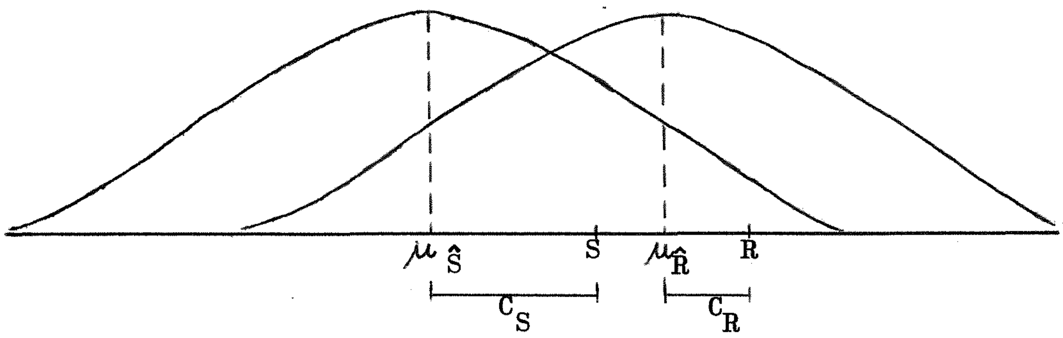

Fig. 2a

Distributions of estimates of S and R, with systematic errors C_S and C_R.

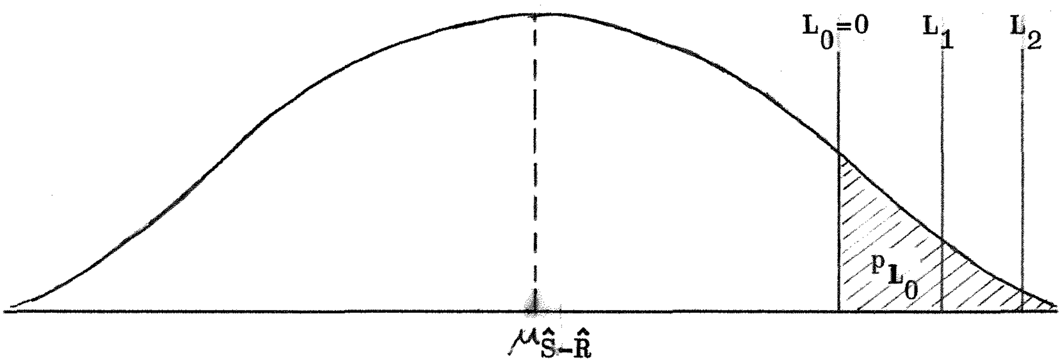

Fig. 2b

Distribution of differences $\hat{S} - \hat{R}$, p_{L_o} representing the decision to overtake, which in this case is incorrect