ROAD USERS' DECISION MAKING IN TRAFFIC; SOME EXAMPLES

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1. Introduction

The road traffic plays an essential role in providing for the needs of transportation in our modern society. No trip can be made without participating in one way or another into the road traffic system. The strongly increasing number of cars has involved a sharp increase of the number of traffic accidents during the sixties. In order to meet this growing traffic unsafety problem several measures were introduced like exacting higher standards of the technical equipment of cars, of the qualifications on getting a driver license and of the lay-out of roads and intersections. As a result since 1972 the number of traffic accidents is decreasing in spite of almost a doubling of the number of cars. Nevertheless the extent of the current traffic unsafety is still not acceptable because of the enormous human harm and economical damage. Since the major failures of the traffic system have been eliminated, the research methods, suitable for improving traffic safety, have to be more complex and refined. Furthermore, given the modern need for transportation, traffic unsafety cannot be tackled separately anymore without influencing the operational functioning of the traffic system. More and more a human-factors approach in research on traffic safety will be needed.

Because of their own responsibilities road-administrators will be interested first of all in improving the lay-out of roads and intersections. The gathering of accident or conflict figures has to be followed by a systematic observation and analysis of the whole traffic process.

In order to illustrate this approach some examples of research will be discussed emphasizing the decision-making element in the human information processing cycle of perception, interpretation, decision-making and handling in relation to the road environment and/or other road users (the actual behaviour versus the environment).

2. The functioning of local dual carriageway intersections

On the basis of an accident analysis (priority accidents on the second carriageway dominant, with locally well-known motorists frequently involved) and because of the relatively low traffic volumes on the main road (daily about 2000 vehicles) it was decided to reconstruct the rural intersection "St. Nicolaasga" from a large-scale dual carriageway inter-
section with a wide median to a simple priority intersection with only marked left-turn lanes on the main road.

In a before- and after-study several aspects of roadusers' behaviour were analysed in detail, like speed on the main road, the way of entering or leaving the main road (with and without separate traffic lanes) and the negotiation of the intersection by traffic from the minor road (Hofstra, 1984). By means of specific video-recordings also an inventory of the looking behaviour of drivers (head-movements) was conducted in order to check whether the reconstruction would result in a better surveyability and a more uniform crossing of the junction.

The reconstruction resulted into a reduction of first head-movements in the wrong direction (firstly to the right) from 12 to 8% and a sharp reduction of the number of head movements both before and during crossing the main road (from 88 to 68% of crossing motorists). In the after period most head-movements took place in the road section prior to the intersection. The effect of not making head-movements during the crossing indicates a more uniform decision making process and a greater certainty (once a decision has been made, it is checked less frequently). In the before period 12 percent of the roadusers is looking also to the left when approaching and crossing the second carriageway, which is redundant in fact. In conclusion in the case of low traffic volumes the simple (and cheap) solution of an intersection with only painted left-turn lanes appears to function better than a large scale dual carriageway intersection.

3. Road design and bicycle traffic

In The Netherlands in urban areas the bicycle contributes substantially to the total demand on transport. Because of its attractive qualities like milieu-kindly, healthy and cheap, the bicycle has gained popularity again during the last years. To stimulate the use of the bicycle some years ago the central government had designed and constructed two demonstration cycle-routes at The Hague and Tilburg, two cities in The Netherlands. Specific road design elements like speed control humps, lane constric-
tions, cobble pavement, etc. were applied in an experimental way. For the greater part their effects on roaduser behaviour and road safety were unknown. The experimental character of this demonstration project enabled systematic research into the functioning of different types of solutions for the same kind of problems.

By means of some well-chosen design elements like lane constrictions and humps it appears possible to control the behaviour of car drivers when intersecting a cycle-track (with priority for bicyclists). Not only these elements do reduce the mean approach speed of cars, but also the minimum speed is reached a few metres prior to the cycle-track instead of on or after the cycle-track for control locations without special provisions, an example of which is given in Fig. 1a. This is one of the indications that car drivers at the experimental locations pay more attention to cycle-track and also to its users, as is illustrated by conflict data, see Fig. 1b (Van der Horst, 1984).
The evaluation method used, i.e. an objective quantification of interacting behaviour between road users from video-recordings (Van der Horst, 1982), enables not only an objective counting of traffic conflicts but also a detailed analysis of the preceding process.

