DESIGN AND CLASSIFICATION OF ROADS FROM THE VIEWPOINT OF DRIVING TASK ANALYSIS

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shortened version

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For every traffic situation in all circumstances the road user ought to make an accurate prediction of both available and required traffic space. Accidents may happen when there are limitations in movement space caused by traffic facilities or by the presence and behaviour of other road users. Depending on the degree of occurrence of combinations of road and traffic characteristics, the road user has built up a pattern of expectation regarding the relationships between the road characteristics and road user behaviour on the road. Road user behaviour is determined, by the road user's route and manoeuvre selection in his vehicle within the given traffic space. In view of the road user's limited perceptive capacity an effort must be made to keep route and manoeuvre selection as simple as possible. The question is how road design can help to facilitate these tasks and what standards the road must meet in order to fulfil this function. Two major elements of the traffic system can be distinguished: limitations on movement and their predictability for the road user. The road plays a major part in movement limitation. Together with traffic characteristics, road characteristics largely influence the effort the road user will have to make in performing his tasks. The road characteristics relevant to driving tasks can be distinguished as:

(a) permanent (in time) and continuous (in place) perceptible characteristics of the cross-section, road markings and road surface;

(b) permanent and discontinuous perceptible characteristics of alignment, cross-section, traffic signs and road surface while, in addition to geometrical factors, frequency, density and sequence are important.

The total behaviour of the individual vehicles determines traffic characteristics. By definition, these are not permanently or continuously present or perceptible along a given road section. Traffic characteristics are not only linked closely with vehicle characteristics but are also determined by road users' relevant characteristics. On the basis of the characteristics of the traffic, the vehicles and the road users, functional requirements will be drawn up for road design which should make driving tasks easier and hence ensure greater road safety. In analysing traffic

behaviour, a need is assumed to exist for a subdivision of roads into categories based on a hierarchy of manoeuvring effort. It has also been reasonably suggested that road and traffic characteristics may adversely influence traffic behaviour and hence road safety by causing frictions (limitations on movement) longitudinally and laterally. It is therefore obviou that according as a road is included in a higher category the standards which road and traffic characteristics will have to meet to be focused on reducing longitudinal and lateral friction. The effectiveness of dividing roads into categories depends on compliance with the following functional requirements:

(a) Consistency of characteristics within the road category. Design criteria for safety, travel time (design speed) and comfort (manoeuvring effort) should be the same for all road characteristics (relation between road characteristics within the category) and should be attuned to vulnerability, top speed, acceleration and deceleration capacity, directional stability and manoeuvrability of vehicles in the lowest category allowed on the road in question.

(b) Continuity of characteristics within the road category. The information the road user needs on limitations of manoeuvring space longitudinally and laterally, which may or may not exist permanently along the entire length of road section in a particular category should be provided by permanent and continuous road characteristics.

(c) Little variation within the road category (uniformity in characteristics. For relationships within the road and traffic characteristics it is assumed that with a corresponding average value (but a difference in distribut ion) a road with more variable characteristics is usually more hazardous.

(d) road categories recognisable by road users. Categories are easier to recognise the fewer they are in number and the easier they are to distinguish from one another. Categories become easier to distinguish if dichotomous characteristics are used (the characteristic is there or not), redundant characteristics (various characteristics are there or not simultaneously) and clearly perceptible category indications or category-typifying road characteristics (permanent and continuous).

Relations between road characteristics themselves and between road characteristics and traffic characteristics (and vehicle characteristics) can be expressed as conditional probabilities based on frequencies of occurrence, per unit of traffic performance (vehicle kilometres travelled). By reference to these frequencies, road users will build up a pattern of expectations of relationships between characteristics of the road and of traffic on that road. A number of examples will show how, road categories can be distinguished with the object of establishing a realistic classification complying with all functional requirements. It still remains a theo-

retical approach which has to be worked out further and checked in parts against empirical investigations. An example illustrating categorisation based on total number of safety criteria is given in the diagram below. From left to right an increase in road-user manoeuvring effort is shown. Vertically the main categories are shown in a hierarchy; from top to bottom there is a decrease in design speed and an increase in the number of permitted vehicle categories:

- motorway (M): all motor vehicles able and allowed to travel faster than, say 70 km/hr;
- "road" (R): all vehicles except cycles and mopeds etc.;
- "street" (S): all vehicles.

	dual carriageway		single carriageway	
	rural	urban	rural	urban
motorway (M) design speed	MI 120	MII 100	--	--
"road" (R) design speed	--	RIII 60	RIV 80	--
"street" (S) design speed	--	--	SV 60	SVI 40

Example illustrating categorisation of roads with a motortraffic function.

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1. INTRODUCTION

Every society attaches great value to mobility: the movement of people, goods and commodities, information, etc. Such movements demand traffic space within which a maximum traffic flow or a minimum resistance must be provided for the moving vehicles. The problems that may arise in determining the location and the design of this space concern, among other things, the shortage of such space and its hazards.

