VISIBILITY ASPECTS OF THE DRIVING TASK: FORESIGHT IN DRIVING

A theoretical note

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1. INTRODUCTION

Participating in road traffic is a complicated affair. The traffic participant must perform a variety of different activities. These activities are different for each different mode of traffic participation; furthermore, they usually differ for different persons, for different traffic situations and for different environmental conditions (day or night, weather, urbanization etc.).

In the following note, we will discuss several aspects of what is usually called "the driving task". The driving task requires a considerable amount of information, for the greater part visual information. We will focus on factors and measures for improving the visual information; emphasis will be placed on the (artificial) road lighting and on the road markings.

The note concentrates on the need to look ahead while driving. The term coined for this is "foresight"; the note deals with the requirements for adequate foresight, as well as with the means to provide the required foresight. It should be stressed here, that the idea of "foresight" primarily puts emphasis on only one of the different aspects of the driving task (the preview mode); another major aspect of the driving task consists of car following (the pursuit mode). Car following is dealt with, but only as far as the foresight aspects are concerned. The note is on foresight; the note is not meant to be a comprehensive discussion on all aspects of the driving task.

First we will make a number of general remarks. The note concentrates on the performance of the drivers of (passenger) cars. Not only do these drivers represent the largest number of road accidents; the car driver may serve as an example for other traffic participants, as basically the different aspects of the performance are very similar - although quantitatively speaking rather different - for all other modes of traffic participation, such as riding a bicycle, a moped or a motorbike, walking as a pedestrian, or driving a truck.

In the note we will deal in Chapter 2 with a number of general aspects of the relevant decision-making processes. In Chapter 3 we will discuss the particular driving task aspects of a car driver. In Chapter 4 we will

describe the different manoeuvres in traffic. In Chapter 5 we will indicate the different visual elements for each of the manoeuvres and each of the task elements. These are summarized in Chapter 6. The note concludes with conclusions and recommendations.

The note is a result of a considerable amount of literature research, and a lot of further considerations. The ideas described here can, however, for a large part be found in the literature. As it is usually not possible to indicate precisely where the different aspects, ingredients and ideas came form, and because in many cases the information from the literature is interpreted rather than quoted, a bibliography does not seem to be very useful. Therefore, we have refrained from including one.

2. DECISION-MAKING PROCESSES

Most human activities are the outcome of some decision-making process. The decision usually has to do with the choice between two (or, occasionally more) alternatives. The choice is made on the basis of the comparison between the expected outcome of the different alternatives; the most "useful" is selected to be executed. It should be stressed that "usefulness" generally involves much more than the purely rational outcome; a human being is a "homo economicus" only to a limited degree. If, however, non-rational elements are included in the assessment of the cost/benefit relationship, the model can be used for all human decisions.

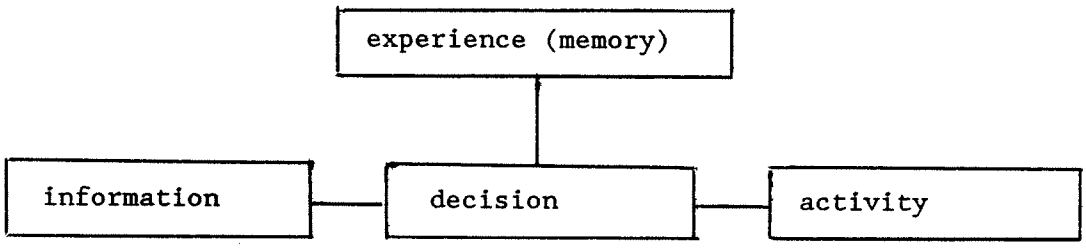
Essential is the expected "usefulness" of the different alternatives. This implies that the decision maker must have at least some overall idea what the result of the alternative will look like; otherwise, the selection will be pure gambling, and the selection process is random. Albeit that such processes occur in human activities, usually human try to avoid such situations. As an example, even where - like playing a lottery - the process is pure chance, people try to include some expected values, like selecting lucky numbers or their birth date. Also in traffic such random selections take place; their randomness, however, requires a quite different approach, and this type of selections will not be discussed here. This note deals exclusively with selections in which advance knowledge plays a certain role. This implies automatically that (driving) experience will have a major impact on the outcome of the selection process. As regards terminology, we will use the term "decision" only when these cognitive aspects play a significant, or even decisive, role.