![Diagram showing speed profiles and number of conflicts based on different minimum TTC values.](image)

**Fig. 1a** Speed profiles (with standard-deviation) of crossing cars involved in interactions with bicyclists for an experimental location (H1) and control location (H11).

**Fig. 1b** Risk-indices (number of conflicts/exposure) based on different minimum TTC (time-to-collision) values.

An design parameter in applying a speed control hump is the distance between the hump and the element it is intended for (here the cycletrack). A comparison of locations where this distance was different (between 0 and 5 m), resulted in a preference for a hump at the beginning of a plateau at a distance of about 4.5 m on either side of the cycletrack.

Another important element in the behaviour of bicyclists concerns the gap-acceptance when intersecting an urban arterial road. Which gap in a traffic stream do bicyclists accept for crossing and what is the influence of the lay-out of the main road, the type of manoeuvre, one or two-way traffic, etc. After the cyclist's decision to accept a gap the consequences have to be evaluated, how is the crossing passing in relation to the oncoming car? For this study video-material was used, available from another demonstration project, viz. "the demonstration project on redesigning urban areas at Eindhoven and Rijswijk", also two cities in The Netherlands (Van der Horst and Ten Broeke, 1984). At two locations the behaviour of cyclists was analysed before and after a reconstruction of the lay-out of the Leenderweg at Eindhoven for two types of manoeuvres, a left-turn by cyclists from the cycle-track along the main road (E1) and a crossing from the minor-road (E2), see Fig. 2.
Fig. 2 Situational maps of the Leenderweg at Rindhoven before and after reconstruction.

Before the reconstruction the main road consisted of a carriageway of 2 x 4.6 m with a dotted middle line. In the after situation the carriageway was reduced to 2 x 3.6 m divided by a painted median with a width of 2 m, completed with a refuge and side-line markings in order to facilitate the crossing for cyclists and pedestrians. For the description of the decision-making behaviour the critical gap (τ_{crit}) is often used, defined as the intersecting point of the cumulative distribution of the rejected gaps greater than a certain gap length t and the cumulative distribution of accepted gaps less than t, see Fig. 3. For the critical gap the probability of rejecting or accepting is the same. Fig. 4 gives the effect of lay-out and the first or second traffic stream. The central refuge zone in the "after" situation reduces the critical gap values, for the first as well as for the second traffic stream. Also the mean crossing time is much lower after the reconstruction.

In order to indicate how "risky" a crossing manoeuvre is, a division of the accepted gap into manoeuvring time and remaining-time (RET) is made. RET is something like the PET measure (Post-encroachment-time), the time-difference between the moment the cyclist has left the path of the oncoming car and the moment the car reaches this leaving point. The lower this RET value the more risk cyclists have taken by accepting this gap. For example the mean RET values "before" and "after" do not differ (Fig. 5). However, for the second stream the probability on very small RET values is significantly lower in the after period. Especially for this crossing the reconstruction was made. Bicyclists are crossing faster the Leenderweg (less delay) combined with a lower risk.
Fig. 3a Cumulative distributions of rejected and accepted gaps by bicyclists for the first traffic stream, critical gap = 7.2 s.

Fig. 3b Idem, for the second traffic-stream, critical gap 5.9 s.

Fig. 4 Critical gap dependent on type of lay-out (BEFORE and AFTER) and the first or second traffic stream to be crossed, type of manoeuvre E1 (left-turn from cycle-track along main road).