The physical planning of socio-economic processes provides a subdivision of the total available space into sub-spaces each with specific functions, or often a combination of functions. Function in this case is defined as "providing the possibility of social activity". At this planning level one should on the whole ensure that the same space is not allocated for conflicting functions. For instance, one road is clearly monofunctional (allowing scope for movement) and the space appertaining to it should be safeguarded against other functions, such as housing and shopping.

The movement of vehicles on the road and relatively to one another is described as road-traffic behaviour. A distinction is made between behavioural choices by individual road users (route selection and choice of manoeuvre) on the one hand and their macroscopic results on the other (attribution of journey groups to road systems and traffic flow characteristics).

Although negative quality aspects of traffic can be distinguished at every level, it is mainly at the manoeuvre-behaviour level that hazards, congestion, discomfort, pollution and waste of energy are attacked.

This paper advocated the recategorisation of existing networks of roads on the basis of a functional physical planning (efficient use of space). Without losing sight of the other quality aspects, the emphasis is put on road safety criteria, since these largely determine the monofunctional character of traffic space.

2. THE ROAD SAFETY PROBLEM

Road hazards as a social problem comprise the overall (annual) loss and damage determined by the number of road casualties and the overall material damage caused to the community by traffic accidents. Road safety measures can be directed towards reducing this loss and damage with a given traffic performance; or they may be directed at limiting traffic performance. In both cases, however, allowance will have to be made for changes in other traffic quality aspects, such as freedom in destination selection, kind of vehicle and route, cost, journey time and comfort of movement and the ecological aspects.

If a given traffic performance is taken as the starting point for research, road safety can be improved by improving traffic facilities (road, traffic control, etc.), vehicles and human beings as road users. For each of the three elements with their interactions, influence factors can be determined that are relevant to the prevention (pre-crash), severity (crash) and follow-up (post-crash) of traffic accidents.

The road user's behaviour is the focal point in road safety research. For every traffic situation in all circumstances the road user ought to make an accurate prediction of both available and required traffic space. Accidents may happen when there are limitations in movement space caused by traffic facilities or by the presence and behaviour of other road users. In actual fact, the available movement space is always limited. For every traffic situation the information on limitations on movement (frictions) both longitudinally and laterally must be presented so clearly that every road user will be able to choose the correct manoeuvres. In this relationships between road characteristics themselves and between road characteristics and traffic characteristics (including vehicle characteristics) are of great importance. Depending on the degree of occurrence of combinations of road and traffic characteristics, the road user has built up a pattern of expectations regarding the relationships between the road characteristics and road user behaviour on the road.

For instance, a road user on a long, direct motorway with little longitudinal friction will also expect little lateral friction, i.e. a wide road with no intersecting or crossing road users (compare a motorway with a residential street). Possible frictions in a traffic space may remain outside the road user's pattern of expectations owing to incorrect furnishing of information and/or by lack of experience of specific combinations of road and traffic characteristics. Road traffic hazards may then be caused by incorrect choices of manoeuvres owing to incorrect predictions of one's own and other road users' traffic behaviour.

Research into road unsafety in the pre-crash stage often comprise a description and analysis of traffic behaviour. Possibilities are thus thought of simplifying road users' decisions regarding route and manoeuvre selection.

3. ROAD USER BEHAVIOUR ANALYSIS

Road user behaviour is determined, after the choice of destination and of vehicle, by the road user's route and manoeuvre selection in his vehicle within the given traffic space. In view of the road user's limited perceptive capacity an effort must be made to keep route and manoeuvre selection as simple as possible. In actual fact, traffic facilities in the form of road systems with road sections, intersections and traffic control have been allotted the function of moving traffic in a space reserved for it, with as little longitudinal friction as possible and also as little lateral friction.

3.1. Manoeuvre selection

For selecting a manoeuvre, the road user receives and assimilates information on the available movement space. The traffic facilities, the presence of other road users and the legal codes limit this available space. Prediction of the extent of space available for movement depends directly on the perceptibility of the road and traffic characteristics limiting scope for movement and is moreover influenced by the drivers' driving experience and skills. In addition, a prediction of the extent of the necessary movement space is required. Here, too, the perceptibility of the road and traffic characteristics, driving experience and skills are of importance.

A decision-theory analysis of manoeuvring behaviour led to the following assumptions (Griep, 1971):

(a) it is assumed that the decision as to whether to make a manoeuvre or not is based on observations of the direction of the difference between available movement space and minimum necessary space (if the vehicle's movement capacity is fully utilised). A correctly observed direction of this difference is possible with an incorrectly observed absolute extent of available and/or necessary space.