Decisions are made only if required; we have indicated that we will not deal with random activities in this note. The requirement is called the "motive" for the activity (or for the decision). The frame of mind that leads to the selection of motives is called the motivation (it should be pointed out that the terminology is may show some differences). Motivation is therefore always an "internal" affair; the motives, however, usually but not always are of an "external" nature. In road traffic, "internal" motives are rare; if they seem to occur, they usually represent in reality some aspect of motivation. As an example: speeding may seem to have time-pressure as a motive; it is, however, more correct to consider urgency as

an aspect of motivation. To be more concrete, one may assume that all activities in traffic (usually called "manoeuvres") are made only if there is some motive to do so; the motive being the fact that the propose of the traffic participation cannot be fulfilled if the manoeuvre is not made. In this respect, the considerations given here imply to a certain degree the idea that human beings make utilitarian decisions. One should realise that this idea is similar to, but not the same as, the postulate that the human being is an "homo economicus" as is sometimes assumed in some psychological theories. As a simple example: if there is a curve in the road, the curve must be negotiated, otherwise the driver would go off the road, and would not be able to reach his destination. The curve presents the motive for the manoeuvre; the motivation may influence the way the manoeuvre is executed.

In this way we have simplified the issue. Motives can always be coupled to concrete objects in the "outside" world of the driver. This means that decisions can only be made when information is available regarding (certain aspects of) the outside world. Furthermore, the decision requires that the driver has expectations as regards the outcome of alternative manoeuvres. It should be noted that "doing nothing" or "just driving on" should be regarded as manoeuvres as well, as they are also an outcome of a decision making process.

This completes the elements of the decision making process. The process can easily be described graphically.



This simple graph may be used as a basis for the discussion of all decision making processes that occur in road traffic. Some of them are fully conscious and rational, whereas others may be almost completely sub-conscious. Others may be only a part of a series - a sequence - of decision-making processes, and finally, "feed-back" loops may be included. For our discussions, the simple graph usually is sufficient.

Decisions fall into two main groups. The first group is the decision simply to react to happenings in the outside world. They are called "reactive decisions"; they often have the characteristics of conditioned reflexes. In psychology, they are often called "stress reducing motives or actions". Often they have a heuristic character. Most of the actions in traffic belong to this group. In view of their likeliness to conditioned reflexes, they depend heavily on experience, and they can be easily be improved by training. The second group is the decision to select a certain "strategy". They look like the decisions made in steering a vessel: a course is set, and deviations from the course are corrected well before the risk of collisions or of grounding is acute. They are called "active decisions". In psychology, they are often called "stress (or tension) increasing motives or actions". Usually they have a cognitive character. This group of actions may be less frequent in traffic, but they are equally important. As they depend more on cognition than on experience, they can be improved primarily by education and schooling, rather than by training.

3. THE DRIVING TASK

3.1. Road safety aspects

Road traffic basically is nothing but the set of activities that is aimed at reaching some destination. All disturbances that may lead to reaching the destination later, with more difficulty, or not at all, are unfavourable for the purpose of the traffic, and should be avoided as far as possible. There is some likelihood with health: the normal state is the healthy one, and disturbances are illnesses. Using this analogy, normal road traffic is often compared to healthy traffic, and disturbances like traffic jams and accidents are compared to illnesses.

Disturbances always have the aspect of a conflict: there is always a conflict of interest between the healthy traffic and the disturbance. Conflicts can be classified, and be placed in an hierarchy, beginning at the "lower" side with simple meetings; "higher up" there are severe conflicts that disturb the flow of traffic, and still "higher" one finds the accidents. It is customary to place fatalities at the "top" of the hierarchy. This hierarchical approach has two important consequences. The first is that the frequency of occurrence diminishes while going from "low" to "high": the number of meetings is much higher than the number of fatalities. The second is that there seems to be a gradual increase in "severity" going from the one extreme to the other. These two aspects are important when one tries to use conflicts as an alterative measure for road safety (one should actually say "unsafety") in stead of accidents.

These considerations are essential when one tries to identify the basic concepts of the present road-traffic system as compared to the system of other modes of transport. Rail traffic and civil air traffic are essentially non-conflict modes of transport. This does not mean that there are no conflicts or accidents; what we mean is that the system is designed in such a way that conflicts are absent; in other words, as long as the system works as designed, there cannot be any conflict and therefore no accident. There is no possible way that two trains, or two planes, can occupy in a way that is accepted by the system, the same rail or air space. The reasoning is that, when no conflicts can occur, *a fortiori* no accidents are possible.

