ALCOHOL AND ROAD SAFETY

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alcohol and road safety

Countermeasures and research

A critical survey of the literature

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STICHTING WETENSCHAPPELIJK ONDERZOEK VERKEERSVEILIGHEID

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Netherlands Road Traffic Act

Section 26

1. It is forbidden for the driver of a motor vehicle, a bicycle or any other carriage or vehicle to drive therewith on a road while under the influence of the consumption of alcoholic drink to such an extent that he cannot be considered to be capable of properly driving the said motor vehicle, bicycle or other carriage or vehicle.

2. It is forbidden for the driver of a motor vehicle to drive the said vehicle on a road while the person who, in accordance with the conditions referred to in paragraph 3(e) of Section 1, is deemed to be driving the vehicle under his direct supervision, is under the influence of the consumption of alcoholic drink to such an extent that he cannot be considered to be capable of properly driving the said vehicle.

3. For the purposes of the present Section any substance, the consumption of which the driver knows or may reasonably be assumed to know can impair his ability to drive, is assimilated to alcoholic drink.

Section 36

1. Any person responsible for the death of another through colliding with or running into or running over that other person when driving a motor vehicle, or through any act to prevent the said motor vehicle from colliding with or running into or running over that other person, shall, if the death of the said other person is caused by the collision or by being run into or run over or by the act to prevent the same, be punished with imprisonment or detention for not longer than one year.

2. Any person who, through colliding with or running into or running over another when driving a motor vehicle, or through any act to prevent the said motor vehicle from colliding with or running into or running over that other person, is responsible for the said other person sustaining grievous bodily harm of such a nature that temporary indisposition or inability to perform the functions of his office or carry on the business of his trade or profession ensues, shall, if the said harm is caused by the collision or by being run into or run over, or by the action to prevent the same, be punished with imprisonment or detention for not longer than nine months.

3. If at the time of the accident the person responsible was under the influence of the consumption of alcoholic drink or a substance as referred to in paragraph 3 of Section 26 to such an extent that he could not be considered capable of driving the said motor vehicle properly, he shall in the case referred to in paragraph 1 be punished with imprisonment for not longer than three years, and in the case referred to in paragraph 2, with imprisonment for not longer than two years.

Contents

Foreword

That the combination of drinking and driving may be dangerous is well-known. As a consequence, many countries have introduced countermeasures to reduce this danger.
These countermeasures are mostly aimed specifically at the drinking driver. A rationale for this kind of measure in terms of relative utility as compared with other measures, e.g. improving driving conditions, is lacking. There is even a lack of data on the reduction in the number of accidents which could be expected as a consequence of countermeasures.
The reason for carrying out this survey of the literature was a request from the Netherlands Ministry of Transport to provide some documentation on countermeasures in the field of alcohol and road safety, especially those aimed at the drinking driver.
In order to be able to do so, a survey of the literature has been made on the nature of the problem 'drinking and driving', and the influence of driver characteristics and of driving conditions on the incidence and seriousness of 'alcohol accidents'. On this base some countermeasures are discussed in terms of their effects on road safety.
Research on drinking and driving carried out in the Netherlands until now has been limited to:
a) laboratory investigations into the effects of alcohol on abilities assumed to be relevant for driving;
b) medical methods for analysis of the alcohol concentration in the blood;
c) opinion polls, e.g. concerning the attitude of drivers to the laying down of a maximum allowable blood alcohol concentration (a countermeasure which may soon be introduced in the Netherlands).
This report, however, is focussed on accident research in the field of drinking and driving. It has been written by D. J. Griep, Institute for Road Safety Research (SWOV), Human Factors Branch.

Voorburg, November 1968.

E. Asmussen

Director Institute for Road Safety Research (SWOV)

1 Introduction

1.1 The nature of the problem

1.1.1 Driving while under the influence of alcohol

Convictions under Sections 26 and 36 of the Netherlands Road Traffic Act in 1964 numbered 5840, or 55 % of all sentences for traffic offences involving drivers of motor vehicles, bicycles or other carriages or conveyances in that year (Central Bureau of Statistics, 1966). If the Dutch car population in the same year is taken to be 1.2 million, one could perhaps conclude that as an average in that year no more than ½ % of all car drivers were on the roads when other than sober.