(b) Risk exists:

1. in the event of an incorrect positive decision, in which by definition the difference between available and necessary space is perceived as positive but is actually negative;
2. in the event of an incorrectly observed extent of the available movement space (in reality smaller than predicted) and/or necessary space (greater than predicted), but a correct positive decision, which is based by definition on a correctly observed positive direction of the difference between available and necessary space.

(c) Hazardous decisions can be corrected:

1. in case (b) 1.: by stopping the manoeuvre (decelerating));
2. in case (b) 1.: by stopping or speeding up the manoeuvre (decelerating or

accelerating).
An unsuccessful manoeuvre results in a crash. The chance of a successful correction is governed by the spare space available for moving longitudinally and laterally and the reserve of reaction capacity. Increasing this chance means making an extra manoeuvring effort.

(d) The criterion for manoeuvring effort might be: standard deviation acceleration and deceleration longitudinally and laterally (acceleration noise) compared with the average speed recorded on a route. An alternative and simpler criterion might be the standard deviation of the speed.

(e) A more hazardous decision criterion increases the number of (correct and incorrect) positive decisions and decreases the number of (correct and incorrect) negative decisions. The result is a reduction in journey time and increased risk.

3.2. Route selection

It can be assumed that with a corresponding journey time the manoeuvring effort required of the driver is lessened, the more the route causes manoeuvring owing to time and placerelated variations in road and traffic characteristics. This applies all the more if such characteristics are more permanent (i.e. less time-related), i.e. the more the road is in a higher category in the hierarchy.

If, in order to reach a destination, a driver could choose between, say, a motorway and a road without separate carriageways and with mixed traffic (fast and slow traffic together), then on the whole the motorway will be preferred because a higher performance level can be reached on it with the same effort. If, in spite of this, a road lower in the hierarchy were to be selected, there will be a number of specific motives for this, such as accessibility and directness of the road and signposting of the route.

The higher the road's level in the hierarchy the lower is its accessibility (fewer connections) and the greater its directness (straightness of alignment). Hence, roads lower in the hierarchy will often have to be used to reach the motorway. Signposting along the road is based on coding with place names, road numbers, directions and distances. Since a road higher in the hierarchy forms the link between bigger service areas and hence often between a larger number of places as well, the usefulness of place-name coding is thereby limited.

4. RELEVANT CHARACTERISTICS OF THE TRAFFIC SITUATION

It can be inferred from the foregoing that road safety will benefit if road users' tasks are made easier. The question is how road design can contribute to easing these tasks and what standards the road must meet in order to fulfil this function. Two major elements of the traffic system can be distinguished: limitations on movement and their predictability for the road user.

The road plays a major part in movement limitation. Together with traffic characteristics, road characteristics largely influence the effort the road user will have to make in performing his tasks: i.e. route and manoeuvre selection.

Observed road characteristics are often associated with traffic characteristics; they call forth a specific expectation of traffic behaviour based on experience of past combinations of road and traffic characteristics. If unexpected traffic characteristics occur on a road (for instance the presence of an agricultural vehicle) or if there are sudden changes in road characteristics (for instance a sharp bend), this demands an extra effort from the road user in making an unanticipated decision on one or more manoeuvres. This may increase the risk, on the one hand by lowering the decision criterion, and on the other owing to incorrect observation of the extent of the available and necessary movement space and/or incorrect observation of the extent and direction of the difference between the available and necessary space.

A correct anticipation by the road user of traffic behaviour on a road section can only be built up if traffic characteristics are continuous over the length of the road.

In many cases, traffic characteristics can be derived from road characteristics, so that continuity in road characteristics can provide a better expectation of traffic behaviour. Discontinuities in traffic characteristics can also be avoided by separating road user categories, each having their own characteristic movements, i.e. by means of continuity in vehicle characteristics.

The road characteristics relevant to driving tasks can be distinguished as:

(a) permanent (in time) and continuous (in place) perceptible characteristics of the cross-section, road markings and road surface (e.g.) number of lanes, the existence of a central reserve, hard shoulder, cycle path).

(b) permanent and discontinuous perceptible characteristics of alignment, cross-section, traffic signs and road surface while, in addition to geometrical factors, frequency, density and sequence are important (for instance, intersection, bends, private driveways, warning signals).

The total behaviour of the individual vehicles determines traffic characteristics. By definition, these are not permanently nor continuously present or perceptible along a given road section.

The traffic characteristics relevant to manoeuvre selection by the individual road user can be subdivided as follows:
- the vehicles' direction of movement:
  . longitudinally: oncoming vehicles, vehicles ahead and behind;
  . laterally: intersecting traffic ('crossing vehicles');
- the vehicles' positions;
- vehicles' changes in position (speed, acceleration and higher derivatives of the position);
- movement capacity and dimensions of the observed vehicles (recognition of the categories to which the vehicles belong).