Fig. 5 Mean remaining time (RET) and proportion of small RET times before and after reconstruction.
4. Drivers' decision making in relation to the yellow-timing of traffic signals

At signalized intersections the task of the road users with respect to other traffic is simplified substantially. However, the road user is charged with other tasks, for example in relation to the traffic signals. An important behavioural aspect consists of the decision-making for stopping or non-stopping at the moment the signal changes from green to yellow. Factors which may influence the decision making process will relate to, among others: the drivers' attitude, the amount of predictability of the situation, an estimate of the consequences of not stopping (the chance of running red, or a conflict with intersecting traffic, or getting a fine) and an estimate of the consequences of stopping (discomfort, waiting-time, the chance of a rear-end conflict). Weighing these factors will also involve the drivers' estimates of the required deceleration on the basis of speed and distance to stop-line, the duration of the yellow phase and the all-red period. Also the behaviour of other road users may influence the decision making.

Especially the duration of yellow-time and all-red time can be influenced directly by the road administrator, besides of course the type of control strategy which is used. As an example effects of the yellow-time will be discussed in some more detail.

From a review of the extensive literature about this topic it appeared that an one second extension of the current values in The Netherlands (3 s yellow for 50 km/h intersections and 4 s yellow for 80 km/h intersections) would optimally adapt to what normally might be expected from car drivers and to what maximally can be achieved under poor circumstances (Van der Horst and Godthelp, 1982). This measure should reduce the number of run-red offences considerably. Furthermore a more uniform decision-making behaviour might also benefit to road-safety. Because the system is better adapted to "normal" behaviour, measures directed to enforcement might be much more effective. However, most of the research referred to isolated intersections or to rather short periods of habitation. Therefore a field experiment with an extension of the yellow time was conducted within a whole area, rather isolated from through traffic and for a period of at least one year. By means of a "before- and after" study the behaviour of car drivers has been evaluated from time-lapse video-recordings (Van der Horst and Wilmink, 1986). First of all it has been checked whether or not the extension of the yellow time had reduced the number of run-red offences. After one year the yellow-time extension with one second appears to half this number, as well related to the total number of vehicles (from 1.1 to 0.5%) as related to the number of deciding vehicles, non-stopping and first-stopping cars after the beginning of yellow (from 13.4 to 5.7%).

In order to describe the decision-making behaviour properly, the stopping drivers have also to be involved. By this the probability of stopping can be calculated, for example as a function of the distance to the stop-line at the moment the yellow signal is switched on. However, a better description is given by the probability of stopping as a function of the potential time to stop-line (TTS), taking into account the individual initial approach speed of each vehicle and assuming vehicles will continue with a constant speed. Fig. 5 gives the results after a log-linear model fit. A small shift of 0.17 s is present. This small adaptation of drivers' behaviour does not change anymore after a period of six months.
An interesting effect of traffic control strategy on drivers' decision-making behaviour appears when comparing these results with data from the literature (Fig. 7). All sets of data, except one, are based on field studies. Mahalel et al. (1985) conducted a laboratory experiment. A remarkable one second shift exists between a vehicle-actuated versus a fixed-time control strategy.

Fig. 7 Probability of stopping as a function of the potential time to stop-line (TTS) at the beginning of yellow, Van der Horst et al. (1985) and Sheffi and Mahmassani (1981) for a vehicle-actuated versus a fixed-time control strategy (Williams (1977), Mahalel et al. (1985) and Hulscher (1984)).
Evidently a vehicle-actuated control leads to a shift in the criterion drivers use. In an earlier stage of the approach process drivers decide to proceed. The characteristics of the decision process itself are not different for both types of control, i.e. the slopes of the curves from the field studies are the same. The different slope of the curve of Mahalei et al. (1985) might indicate a somewhat deviant behaviour in laboratory circumstances.

5. Final remarks

The given research examples illustrate how the functioning of specific road elements can be evaluated in terms of resulting behaviour of road users under normal conditions instead of in terms of the traffic unsafety itself. In this approach the emphasis was put on drivers' decision-making. Together with the phases of perceiving and processing of information (for example relating with visibility, conspicuity, recognizability and comprehensibility of all kind of information-carriers in road traffic) the decision-making phase is an important one in the whole traffic process and strongly affected by the road users possibilities and limitations. Because of the dynamic nature of this process a description by time related measures such as TTC, GAP, RET or PST, TTS, etc. is inevitable, especially for a better understanding about how road users are handling critical traffic situations.

6. References