Road traffic, and street-car (tram) traffic, and naval traffic as well for that matter, operate on a completely different principle. Conflicts are accepted. It is assumed that the traffic system, or the - collective of - the traffic participants will operate in such a way that, although conflicts may be frequent, accidents will be avoided (or rather, will be limited to a socially acceptable level). As an example, most intersections are non-signalled, implying that traffic from different directions will have conflicts. It is expected that road users will behave in such a way that collisions are avoided. In some cases the road users are supported by rules or regulations, like e.g. "traffic from the right has priority". In many cases one goes even one step further: conflict situations are intentionally created in order to force the road users (usually the drivers of passenger cars) to behave in a fashion that is considered desirable from other points of view. In many residential areas, cycle tracks and sidewalks are removed on purpose in order to reduce driving speed, a benefit from the point of view of noise reduction or of environmental protection. The authorities count on the drivers to adapt their driving style is such a way that the number of accidents will not increase, at least not to a non-acceptable degree.

3.2. Task aspects

The sequence of decision-making processes that has to be followed by a car driver is usually called the "driving task". As indicated above, the usefulness of the activities are essential for our considerations; this means that taking part in traffic is done not random, but to some purpose. Traffic participation is considered as being functional.

Obviously, the propose of taking part in traffic is to reach the trip destination. For our deliberations it is convenient to subdivide this purpose in three distinct goals, although in reality they are very much intertwined. The goals each have their "sub-tasks". The three sub-tasks are:

- reaching the destination by selecting and maintaining the correct route;
- avoiding obstacles while under way towards the destination;
- coping with emergencies while performing the two other sub-tasks.

The sub-tasks are quite different in nature. The first sub-task - the selection and maintenance of the route - involves decisions that are made for a large part even before the beginning of the trip. When the decisions are incorrect, the result is that the destination will not be reached, or not reached in time, resulting in loss of time and/or money (apart from frustration etc.). The loss may be called "economic".

The second sub-task originates while driving. It refers to discontinuities in the run of the road, and to the presence of other traffic participants. The decisions relate to the avoidance of the hazards that are presented by the discontinuities and the other participants. When the decisions are incorrect, collisions may result. Apart from not reaching the destination with its economic loss, the consequences are further the losses of goods and properties, and maybe even injuries or even fatalities. The consequences are of a road safety nature. It should be noted that drivers often choose another route when they expect to meet discontinuities or traffic participants; in this way, the decisions on the "higher" level are influenced.

In both cases that are described here, the essential feature is that there is adequate time to acquire and process the necessary information, to make the decision, and to execute the manoeuvre. In many instances, this is not the case. Unexpected and unwanted (dangerous) emergencies may arise, that require a fast reaction of the driver in order to avoid collisions. This is the third sub-task: coping with emergencies. Usually, the information on which the decision must be made is inadequate, incomplete or even wrong, the time for making the decision is very short, and the time to execute the manoeuvre is often simply not sufficient.

3.3. Foresight

Taking action costs time. First, the (visual) observations must be made; after that, the decision must be made, and finally, the action must be performed. It is customary to discern the following "times":

- detection time
- reaction time
- decision time
- action time.

The time required for the action will entail as well the time needed to prepare for the action, e.g. the shifting of the foot from the accelerator to the brake pedal. It might be noted that here, as elsewhere, the terminology might differ from place to place. In a more sketchy way, the detection time, the reaction time (proper) and the decision time are taken together as the "(overall) reaction time". The important point is, that the time involved may be quite considerable, more in particular when one deals with the actions to be taken by the driver of a fast-moving car.

Obviously, a decision can only be adequate when the time to make it is available. This implies that the object (or the group of objects) that make the action (the manoeuvre) necessary, must be visible at a distance large enough to make the observations and the decision, and to perform the action (to execute the manoeuvre). To describe the required time interval we use the term foresight. Foresight can be expressed in distances or in time intervals, depending on the questions that must be answered. When the driving speed is known, the distances and the time intervals can easily be converted into each other. Sometimes, the term "preview" is used in stead of foresight; this use may lead to confusion as preview is a rather specific term in control engineering.

4. MANOEUVRES

4.1. A hierarchy of manoeuvres

Manoeuvres can always be considered as a means (a road) to reach a goal (a target or a destination). Means and goals can be listed in an hierarchical system in such a way that the means at a certain level is a goal (actually a sub-goal) on a lower level. As an example: if the goal is to go from town A to city B, the means (the road) will lead through the village C. Now, reaching the village C is a sub-goal for which the intersection at D must be passed. Reaching the intersection D is a sub-sub-goal etc. In the other direction this hold as well: reaching the city B is the means to be able to attend the congress about E, and is a super-means. In this way, the hierarchy can be extended in both ways to "infinity". The point is, that means and goals are only relative concepts, and that each goal can be considered as a means for another goal. Manoeuvres can therefore also be listed in an hierarchical system. Three levels are of particular interest for the description of the driving task:

(a) level of complex manoeuvres
(b) level of elementary manoeuvres
(c) level of manoeuvre parts.