The relevant vehicle characteristics are:
- (top) speed;
- dimensions;
- accelerating and decelerating capacity;
- stability and manoeuvrability;
- perceptibility (visibility, conspicuousness, recognisability and locatability).

There is a very wide variety of vehicles, or put more generally, of vehicles that can use public thoroughfares. Improvement of their perceptibility and lessening of the uncertainty about movement aspects of observed vehicles can be achieved by indicating the vehicle's category as regards movement potential, governed by permanent features such as dimensions, range of speeds and the appropriate behaviour rules.

Possibilities of improvement by using such a system of category indications are given by Roszbach (1974) in a more detailed discussion, which also raises the question of visibly signalling time-related movement characteristics in rear-lighting configurations.

Traffic characteristics are not only linked closely with vehicle characteristics but are also determined by road users' relevant characteristics:

- age;
- driving experience and skill and the consequent risk assessment and acceptance;
- internal factors of a physical and mental nature.

A combination of these characteristics influences the process of anticipation, observation, information assimilation, decision and action.

In the following, the emphasis will be put on improving traffic facilities (road characteristics) from the viewpoint of road safety. Proceeding from the characteristics of the traffic, the vehicles and the road users', functional requirements will be drawn up for road design which should guarantee an easing of driving tasks and hence greater road safety.

5. FUNCTIONAL REQUIREMENTS FOR ROAD DESIGN

The functional requirements for road characteristics can be classified as follows:

5.1. Functional for route selection

In route selection, roads are classified according to their characteristics in a number of categories according to hierarchic levels of the required manoeuvring effort. Motives in route selection will be accessibility and directness of the road and signposting of the route.

(a) Accessibility of the road should be maximal on roads in the lowest category in the hierarchy and minimal on those in the highest. One speaks of roads with a precinct function (for instance in residential and shopping districts) and those with a flow function (for instance motorways). The permanent and discontinuous road characteristics determining accessibility are the intersections and the private driveways. As the number of intersections and/or driveways per road-length increases, the road's precinct function increases at the expense of its flow function and vice versa.

(b) The road should be more direct the higher the category level. More directness means a straighter alignment, i.e. none or only very gentle horizontal and vertical bends.

(c) For signposting the route not only discontinuous road characteristics in the form of warning signals (specially at intersections) are suitable but also continuous characteristics, such as colour and configuration of markings and lighting or flat roadside marking posts, with route indications at close and regular intervals.

5.2. Functional for manoeuvre selection

Generally speaking, road characteristics should call forth the correct anticipation by road users of:

(a) the limitations of their own manoeuvring space, longitudinally by the geometric elements of the track and longitudinal profile, laterally by the geometric elements of the cross-section, and longitudinally and laterally by the nature of the road surface and the traffic signs. And also owing to legal codes, for instance by prohibiting overtaking with continuous centre lines.

(b) the possible presence of other road users in the manoeuvring space, subdivided into pedestrians and vehicle categories. Though in the present situation associated with the legally permitted presence of one or more specific vehicle categories, it is still only the traffic signs placed at the beginning of the particular road section that give any certainty about the correctness of this expectation.

(c) possible manoeuvres by the road users present. Longitudinally, manoeuvres can be classified according to longitudinal and lateral position and changes in position of oncoming vehicles and of vehicles ahead and behind as compared with the longitudinal and lateral position and changes in position of the user's own vehicle and compared with the boundary of the carriageway or lane.

All these continuous and discontinuous road characteristics, together with the traffic characteristics that occur, indicate the scope for such manoeuvres.

Laterally, manoeuvres can be classified primarily according to lateral position and changes in position of intersecting road users as compared with user's own vehicle movements and the road boundary. The road characteristics that should indicate the nature of these manoeuvres are often permanent and discontinuous (intersection, driveways, crossing places, zebra crossings, traffic signs indicating crossing road users) and are sometimes non-permanent and discontinuous (traffic signals not in permanent use at intersections, etc.).

5.2. Functional with regard to a categorisation of roads

In analysing traffic behaviour, a need is assumed to exist for a subdivision of roads into categories based on a hierarchy of manoeuvring effort. It has also been reasonably suggested that road and traffic characteristics may adversely influence traffic behaviour and hence road safety by causing frictions (limitations on movement) longitudinally and laterally. It is therefore obvious that according as a road is included in a higher category the standards which road and traffic characteristics will have to meet to be focused on reducing longitudinal and lateral friction.

The effectiveness of dividing roads into categories depends on compliance with the following functional requirements:

(a) Consistency of characteristics within the road category. Given the reservation of a road for a specific category and the selection of road users having access thereto, the functional characteristics of this road can be determined in relation to the movement capacity and dimensions of the selected vehicle.