In Canada, the United States and Czechoslovakia checks have been made of the blood alcohol concentrations of drivers picked at random from the traffic at times and places where road accidents have previously occurred. Each of these studies in the different countries concerned revealed that at least 10 % of the drivers involved had blood alcohol concentrations higher than 10 mg per 100 ml (See Table 1, p. 12). If it is assumed that these drivers are representative for all road users, the actual number of non-sober drivers would be one in ten.
Although checks of this type have not been carried out in the Netherlands, it can nevertheless be assumed that the number of 'alcohol-containing' drivers on Dutch roads is many times greater than the statistics for traffic offences would appear to indicate. It seems reasonable to take the figures found in Canada, the United States and Czechoslovakia as maxima. In the countries where investigations have been carried out, the consumption of alcoholic drinks per head of population is higher than in the Netherlands (4.2 litres at 100 % in the Netherlands; 6.4 litres at 100 % in the U.S.A.; 5.9 litres at 100 % in Canada) according to data published by the Dutch Spirits Board for 1965. It is also possible that there is more 'driving under the influence' in those countries.

1.1.2 The number of 'alcohol accidents'

On the basis of the number of convictions for motoring offences when under the influence of alcohol in the Netherlands, it could be concluded that alcohol contributes to no more than 2 % of the total number of accidents. However, these convictions did not all follow as a result of accidents, so that the percentage should in fact accordingly be even lower than 2. Since 1-1-65,

Dutch police officers have been instructed 'to check in every reported accident the possible use of alcohol by the drivers etc. involved'. As a result the number of 'alcohol accidents' (accidents in which at least one of the road users involved, e.g. drivers, is not sober) as reported by the police has risen from 2 to 3 % of the total number of accidents.
On the ground of the findings of systematic research in other countries into the blood alcohol concentrations of drivers involved in accidents, **at least** 12 to 17 % of these drivers are found to have blood alcohol concentrations in excess of 0. For accidents resulting in the death or serious injury of those involved, blood alcohol concentrations above 0 are found in 46—60 % of the cases (See Table 1, p. 12).

It must therefore be assumed that the official statistics lead to both the actual number of non-sober drivers on the roads and the actual number of accidents where alcohol is a contributory factor being greatly underestimated.

1.2 The relation between driving under the influence of alcohol and the incidence of accidents

From the theoretical angle the best way of investigating the danger of alcohol on the road would be to determine the probability of an accident for each individual road user per kilometre driven, with and without alcohol consumption and under identical conditions as regards vehicle, road, traffic and weather conditions or the risks inherent in those conditions. Tests of this nature are, however, impossible in practice.

Most research workers investigate the effects of alcohol consumption in laboratory situations. This effect is then assessed on the basis of criteria such as reaction time, visual performance and other abilities assumed to be relevant in the driving situation. Although tests of this sort can provide indications regarding whether or not human performance is impaired by alcohol, they do not give any information on the chance of accident involvement in relation to blood alcohol concentration. It is not possible therefore to use such tests to provide an unambiguous statement of the precise blood alcohol concentration above which the probability of an accident is greater than when one is sober. Research into the number of accidents where alcohol has played a role does not give information on the probability of accident involvement as a function of the blood alcohol concentration, since no data are available on alcohol consumption which does not result in road accidents. This relation can be found by comparing drivers who have been involved in accidents and those who have not. The blood alcohol concentration found for the two groups is compared, together with any other variables relating to the driver, vehicle, road, traffic and weather conditions which could also influence the likelihood of an accident. When no differences can be found between any of the variables except the blood alcohol concentration, the probability of an accident due to alcohol can be calculated straight away. If this condition is not met and the two groups differ as regards other variables as well as alcohol consumption, the probability of an accident due to alcohol can only be determined after correction for the influence of the other variables concerned, such as age and driving experience. In order to do so, sufficient data should be available for all possible combinations of variables. This condition has not been fully satisfied in any study carried out to date.