The major complex manoeuvres are:

- just going on (as a result of the relevant decision);
- negotiating a curve;
- overtaking and passing a preceding vehicle without opposing traffic;
- overtaking and passing a preceding vehicle when opposing traffic is present;
- passing a (priority) intersection;
- passing an intersection with traffic signals;
- passing a "roundabout";
- coming to a stop for a T-junction, or for a traffic signal.

The elementary manoeuvres are:

- just going on;
- adjusting speed;
- swerving around;
- leaving the traffic lane;
- coming to a stop.

The manoeuvre parts are:
- just going on;
- adjusting the speed (to the desired speed or to the speed of the preceding vehicle);
- adjusting the lateral position within the driving lane.

The hierarchical structure of the manoeuvres results from the fact that each manoeuvre represents (is the outcome of) a decision. Each decision has a "goal" and a "way". The way must be followed in order that the goal can be reached. The terminology is derived from the route-selection process (one of the manoeuvre levels of the driving tasks); as a metaphor it can be used for all human activities. For all decisions a goal and a way can be defined; the hierarchical structure follows from the fact that the "way" at a certain level is the "goal" at a lower level, and vice versa: each goal is a way at a higher level.

As the traffic manoeuvres can be grouped in an hierarchical structure, each elementary manoeuvre can be composed from manoeuvre parts, and each complex manoeuvre can be composed from elementary manoeuvres. The hierarchy can be extended on both ways: on a still "higher" level the selection of the trip destination, the trip motivation, the route and the mode of transport can be found. These represent decisions that are made before the start of the trip, and therefore fall outside the scope of this note. Similarly, the hierarchy can be extended to the "lower" activities; art a lower level, one may define the handling of the controls of the vehicle (steering wheel, accelerator, brake pedal etc.). Also these "sub-manoeuvres" are not discussed in this note, as they are not directly related to information acquired from outside the vehicle.

4.2. Manoeuvres in road traffic

A car is a surface vehicle, implying that there are two degrees of freedom for movement: lengthwise and crosswise (indicated here with x and y). In this respect, a car is similar to a vessel, that also has two degrees of freedom, but different from a train (one degree of freedom) or a plane (three degrees of freedom).

In principle, the selection of the values of x and y (and all time derivatives) is up to the driver; the decisions are made on line and in situ - meaning that there are no other authorities like traffic control or time tables. In reality, things are rather different. Restrictions of a physical, behavioural or legislative nature make that the actual possibilities for drivers are very limited indeed; in fact, only four are open for manipulation by the driver in normal traffic:

* dx/dt; the forward driving speed;
* d^2x/dt^2; the lengthwise acceleration or deceleration;
* y; the lateral position;
* dy/dt; the crosswise speed.

And even these four cannot be chosen at will as a result of the presence of road limits, speed limits, vehicle performance and other traffic.

This means that all traffic manoeuvres essentially have to be composed of these four parts.

Using these restrictions, the sub-tasks can be specified further. The end result is eight different sub-tasks, each involving different combinations of the information processing and of the degrees of freedom available for manipulation.

1. Maintaining the lateral position within the driving lane
2. Maintaining the speed
3. Maintaining the route (the course) on straight stretches and in curves
4. Overtaking: changing traffic lanes
5. Overtaking with opposing traffic
6. Adjusting speed for discontinuities or other traffic
7. Adjusting speed and lateral position for discontinuities or other traffic
8. Coping with emergencies.

In each of these eight cases we can indicate what manoeuvres may be required; for each manoeuvre we can indicate the type of information that is required to make the decision, and the moment in time when the information must be available in order to make the decision in time. It should be kept in mind that a manoeuvre at a specific level includes in principle all manoeuvres at all lower levels. This includes the acquisition of the information that is needed for these lower manoeuvres.

We will discuss these details in the next sections, each of which will be structured in the same way. First we will indicate the relevant task elements and the relevant manoeuvres with their specific process times. Further the required preview time will be derived from the process time of the manoeuvres. The next step is deriving the foresight distance for a number of specific types of road. We have based our considerations on three classes of road, which might serve as a global representation of the major part of the road network. These road classes are:

- Class A: Urban roads (thoroughfares and all urban roads with a traffic function) with a nominal driving speed of 15 m/sec (about 50 km/h).
- Class B: Rural trunk roads (primary roads) with a nominal driving speed of 25 m/sec (about 90 km/h).
- Class C: Rural freeways (motorways, limited access highways) with a nominal driving speed of 35 m/sec (about 125 km/h).