The main possibilities of movement are top speed, acceleration and braking power, directional stability and manoeuvrability. In view of the great differences in vehicles' movement capacity and dimensions, a basic solution might be to create a system of road categories arranged according to vehicle categories. This principle is already partly applied, as is testified to by the separate footpaths and cycle paths provided in practice and the system of motorways. Roads for mixed traffic offend this principle.

The road geometry should guarantee the minimum distribution in vehicles' movement characteristics. Ideally, this means for instance that roads where cyclists or even pedestrian (in residential areas etc.) are allowed should have such characteristics, like a narrow carriageway and winding track, so that speeds greater than, say, 20 to 30 km an hour would be impossible.

Design criteria for safety, travel time (design speed) and comfort (manoeuvring effort) should be the same for all road characteristics (relation between road characteristics within the category) and should be attuned to vulnerability, top speed, acceleration and deceleration capacity, directional stability and manoeuvrability of vehicles in the lowest category allowed on the road in question.

(b) Continuity of characteristics within the road category. The information the road user needs on limitations of manoeuvring space longitudinally and laterally, which may or may not exist permanently along the entire length of road section in a particular category should be provided by permanent and continuous road characteristics. For instance, on a well discernible second carriageway the presence of oncoming vehicles should be impossible; with a well discernible cycle path the absence of cycles on the main carriageway will be indicated. Another possibility in this connection is a type of marking or some other form of continuous traffic sign indicating the permitted vehicle category or categories and perhaps the road category itself.

(c) Little variation within the road category (uniformity in characteristics).

For relationships within the road and traffic characteristics it is assumed that with a corresponding average value (but a difference in distribut ion) a road with more variable characteristics is usually more hazardous. This relates, for instance, to the place-related radius of bends and the time-related presence of slow traffic. It is also assumed that road hazards increase more according as the distribution round the average value is caused by several extreme values and also according as the road is classified in a higher category in the hierarchy.

(d) Road categories recognisable by road users.
Categories are easier to recognise the fewer they are in number and the easier they are to distinguish from one another. Usefulness to road users implies a limited number of road categories (not more than seven or eight). Categories become easier to distinguish if dichotomous characteristics are used (the characteristic is there or not), redundant characteristics (various characteristics are there or not simultaneously) and clearly perceptible category indications or category-typifying road characteristics (permanent and continuous).

Relations between road characteristics themselves and between road characteristics and traffic characteristics (and vehicle characteristics) can be expressed as conditional probabilities based on frequencies of occurrence, per unit of traffic performance (vehicle kilometres travelled). By reference to these frequencies, road users will build up a pattern of expectations of relationships between characteristics of the road and of traffic on that road. Owing to the present road classification, for instance, high densities are often associated with wide roads, wide bends and separation of intersecting traffic in time (with traffic signals) or place (with two-level intersections).

In the case of a motorway the characteristics of separate carriageways and two-level intersections have by definition mutual implications. But not all roads with separate carriageways have two-level intersections, nor do all two-level intersections occur on dual carriageways. A road with separate carriageways does not therefore imply the existence of two-level intersections. Owing to the frequency of their occurrence, however, the road user will assume this relationship to exist. This will be stronger if there is a stronger association between the original characteristic (for instance separate carriageways) and the derived ones (for instance two-level intersections, absence of slow traffic).

The road user's pattern of expectations is determined not only by his experience but also by the discernibility of the original characteristic. For permanent and continuous dichotomous characteristics this discernibility is greater than for metric characteristics. Compare, for instance, the characteristic of separate/not separate carriageways with that of belonging/not belonging to a specific lane-width class. In any case, it is not always as easy to see whether carriageways are separated or not.

The effective functioning of road category depends on the way in which the road characteristics create the correct expectation in the road user relatively to his own traffic behaviour (route and manoeuvre selection) and that of others.

Expressed as probabilities, the information on road and traffic characteristics A is ideal if, given a road characteristic 0, the expectation value of characteristics A occurring equals 1 or 0, i.e. $P(A/0) = 1$ or 0. In that event the absolute difference between $P(A/0)$ and $P(\bar{A}/0)$ is equal to 1 and hence the distinguishability of the derived characteristics A, given the original characteristic 0, is maximal. This conforms to the statistical decision theory (cf. Sidowski, 1966) in which the relation between the conditional probabilities is the criterion for distinguishability of the derived characteristics given the original characteristic.

In situations in which conditional probabiliteis differ only slightly from 1 or 0, dangerous conflicts occur by incorrect expectations relatively

to available and necessary movement space: belated observance or non-observance of the existence of movement limitations in the form of level intersections, sharp bends, slow moving vehicles, crossing pedestrians, etc. on roads with separate carriageways. It is assumed that as from certain limits the road user disregards probabilities. If the values are between the certainties ($P = 1$ and $P = 0$) and these limits, two different situations may occur, i.e.: the disregard of conditional chances relating to absence or presence of serious conflict situations (for example the presence or absence of cyclists is disregarded). In the latter event the absolute number of conflict situations will generaly be low, but the severity of the conflict situation may be many times greater than with chances around 0.5.

