A measuring instrument is being developed for evaluating design elements as applied in the demonstration project on Cycle Routes in The Hague and Tilburg. Behaviour observations were made at four locations on the cycle routes with both film and video shots. It was examined to what extent observers were able to make simple, reliable records from the shots.

There was also a quantitative analysis of the film and video pictures in order to establish road users' behaviour in terms of course, course changes, speed, changes in speed and interaction with other road users. Both techniques, film and video, gave comparable results. The use of video is preferable, mainly in view of the cost.

In the meantime, equipment has been developed enabling direct selection from video pictures (see appendix). But the quantitative analysis continues to be expensive and time-consuming.

As there is no suitable measuring instrument yet for recording and assessing road users' behaviour characteristics, the Traffic Engineering Department of the Public Works Department requested the Institute for Perception IZF-TNO to make a preliminary instrumental-methodological study for development of a measuring instrument for behaviour observation. The behaviour observations will also have to fit in with the long-term research, the emphasis of which is more on establishing behaviour relevant to road-safety research (including the establishment of serious conflict behaviour between road users). One objective is that there must be a pronounced effort to develop objective techniques.

Measurable behaviour characteristics of cycle traffic as related to road characteristics, and also as related to other road users, include course, course changes, speed, changes in speed, but also
rear orientation, indicating direction and the like. Attention is paid especially to interactions with other road users.

The video equipment consisted of a Sony camera Type VCK 2100 A and a Sony video recorder EV-320 CE. Use was also made of a video-timer, which gave the time accurate to whole seconds in the picture. Video pictures were taken for one hour per location. They were taken from a fixed camera position at a speed of 25 frames a second. The video-recorder was started manually the moment traffic (bicycle or car) arrived from one of the directions in question. Recording stopped when the vehicles had vanished from the picture.

Quantitative analysis consists of selecting positions of points of the vehicle on stills. Firstly, a black and white film was made of the video shot. At present, video-pictures can be selected directly. By means of transformation rules, the positions in the plane of the film can be translated into positions in the plane of the street. First of all, there is a transformation from film coordinates to street coordinates. The street coordinates are given relative to a more or less arbitrary system of axes. By differentiating successive positions in time, the speed of the vehicle can be obtained. One frame was selected from every six. The output is a plot of the successive positions per manoeuvre in a diagrammatic plan of the location and also graphs of speed and acceleration as related to time or to the road traversed (Figure 1 and 2).

A start was made with a description of bicycle-car interactions. It was examined whether the time-to-collision technique of Hayward (1972) and Hyden (1977) could be used for this description.

As an example, the calculation of the TTC for the selected manoeuvre combinations was chosen. The method of calculation is as follows:
In the street-plane, the positions of a given point of each of the two vehicles at successive times are known in the form of x and y coordinates. Four third-grade polynomials are estimated as a function of time, by means of the least squares method (Seifert & Steeg, 1960):
\[ x = x_1(t) \quad \text{for vehicle 1} \]
\[ y = y_1(t) \]
\[ x = x_2(t) \quad \text{for vehicle 2} \]
\[ y = y_2(t) \]

The general structure is: \( f = a + bt + ct^2 + dt^3 \). The courses travelled in the street-plane can be derived from this as continuous curves; see Figure 3 for example. With the aid of the approximation method of Newton–Raphson (Stoer, 1972), the point where both courses intersect (point S) is calculated together with the appropriate times \( t_1 \) and \( t_2 \), the moment at which the given point of vehicle 1 or vehicle 2 passes S, the point of intersection.