Finally, the visually critical elements will be indicated for all these cases; that are the elements for which the lighting must ensure their visibility.

5. VISUAL ELEMENTS FOR DIFFERENT CLASSES OF ROAD

5.1. Maintaining the lateral position within the driving lane

Task elements

Adjusting the lateral position by slight adjustments of the steering wheel.

Manoeuvres

As this is - for an experienced driver at least - a routine task, it will not be greatly influenced by variable factors like attention, arousal etc. The actual process time is in the order of 3 seconds.

Foresight

The process time of 3 sec (or less) leads to a foresight of 3 sec as well. For different road types the foresight distance is given in the following table:

Road type	Foresight distance (m)
A	45
B	75
C	105

Visually critical elements

The visually critical elements are:

- the side limits of the road; in most cases the sides are indicated by curbstones or marked by road markings;
- the centre of the road, or the lane limit.

Remarks

- On major roads, both urban and rural, the lane demarcations are indicated by road markings. On most minor roads, lane markings are absent.
- The absence of centre lines is often considered as a major road safety hazard. Keeping the right lateral position is reduced to guess-work. Often the only clue is the perceived position of opposing traffic.
- The information can be supported, but not be taken over by delineators.

• Far out the most critical situation is the wet-night situation, particularly on unlit roads.

5.2. Maintaining the driving speed

Task elements

The task elements are:

- adjusting the speed according the desired (set) speed;
- adjusting the speed according the speed of preceding vehicle(s).

Manoeuvres

As this is - for an experienced driver at least - a routine task, it will not be greatly influenced by variable factors like attention, arousal etc. The actual process time is in the order of 3 seconds; for following the speed of preceding traffic probably somewhat less.

Foresight

The process time of 3 sec (or less) leads to a foresight of 3 sec as well. For different road types the foresight distance is the same as in para. 5.1.

Visually critical elements

The visually critical elements are:

- the side limits of the road; in most cases the sides are indicated by curbstones or marked by road markings;
- the centre of the road, or the lane limit;
- the preceding vehicle(s), particularly their markers and marking lights.

Remarks

• For speed adjustment according to a set (desired) speed, the visually critical elements are almost the same as for the maintenance of the lateral position.

• For speed adjustment in accord with the speed of preceding cars, obviously these preceding vehicles present the most important visually critical element.

• On major roads, both urban and rural, the lane demarcations are indicated by road markings. On most minor roads, lane markings are absent.

• The absence of centre lines is often considered as a major road safety

hazard. Keeping the right lateral position is reduced to guess-work. Often the only clue is the perceived position of opposing traffic.

- The information can be supported, but not be taken over by delineators.
- Far out the most critical situation is the wet-night situation, particulary on unlit roads.

5.3. Maintaining the route

Task elements

Assessing the course of the road, particularly the curves in the road.

Manoeuvres

On straight roads: just continue with the same speed and direction.
In curves: adjusting the steering wheel to the curve.

Foresight

The foresight time depends on the driving speed. The foresight is for the different road types is given in the following table:

Road type	Foresight time (sec)	Foresight distance (m)
A	10	150
B	15	375
C	20	700

Visually critical elements

The visually critical elements are:

- general elements of landscape or townscape;
- lighting columns, and (particularly at night) lanterns with burning lamps;
- delineators
- road markings (only for roads of type A).

Remarks

- Maintaining the route or course of the road is often considered as primarily a matter of driving comfort; this is probably true for straight roads, but probably not for curves.

• As lamps of the public lighting often can be seen at a large distance, the night-time visibility of the run of the road is often superior to the day-time visibility.
• In many cases the information can be supported, but not taken over by additional road signs.

5.4. Overtaking: changing traffic lanes

Task elements

The task elements are:
- assessing the lateral position, the speed and the course of the road (as in earlier sections);
- assessing the speed and position (longitudinal and lateral) of the other traffic travelling in the same direction;
- adjusting the lateral position by adjustments of the steering wheel as required by the overtaking manoeuvre.

Manoeuvres

Adapt the lateral position to the lane changes. On straight roads: continue with the same speed and in the same direction. In curves: adjusting the steering wheel to the curve.

Foresight

The foresight time consists of two elements. The first is the foresight needed to maintain the course as in para. 5.3. The second is the foresight needed for the actual overtaking manoeuvre. The manoeuvre without opposing traffic is usually relevant only for dual carriage-way roads (divided highways). The required time for a lane change is for preparation 3 to 5 sec and for execution of the manoeuvre 5 to 7 sec; total 8 to 12 sec.