6. EXAMPLES OF ROAD CATEGORIES BASED ON SAFETY CRITERIA

A categorisation of roads that can be described as ideal from the road safety aspect must be based on all the above-mentioned functional requirements. A number of examples will show how, by applying the individual functional requirements and testing them in practice, road categories can be distinguished with the object of establishing a realistic classification complying with all functional requirements. It still remains a theoretical approach which has to be worked out further and checked in parts against empirical investigations.

6.1. Classification according to manoeuvring effort longitudinally and laterally

The point of departure for classification is a hierarchy of roads based on manoeuvring effort arising from longitudinal and lateral frictions. An increase in longitudinal friction should be accompanied by a proportional lateral friction. Figure 1 shows diagrammatically how road categories can be distinguished.

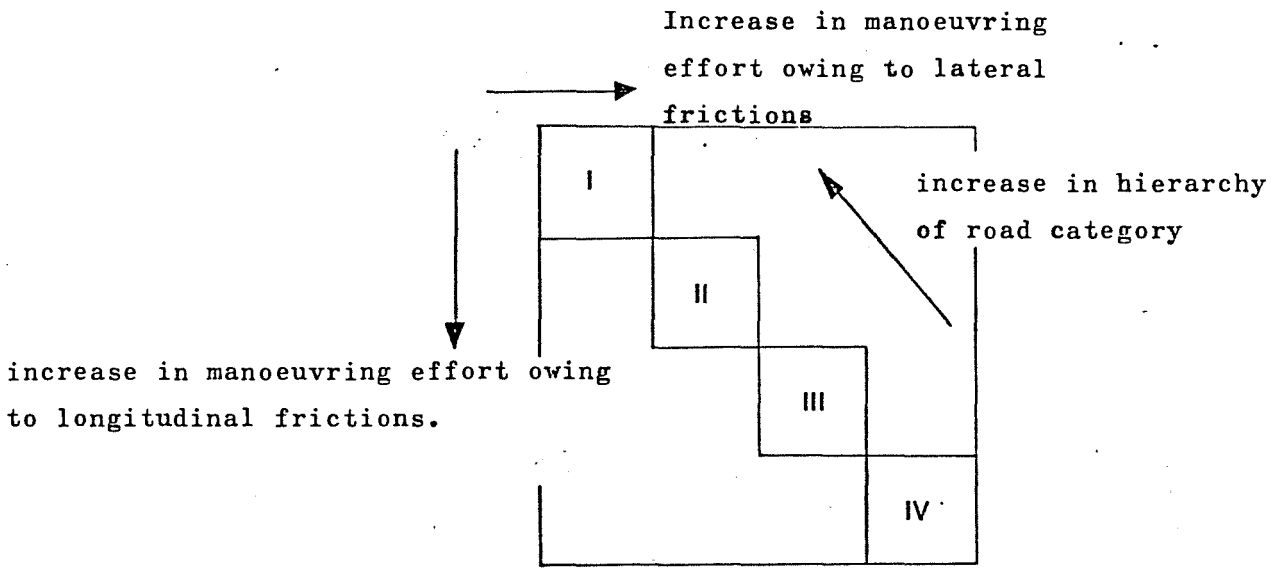

Figure 1. Diagrammatic classification of roads based on manoeuvring effort.

The lateral friction is plotted horizontally and the longitudinal friction vertically. The ideal road categories are on the diagonal. A decrease in lateral friction reduces the accessibility (precinct function) of the road and a decrease in longitudinal friction increases the directness of the road (its flow function).

6.2. Categorisation based on vehicle categories

Although it is not impossible that at some future time special traffic facilities might be available for every type of road user, any road classifi-

cation will have to allow for mixed use of roads by vehicles with varying movement capacities and dimensions. But the pedestrian will no longer have to be forced to use the carriageway part of the road except for crossing over. As regards vehicles, roads can be classified according to the lowest permitted vehicle category in the hierarchy. The sequence below is based on movement capacity, the main aspect being speed, and the vehicle's dimensions.

Category 1: vehicles, say 1.20 m tot 1.80 m wide: private cars, small delivery vans, etc. belonging to fast traffic;

Category 2: vehicles wider than 1.80 m; lorries, buses, etc.;

Category 3: vehicles narrower than 1.20 m: three wheelers, motor cycles, etc.;

Category 4: vehicles with three or more wheels belonging to slow traffic (maximum speed 20 to 40 km/hr);

Category 5: mopeds;

Category 6: cyclists.

Within the present constellation of road in the Netherlands, there are roads where vehicles are sometimes kept away because of their dimensions (length, breadth or height restrictions), axle loads or noise (mopeds in city centres or recreational areas). The following general road categories accessible to motor traffic would seem realistic:

I - motorways; open to vehicle categories 1 to 3;

II - "roads"; permitted vehicle categories 1 to 4;

III - "streets; permitted vehicle categories 1 to 6.