On the assumption that, always as from the present time \( t \), there will be no more changes in course or speed, a straight line is estimated at quarter-sec. intervals for every vehicle through the present point and the three preceding points. The intersection of these lines is again determined, and it is checked whether the vehicles are travelling on a collision course. They are doing so at time \( t \) if either of the following two conditions is satisfied (Figure 4):

\[ t_{A1} < t_{A2} < t_{B1} \quad \text{............... (2)} \]
\[ t_{A2} < t_{A1} < t_{B2} \quad \text{............... (3),} \]

in which, taking the vehicle's dimensions into account:

\[ t_{A1} = t_{p1} - \frac{l_{a1} + b_{r2}}{V_1} \]
\[ t_{B1} = t_{p1} + \frac{a_{b1} + b_{12}}{V_1} \]
\[ t_{A2} = t_{p2} - \frac{l_{a2} + b_{11}}{V_2} \]
\[ t_{B2} = t_{p2} + \frac{l_{b2} + b_{r1}}{V_2} \]
$t_{P1} =$ moment at which point P1 passes intersection point S
$t_{P2} =$ moment at which point P2 passes intersection point S
$V_1 =$ speed of vehicle 1
$V_2 =$ speed of vehicle 2

The above applies to a $90^\circ$ angle of intersection. Adjustments can be made for other angles. Special computations have to be done if one of the vehicles has a speed of zero. If (2) or (3) is satisfied, a collision will occur if the courses and speeds remain unchanged.

The time-to-collision, TTC, will then be
for (2): $TTC = t_{A2} - t$
and for (3): $TTC = t_{A1} - t$

Determination of the TTC for successive times allows it to be plotted as a function of time, but only if (2) or (3) is satisfied. Examples of such curves are given in Figure 5, where these TTC curves are plotted for several combinations of manoeuvres at location 4.

The top limit for the calculating process has been taken at 5 sec. In Figures 5a, b and d, the TTC falls below 1.5 sec. Such situations are described by Hayward and Hyden as serious conflict situations.

Without claiming that the problem has been dealt with exhaustively, it can be said that in view of the foregoing, the method of selection and analysis of video pictures, certainly seems a suitable means of arriving at descriptive criteria for conflict situations.
Fig. 1: Example of position plot location 1
Graph a: speed as a function of course travelled
Graph b: acceleration as a function of course travelled
Graph c: speed as a function of time
Graph d: acceleration as a function of time
Fig. 2: Example of position plot location 2
Fig. 3: Estimated curves in street-plane for a combination of manoeuvres at location 4

Fig. 4: Characteristics of vehicles in question for determining TTC curves
Fig. 5: TTC curves for several combinations of manoeuvres at location 4
Appendix

A description of the video-equipment, used for behaviour observations at intersections of the Cycle Routes in The Hague and Tilburg.


Video-recording equipment

The recording equipment consists of the following elements (see Fig. 1):

Camera: black/white, Sony 3250

Timer: For-, VTG-33 (month, day, hour, minutes, seconds, 1/100 sec.)

Frame encoder: Own development

Video-recorder: Sony Umatic Video-cassette recorder VO 2850

The frame-encoder labels each frame separately. Digital information is stored at the start of each video-line. Within each frame the complete digital code (24 bits) is repeated four times. So, the decoder can always read the digital code at least twice, whereever the separation of two successive frames ('noise bar') is being (at stillstanding video-pictures), see photo on the next page.

Video-analysis equipment

This equipment is used for reading x- and y-positions of special points in a stillstanding video-picture. The operator indicates a point by positioning two crosshairs, continuously by a joy-stick (velocity control)
Fig. 2.
or step-by-step by four push-buttons.

A block-diagram is shown in Fig. 2.

A mini-computer (DEC, PDP 11/03, 28K memory) is used as a central supervisor. Many different functions can be realised easily in software. Communication between computer and other devices takes place by 8 digital channels of 24 bit each. By a special joy-stick search module (Sony SM-02) the video-tape can be winded or rewinded under computer control (with an adjustable speed between zero and three times the normal speed). By reading the special frame-code each desired video-picture can be searched automatically. Also the "noise bar" can be placed at the bottom of the monitor screen by the computer.

The operator has at his disposal a normal teletype and a special keyboard, consisting a.o. of 16 push-buttons, to which a function can be related in software. For example on a special command ("point ready") the computer reads the x- and y-positions of the cross-hairs, and positions the cross-hairs on predicted x- and y-coordinates of the next point. The operator has only to correct these coordinates with a few steps. The collected data are stored on disc of the central computer of the institute (PDP 11/40). The system offers the possibility for a quantitative analysis of stillstanding video-pictures.