The foresight is:

Road type	Foresight distance (m)
(A	120 to 180; not relevant in practice)
(B	200 to 300; only relevant on divided highways)
C	280 to 420

Visually critical elements

The visually critical elements are:

- general elements of landscape; lighting columns; road markings, delineators; curbstones; centre lines (as in para. 5.1; 5.2 and 5.3);
- vehicles travelling in the same direction.

Remarks

- The visual critically elements are the same as those in para. 5.1 and 5.2, but in addition one must reckon with the vehicles.
- Usually, the visibility of vehicles can be supported by signalling lights.
- In many cases the overall shape of the vehicles is not (sufficiently) visible. Signalling lights are essential. This may be the case both at day as at night.
- Almost all divided highways are of type C.

5.5. Overtaking with opposing traffic

Task elements

The task elements are:

- assessing the lateral position, the speed and the course of the road (as in earlier sections);
- assessing the speed and position (longitudinal and lateral) of the other traffic, travelling in the same and in the opposite directions;
- adjusting the lateral position by adjustments of the steering wheel as required by the overtaking manoeuvre.

Manoeuvres

Adapt the lateral position to the lane changes. On straight roads: continue with the same speed and in the same direction. In curves: adjusting the steering wheel to the curve.

Foresight

The foresight time consists of two elements. The first is the foresight needed to maintain the course as in para. 5.3. The second is the foresight needed for the actual overtaking manoeuvre. The overtaking manoeuvre with opposing traffic is not relevant for divided highways. For two-lane roads (and other single-carriageway roads), the foresight time (distance) must

take into account the opposing traffic, driving at essentially the same speed. First, this involves the total overtaking manoeuvre. Apart form changing lanes, the slower vehicle must be passed, and the lane change must take place in opposite direction, back to the proper lane. Estimated values are:

- preparation 3 to 5 sec
- lane change 5 to 7 sec
- passing the vehicle 2 to 6 sec
- lane change (back to the proper lane) 5 to 7 sec

Total 15 to 25 sec.

The foresight is:

Road type	Relative speed opposing traffic (m/sec)	Foresight distance (m)
A	30	450 to 750
B	50	600 to 1250
(C	70	1050 to 1750; not relevant in practice)

Visually critical elements

The visually critical elements are:

- general elements of landscape; lighting columns; road markings, delineators; curbstones; centre lines (as in para. 5.1; 5.2 and 5.3.);
- vehicles travelling in the same direction (as in para. 5.4);
- vehicles travelling in opposite direction.

Remarks

o The visual critically elements are the same as those in para. 5.1 - 5.4, but in addition one must reckon with the opposing vehicles.

o Usually, the visibility of vehicles can be supported by signalling lights.

o Almost all roads of type A or B are single-carriageway roads.

5.6. Adjusting speed for discontinuities or other traffic

Task elements

The task elements are:

- perceiving the obstacle or the other traffic participant;
- adjusting the speed according to the nature of the discontinuity or to the speed of other participants (vehicles);
- coming to a stop in case the discontinuity requires this.

Manoeuvres

Adjusting (usually reducing) the speed and if needed, coming to a stop.

Foresight

The foresight depends on the driving speed, the desired speed at the end of the manoeuvre, and the type of road (in view of the discontinuity or the other participant being expected or not).

The foresight will be given here only for the extreme case, being coming to a stop. The stopping distance equals the required preview. The stopping distance depends on the reaction time (rather brief for objects that are expected; see also para. 5.8), the driving speed, the type of road and the retardation. Although modern cars may have excellent braking performance (up to 8 m/sec^2 on dry roads), normal driving practice where a reasonable degree of driving comfort is maintained, restricts the practical retardation to 2.5 m/sec^2. This value is used here. The foresight estimates are as follows.

Road type	Reaction time (sec)	Stopping distance (m) (= foresight distance)
A	1	60
B	2	175
C	3	350

Visually critical elements

The visually critical elements are:

- general elements of landscape or townscape (other than para. 5.3), indicating the discontinuity;

- lighting columns, and (particularly at night) lanterns with burning lamps (other than para. 5.3) indicating the discontinuity;
- road markings, delineators, (other than para. 5.3), indicating the discontinuity.;
- pre-warning sings or signals indicating the discontinuity;
- other traffic participants (motor vehicles, mopeds, pedal bicycles, pedestrians).