1.2.1 The concentration of alcohol in the blood of drivers involved in accidents and of drivers not involved in accidents

Although the findings of studies made so far are not entirely unambiguous, since while blood alcohol concentration has been compared for both groups not all the other relevant variables were the same or, where different, could be accounted for, the results correspond in that the blood alcohol concentrations of drivers involved in accidents are statistically higher than those of more or less comparable drivers who have not had accidents. Table 1 provides a survey (See p. 12).

In the Borkenstein study, data for the accident group could not be obtained in 30 % of the cases. If for accident drivers non-soberness is more frequent and b.a.c.'s are higher than for non-accident drivers, then the Borkenstein data give an underestimation of the real number of non-sober accident drivers and their b.a.c.'s.

Blood alcohol concentration was measured by blood analysis or estimated by breath analysis. The results of these two methods may differ both as a function of random errors and as a function of a systematic error. Breath analysis as a rule gives an underestimation of the blood alcohol concentration. However, data on the number of blood alcohol concentrations obtained by blood analysis or estimated by breath analysis are not given for either the accident group or the control group in the Borkenstein report.

Another difficulty, although not specific for the Borkenstein study, is the existence of differences in time between the moment the blood or breath is taken and the moment the accident happens or the control driver passes the accident site.

No data are available on this subject in the official report. A reasonable assumption is that the average time lapse was larger for the accident group compared with that for the control group. As a result less alcohol would be eliminated from the blood in the control group. In other words: the assessed blood alcohol concentration for the accident group would be relatively too low. Both arguments lead to the conclusion that the assessed blood alcohol concentration will be probably relatively too high for the control group.

The study by Lucas et al. was selective as it was restricted to accidents between 18.30 and 22.30 hrs; moreover the comparison between accident and control group was incomplete - only type of vehicle and age of driver - and not based on the traffic flow at the place of the accident.

The way in which Vamosi obtained his control group is not clear. This study left out of consideration accidents which occurred between 20.00 and 06.00 hrs, although these night hours form the period when a relatively large number of 'alcohol accidents' occur. See 1.3.

The Holcomb study was limited to drivers who had to be hospitalized following

Table 1. Alcohol consumption and road accidents

Authors	Plan and extent of study	Results		
			Total number of persons	% with b.a.c. > 10 mg/100 ml
Borkenstein et al. U.S.A., 1964	All accidents involving motor vehicles in Grand Rapids (Michigan) during one year. Control group taken at random from traffic flow at places and times accidents did occur during a three-year period before the study was made. Blood alcohol concentrations for both groups measured by breath or blood analysis.	Accident group	5985	17 %
		Control group	7590	11 %
			Total number of persons	% with b.a.c. > 0 mg/100 ml
Lucas et al. U.S.A., 1955	Accidents involving motor vehicles between 18.30 and 22.30 hrs. Control group not taken at random from traffic flow at place of accident, but selected according to type and age of the vehicle involved in the accident. Vehicle not always selected from traffic flow in same direction. Method as above.	Accident group	423	12.5 %
		Control group	2015	8.7 %
			Total number of persons	% with b.a.c. > 30 mg/100 ml
Vamosi Czechoslovakia, 1960	Car drivers involved in an accident and/or convicted of drunken driving, between 06.00 and 20.00 hrs. The way in which the control group was selected is not clear. Blood alcohol concentrations in both groups determined by blood test.	Accident group	418	70.6 %
		Control group	418	11.2 %
			Total number of persons	% with b.a.c. > 0 mg/100 ml
Holcomb Canada, 1938	Car drivers hospitalized after accidents who consented to urine tests. Control group made up of car drivers picked at more or less corresponding places but at different times from those of the accidents and who consented to breath tests being made.	Accident group	273	47 %
		Control group	1750	12 %
			Total number of persons	% with b.a.c. > 0 mg/100 ml
McCarrol and Haddon U.S.A., 1963	'Guilty' drivers involved in fatal car accidents. Blood alcohol concentrations obtained from autopsy data. Control group taken at random from car drivers selected from the traffic at the same places and corresponding times as the accidents. Blood alcohol concentrations obtained by breath tests.	Accident group	34	60 %
		Control group	217	26 %
			Total number of persons	% with b.a.c. > 0 mg/100 ml
McCarrol and Haddon U.S.A., 1963	Pedestrians killed in road accidents. Method as above.	Accident group	50	75 %
		Control group	200	34 %