References below to "roads" and "streets" relate to categories II and III above.

6.3. Categorisation based on speed behaviour

Decreasing longitudinal and lateral frictions imply a higher driving speed. Ideally, the design speed (V_{des}), on which all road characteristics within a road category should be based, are very closely related to the speed actually driven and the speed limit applying to the road category.

A widely used standard, for instance, is: $V_{des} = V_{limit} = V85$ (=85 percentile value of the actual speed distribution). In 1974, especially the V_{limit} for the highest road category has been debated: 100, 110, 120 or 130 km/hr? The design speed for motorways, however, will on the whole never be lower than 120 km/hr. A clear distinction can be obtained between the various road categories as regards speed behaviour by making at least 20 km/hr difference in design speed and/or speed limit for the road categories high in the hierarchy and at least 10 km/hr difference for the lower ones. The design speed level should be determined in relation to the movement capacity of the lowest vehicle category in the hierarchy allowed on the road.

For the speed limits of road categories it would seem reasonable to require that speed limits should not exceed design speeds.

6.4. Categorisation based on longitudinal driving direction

Longitudinal traffic can be subdivided into one-way and two-way traffic. By analogy, road categories can be divided into one-way roads and two-way roads. The longitudinal friction can be assumed to be greater on single carriageways than on dual carriageways, for instance because of the greater manoeuvring effort for overtaking and the greater chance of glare from on-coming vehicles' headlamps after dark.

6.5. Categorisation based on lateral driving direction

Lateral traffic may occur at intersections of equivalent or differing road categories and on road sections between intersections, at driveways crossings, etc. A classification of the types of intersections can, by analogy with the categorisation of roads, be drawn up for the hierarchy in manoeuvring effort:

A. Intersections with two-level crossing traffic and with right or left merging and diverging traffic;

B. Intersections with level crossing traffic and with traffic signals;

C. Intersections with level crossing traffic and right-of-way regulation.

Roads can be subdivided according to type of intersection into the following categories:

I : roads with only type A intersections: motorways;

II : roads with type A and B intersections: "roads";

III: roads with type B and C intersections: "streets".

This subdivision precludes intersection of motorways with "streets". But of course there may be two-level intersections between all road categories if it not possible for traffic to interchange between the intersecting roads. Crossing traffic on the road between the intersections will be more common the greater the density of building along the road.

6.6. Categorisation based on building density along the road

The influence of road surroundings on traffic behaviour is difficult to express in quantitative terms. But building density along the road is likely to be closely correlated with heterogeneity in longitudinal and lateral movement characteristics. Though it is assumed that road users will generally react with greater alertness on urban roads with high building density than on rural roads. This calls for a distinction between rural and urban motorways, "roads" and "streets", based on the expectation of less or greater manoeuvring effort within each of the road categories mentioned. On urban roads, therefore, more crossing traffic is likely between intersections than on rural roads owing to the high frequencies of driveways and (non-) signalised crossings (for cyclists, pedestrians, etc.).

In the Netherlands, the present distinction between roads inside and outside built-up areas is laid down by law in the Road Traffic Act.

The change from roads outside a built-up area to roads inside a built-up area is often detectable by road users only by way of a single traffic sign stating the place name in combination with a speed limit. By using a quantitative standard, such as building density along a specific length of road and within a distance of 100 metres on each side of the road, rural and urban roads might be defined, if need be together with change-over categories

6.7. Categorisation based on total number of safety criteria

The following presents a categorisation, as functional as possible, for discussion. This example does not go into the practical and financial implications. It should be looked upon as the first stage of an extensive study to seek practicable road categories guaranteeing high quality overall traffic disposal (inclusive safety and level of service).

The diagram, Figure 2, shows horizontally the characteristics of the dual carriageway against the single carriageway and rural against urban, grouped so that from left to right an increase in road-user manoeuvring effor is shown. Vertically, the main categories are shown in a hierarchy; from top to bottom there is a decrease in design speed and an increase in the number of permitted vehicle categories:

- motorway (M): all motor vehicles able and allowed to travel faster than, say 70 km/hr;
- "road" (R): all vehicles except cycles and mopeds etc.;
- "street" (S): all vehicles.

	dual carriageway		single carriageway	
	rural	urban	rural	urban
motorway (M) design speed	MI 120	MII 100	--	--
"road" (R) design speed	--	RIII 60	RIV 80	--
"street" (S) design speed	--	--	SV 60	SVI 40

Figure 2. Example illustrating categorisation of roads with a motortraffic function.