Remarks

- The most important discontinuities in the road are T-junctions, priority junctions and signalled junctions (traffic signals).
- The consequences of the discontinuity for the traffic depends on the required speed adjustment. This adjustment may vary from zero to maximum (coming to a stop). General rules cannot be given.
- The consequences of a wrong or untimely decision are severe: the result will be a collision, which can be avoided only when an emergency manoeuvre is executed (see para. 5.8).

5.7. Adjusting speed and lateral position for discontinuities or other traffic

Task elements

The task elements are:
- perceiving the obstacle or the other traffic participant;
- adjusting the speed according the nature of the discontinuity or to the speed of other participants (vehicles).
- adjusting the lateral position in the traffic lane or while leaving the traffic lane;
- coming to a stop in case the discontinuity requires this.

Manoeuvres

Adjusting (usually reducing) the speed; swerving around (an obstacle); changing traffic lanes; and if needed, coming to a stop.

Foresight

The foresight as regards the lateral position is equal to the foresight required for maintaining the lateral position (as in para. 5.1), or changing traffic lanes (as in 5.4 and 5.5).

Road type	Route maintenance	Foresight distance (m) overtaking traffic in same direction (after para. 5.4)	overtaking with opposing traffic (after para. 5.5)
A	150	120 to 180	450 to 750
B	375	**	600 to 1250
C	700	280 to 420	**

**: not relevant in practice

The foresight as regards coming to a stop is as in para. 5.6.

Visually critical elements

The visually critical elements are:

- general elements of landscape; lighting columns; road markings, delineators;
- pre-warning sings or signals indicating the discontinuity
- other traffic participants (motor vehicles, mopeds, pedal bicycles, pedestrians).

Remarks

- The same remarks as in para. 5.6 are made; only the consequences are more severe as at least two manoeuvres are involved.
- The consequences of the discontinuity for the traffic depends on the required speed adjustment. This adjustment may vary from zero to maximum (coming to a stop). General rules cannot be given.
- The consequences of a wrong or untimely decision are severe: the result will be a collision, which can be avoided only when an emergency manoeuvre is executed (see para. 5.8).

5.8. Coping with emergencies

Task elements

Reacting as fast as possible to the emergency.

Manoeuvres

Swerving around; reducing speed; coming to an emergency stop.

Foresight

The foresight required for swerving around is similar to that as given in para. 5.3. As driving comfort is no consideration, the "reaction" time can be much shorter. Preview estimates are:

Road type	Foresight time (sec)	Foresight distance (m)
A	3	45
B	5	125
C	7	250

The foresight required for reducing speed depends on the driving speed and the desired speed after the manoeuvre and can range from zero to a maximum for coming to a stop.

The foresight for coming to a stop is similar to that as given in para. 5.6.

The retardation, however, in an emergency stop is much higher. On dry roads, it may be 6 to 7 m/sec^2; on wet roads for cars about 5 and for trucks about 3.5 m/sec^2. For the calculations, 5 m/sec^2 will be used. As the emergency is unexpected, the required reaction time is considerable. The foresight estimates are (rounded-off values; calculated values between brackets):

Road type	Reaction time (sec)	Stopping distance (m) (= foresight distance)
A	2	55 (52,5)
B	3	140 (137,5)
C	4	270 (262,5)

Visually critical elements

Visually critical elements can be any object that presents itself suddenly

in the field of view, particularly if the presence is not in line with the general pattern of expectation. The most frequent and the most important seem to be (derived from accident studies; not in an order of priority):

- kerbs
- objects in the shoulder of the road (poles, signs, etc)
- other motor vehicles
- two-wheelers
- pedestrians
- objects dropped from vehicles (tires, exhausts, stones, boxes etc).

Remarks

- The same remarks as the earlier sections hold, as in spite of the need to perform an emergency manoeuvre as regards a specific traffic obstacle, the other traffic aspects remain equally pressing;
- The consequences of a wrong or untimely decision are severe: the certain result will be a collision, as it is precisely the emergency manoeuvres that are needed to avoid collisions. And if these fail, a collision cannot - by definition - be avoided;
- Aspects of driving comfort can be disregarded.

6. SUMMARY OF FINDINGS

6.1. Class A roads

Urban roads (thoroughfares and all urban roads with a traffic function) with a nominal driving speed of 15 m/sec (about 50 km/h).

No	Manoeuvre	Foresight	Visually critical objects
5.1.	Lateral position	45 m	road markings
5.2.	Speed control	45 m	road markings
		...	(preceding vehicles)
5.3.	Curves	150 m	road markings, light columns, delineators
5.4.	Overtaking without opposing traffic		(not relevant)
5.5.	Overtaking with opposing traffic	450-750 m	light columns (opposing vehicles)
5.6. 5.7.	Stopping for discontinuities	60 m	road markings, delineators, pre-warning signs, pre-warning signals, traffic signs, traffic signals
5.8.	Emergency manoeuvres		
	- swerving	45 m	(road markings), obstacles (other traffic
	- emergency stop	55 m	obstacles (other traffic)

6.2. Class B roads

Rural trunk roads (primary roads) with a nominal driving speed of 25 m/sec (about 90 km/h).