an accident. The blood alcohol concentration in the control group was determined by breath analysis, while urine analysis was used for the accident group. The latter method must, however, be qualified as unreliable (Froentjes, 1962).
McCarrol and Haddon studied fatal accidents only, using data relating to 50 pedestrians and 34 drivers killed in road accidents. These numbers limit the generality of the findings.

The results found by Holcomb and McCarrol and Haddon compared with the findings of Lucas and Borkenstein indicate that alcohol chiefly, though **not exclusively,** plays a role in the case of accidents resulting in hospitalization and/or death of the drivers concerned. See also 1.3.
Compared with the results of the other studies made in the U.S.A., Lucas' findings are deviant. This could be because he collected his material between 18.30 and 22.30 hrs; the number of 'alcohol accidents' in the total road accidents is greater during the evening and night than in daytime. See also 1.3.
In comparison with the findings of the U.S. studies, the extremely large part played by alcohol in accidents as found by Vamosi indicates that there are differences from country to country as regards the probability of alcohol accident involvement. This can result from differences in road conditions, but also from differences in traffic flow and especially in the way in which accidents are recorded, e.g. differences in registration level of day and night accidents.

1.2.2 The probability of accident involvement as a function of the blood alcohol concentration (b.a.c.)

Table 1 does not furnish information on the probability of accident involvement as a function of the blood alcohol concentration. It cannot therefore be used to calculate the number of accidents attributable to alcohol. To do so the accident and control groups must be comparable, at each alcohol concentration class, in other factors than the b.a.c. that are also relevant for the incidence of accidents, e.g. driving experience, age, sex. The larger the number of drivers included in each class, the greater will be the accuracy of the comparison. In fact the accident and control groups should not only be comparable by blood alcohol concentration class but also overall, i.e. both by class and as a single group. The latter does not have to be the case when the variables on which comparison is based vary from class to class. In that case the differences in the probability of accident involvement as a function of the b.a.c. could then also be explained by the differences in these other variables between the various classes. This possibility always occurs when different groups of persons are used in the control group and the accident group.
Unless they were all taken into account, these problems could not be satisfactorily solved. Borkenstein's study is an exception in this respect, to some extent at least.

There is accordingly little to be learned from the calculation of the accident risk in relation to b.a.c. Useful information can, however, be obtained by assuming that any compensatory or aggravating effect of variables other than the b.a.c. is subject to a maximum alcohol concentration (80-100 mg/100 ml according to Borkenstein. See also 1.4.).

Table 2. **Drivers involved in accidents attributable to alcohol**

BORKENSTEIN					LUCAS				
B.a.c. in mg/100 ml	Accident group	Control group	Drivers whose involvement in accidents can be attributed to alcohol		B.a.c. in mg/100 ml	Accident group	Control group	Drivers whose involvement in accidents can be attributed to alcohol	
			Estimated number $a_1 - \frac{c_1 \times a_0}{c_0}$	Percentage of accident group $\frac{100}{5985} \times \left(a_1 - \frac{c_1 \times a_0}{c_0}\right)$				Estimated number $a_1 - \frac{c_1 \times a_0}{c_0}$	Percentage of accident group $\frac{100}{423} \times \left(a_1 - \frac{c_1 \times a_0}{c_0}\right)$
	1	2	3	4		5	6	7	8
0— 49	5398 (a_0)	7345 (c_0)	0	0	0— 49	328 (a_0)	1839 (c_0)	0	0
50— 99	210 (a_1)	187 (c_1)	73.6	1.2	50— 99	30 (a_1)	109 (c_1)	10.4	2.4
100—149	186 (a_1)	44 (c_1)	153.9	2.6	100—149	17 (a_1)	39 (c_1)	9.9	2.1
⩾150	191 (a_1)	14 (c_1)	180.9	3.2	⩾150	48 (a_1)	28 (c_1)	42.9	10.1
total	5985	7590		7.0 %	total	423	2015		14.6 %