The proposed classification relates only to roads open to the public for motor traffic; moped, cycles and pedestrians are thus disregarded. So are typical precincts such as car parks, market squared, paths in residential and shopping areas and unpaved roads used for farming and/or recreation. The idea is that motor traffic has access to such areas only if its destination or origin is in them.

The ability to distinguish these categories requires, in addition to the dichotomous characteristics: dual/single carriageway and rural/urban, a third, permanent, continuous and discernible characteristic, for instance a sign showing the main category (M, R, S) implicitly indicating the permitted vehicles categories, or a sign showing a category-related speed limit.

Road marking seems a suitable means of aiding recognition of road categories. It is permanent and continuous and, with properly chosen materials (re-reflective) and regular maintenance, it is also clearly observed under practically all conditions (darkness, bad weather, fog, etc.; except for snow).

The hierarchic level of the road categories runs along with the decrease in design speed. This helps to make it possible to achieve consistency in road characteristics.

All that remains is to deal with the intersections of the various road categories. The classification principle given in section 6.5. leads to the following proposals:

- A motorway should have two-level intersections with all road categories and only junctions with merging and diverging lanes at intersections with other motorways and "roads".
- A "road" should not only have the above possibilities, but also level intersections with other "roads" and "streets", either signalised or with right-of-way regulation.
- Intersections of "streets" with other streets should be level and regulated with right-of-way rules.

Other road and traffic characteristics of intersections can be derived from the characteristics of the road categories joining up with them.

The realization of road categorisation often demands costly long-term reconstructions of present traffic facilities. For traffic situations not yet adapted to the requirements for the category, specific warning systems will have to be used. The social cost and benefit involved in such a reconstruction warrant extended research. The Institute for Road Safety

Research (SWOV) has therefore given high priority in its research programme to basic research on "Road Categorisation".

The next stage in this research consists of stocktaking the relevant characteristics of Dutch roads, in order that theoretical classification principles can be tested empirically and a list of priorities for further measures be drawn up. This long-term research is being carried out in collaboration with official bodies and private organisations dealing with traffic and road safety.

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ANNEX 1

Assume the aggregate motor traffic performance (Ω) on a road system to be subdivided as follows:

1. 40% of the motor vehicle kilometres are driven on roads with separate carriageways (original characteristic 0); i.e. 60% on single carriageways ($\bar{0}$);

2. 70% of motor vehicle kilometres are driven on motorways; i.e. slow traffic is present for 30% or is at least permitted (derived characteristic: absence ($\bar{A}$) or presence (A) of slow traffic);

3. the combined existence of the characteristics of separate carriageways and of slow traffic (A0) occurs for only 1% of the aggregate motor traffic performance.

These assumptions give the a priori chances of the probability of occurrence, in tabular form:

	0	$\bar{0}$	
A	P(A0) 0,01	P(A$\bar{0}$) 0,29	P(A) 0,30
$\bar{A}$	P($\bar{A}$0) 0,39	P($\bar{A}\bar{0}$) 0,31	P($\bar{A}$) 0,70
	P(0) 0,40	P($\bar{0}$) 0,60	P(Ω) 1

and the conditional chances:

	/0	/$\bar{0}$
A/	P(A/0) 0,03	P(A/$\bar{0}$) 0,48
$\bar{A}$/	P($\bar{A}$/0) 0,97	P($\bar{A}$/$\bar{0}$) 0,52

(example of conditional chance calculation:

$$P(A/0) = \frac{P(A0)}{P(0)} = \frac{0.01}{0.40} = 0.03).$$

Owing to the low a priori chances P(A0) = 0.01 and the likewise low conditional probability P(A/0) = 0.3, this example will disregard the possible presence of slow traffic on dual carriageways. In this case there is no relationship between the characteristic of single carriageway and that of slow traffic, in view of the almost identical conditional chances (P(A/$\bar{0}$) and P($\bar{A}$/$\bar{0}$).

The situation improves after elimination of dangerous conflicts due to incorrect expectations, i.e. denominating dual carriageway roads as motorways.

The appropriate probabilities are:

a priori

	O	$\bar{O}$	
A	0	0,29	0,29
$\bar{A}$	0,40	0,31	0,71
	0,40	0,60	1

conditional

	/O	/$\bar{O}$
A/	0	0,48
$\bar{A}$/	1	0,52

Lastly, an ideal but unrealistic situation can be obtained by also allowing no doubt to exist about the presence of slow traffic on single carriageways. The probabilities would, for example, be:

a priori

	O	$\bar{O}$	
A	0	0,50	0,50
$\bar{A}$	0,50	0	0,50
	0,50	0,50	1

conditional

	/O	/$\bar{O}$
A/	0	1
$\bar{A}$/	1	0

This results in only two distinct road categories, i.e.:

(a) dual carriageway roads for motor traffic only;

(b) single carriageway roads with mixed traffic.

All other derived road and traffic characteristics can be related to the original characteristic in the same way.