No.	Manoeuvre	Foresight	Visually critical objects
5.1.	Lateral position	75 m	road markings
5.2.	Speed control	75 m	road markings
		...	(preceding vehicles)
5.3.	Curves	375 m	light columns, delineators
5.4.	Overtaking without opposing traffic		(not relevant)
5.5.	Overtaking with opposing traffic	600-1250 m	light columns (opposing vehicles)
5.6. 5.7.	Stopping for discontinuities	175 m	(road markings), delineators, pre-warning signs, pre-warning signals, traffic signs, traffic signals
5.8.	Emergency manoeuvres		
	- swerving	125 m	obstacles (other traffic)
	- emergency stop	140 m	obstacles (other traffic)

6.3. Class C roads

Rural freeways (motorways, limited access highways) with a nominal driving speed of 35 m/sec (about 125 km/h).

No	Manoeuvre	Foresight	Visually critical objects
5.1.	Lateral position	105 m	road markings
5.2.	Speed control	105 m	road markings
		...	(preceding vehicles)
5.3.	Curves	700 m	light columns, delineators
5.4.	Overtaking without opposing traffic	280-420 m	light columns, delineators
5.5.	Overtaking with opposing traffic		(not relevant)
5.6.	Stopping for		
5.7.	discontinuities	350 m	(road markings), delineators, pre-warning signs, pre-warning signals
5.8.	Emergency manoeuvres		
	- swerving	250 m	obstacles (other traffic)
	- emergency stop	270 m	obstacles (other traffic)

7. CONCLUSIONS

As a conclusion, it can be indicated that for urban roads with a traffic function, the required foresight is for stationary objects between 45 and 150 meter, for overtaking up to 750 m, and for emergency manoeuvres about 50 m.

For rural trunk roads (primary roads), the required foresight for stationary objects is between 75 and 375 m, for overtaking up to 1250 m, and for emergency manoeuvres about 140 m.

For rural motorways, the required foresight is for stationary objects is between 100 and 700 meter, for overtaking up to about 400 m, and for emergency manoeuvres about 250 m.

It should be stressed that these values of the required foresight are larger, and often very much larger than the values that are usually quoted in the literature; also they are much larger than the values that are commonly in use in driver training and education. The reason is that the values that are commonly in use are based on juridical premisses, where it is required by law (and supposedly enforced by police) that the driver must be able to stop his vehicle in the time and in the space that is available and that can be overseen as being available. For this, one usually takes a very short overall reaction time (e.g. 1 sec, corresponding to a very alert driver who reacts to objects or situations that are fully expected) and a very large braking retardation (e.g. up to 5 or even 7 m/sec^2, corresponding to the legal minimum, or even to the practical maximum for good new vehicles on dry roads). In the earlier sections of this note, it has been shown very clearly that neither assumption is relevant for normal traffic, and that in combination they completely wrong.

The consequence is of using incorrect values for the required foresight that are very much too short is, that many technical solutions and technical equipment is not adequate, and that much of the information given to the driving population (and to pedestrians and cyclists as well, for that matter) is dangerously misleading. As an example: many people believe that it is perfectly safe to drive with a speed of 100 km/h in fog when the (meteorological) visibility is about 200 m (a rather dense fog), the

reason being that the 200 m exceeds quite considerably the "safe stopping distance" that is assumed to be 100 m at a speed of 100 km/h. According to the calculations given above, the required foresight for an emergency manoeuvre is already about 250 m, whereas the required foresight for other, perfectly normal, manoeuvres ranges up to 700 m. Here, the adherence to the generally accepted (very much too short) foresight distances may lead to very dangerous situations; the frequent extremely heavy fog accident ("pile-ups") are a very clear proof of this.

We will end this note with the remarks that are made in the Introduction. The note discusses several aspects of the driving task; more in particular on the need to look ahead while driving ("foresight"). The note deals with the requirements for adequate foresight, as well as with the means to provide the required foresight. The concept of foresight puts emphasis on one particular aspect of the driving task: the preview mode. Other major aspects such as car following (the pursuit mode) are dealt with, but only as far as the foresight aspects are concerned. It is stressed in the Introduction that this note is on foresight, and not on all aspects of the driving task.