a = Accident group

c = Control group

index o = number of persons with blood alcohol concentrations lower than 50 mg/100 ml (60 mg/100 ml; 30 mg/100 ml).

index l = number of persons with blood alcohol concentrations higher than 50 mg/100 ml (60 mg/100 ml; 30 mg/100 ml), divided into three classes.

A rationale for applying the method to estimate the number of drivers whose involvement in accidents can be attributed to their blood alcohol concentration is given elsewhere (Allsop, 1966).

Dutch courts mostly take a blood alcohol concentration of 100-150 mg/100 ml as the criterion for being 'under the influence'. See also 2.4.2. The possibility of compensatory factors still playing a role over the 100 mg/100 ml level in general seems virtually negligible.
Taking into account the possibility of compensatory effects below this level, it is interesting to check whether or to what extent accidents attributable to alcohol occur above it. The material gathered by Borkenstein, Lucas, Holcomb and Vamosi has been used for this purpose, the results of the exercise being given in Table 2 (See p. 14 and 15). The borderline between sober and non-sober is here variously taken as 30, 50 or 60 mg/100 ml owing to the different blood alcohol concentration classes adopted in the studies concerned.

HOLCOMB					VAMOSI				
a.c. in g/100 ml	Accident group	Control group	Drivers whose involvement in accidents can be attributed to alcohol		B.a.c. in mg/100 ml	Accident group	Control group	Drivers whose involvement in accidents can be attributed to alcohol	
			Estimated number $a_1 - \frac{c_1 \times a_0}{c_0}$	Percentage of accident group $\frac{100}{270} \times \left(a_1 - \frac{c_1 \times a_0}{c_0}\right)$				Estimated number $a_1 - \frac{c_1 \times a_0}{c_0}$	Percentage of accident group $\frac{100}{418} \times \left(a_1 - \frac{c_1 \times a_0}{c_0}\right)$
	9	10	11	12		13	14	15	16
— 59	183 (a_0)	1671 (c_0)	0	0	0— 29	123 (a_0)	370 (c_0)	0	0
—109	28 (a_1)	56 (c_1)	17.4	6.4	30— 99	89 (a_1)	37 (c_1)	76.8	18.3
—149	22 (a_1)	16 (c_1)	19.0	7.0	100—149	82 (a_1)	8 (c_1)	79.4	19.0
≥150	37 (a_1)	7 (c_1)	35.7	13.2	≥150	124 (a_1)	3 (c_1)	123.0	29.4
al	270	1750		26.6%	total	418	418		66.7%

A blood alcohol concentration of 50 or 60 mg/100 ml as the dividing line between sober and non-sober is quite tolerant. The estimates given in the table are accordingly conservative.

Table 2 (columns 1, 5, 9, 13) shows that in about 65-70 % of the accidents involving non-sober drivers, blood alcohol concentrations higher than 100 mg/100 ml were found. In the control group the percentage of drivers with b.a.c.'s > 100 mg/100 ml is about 25-40 % of the total number of non-sober drivers (See Table 2, columns 2, 6, 10, 14). If one makes the reasonable assumption that the limit for the influence of compensatory factors can be set a 100 mg/100 ml (see Borkenstein, 1964), it is apparent from Table 2 (columns 4, 8, 12, 16) that an estimated three out of every four accidents attributable to alcohol, are attributable or due to blood alcohol concentrations over the 100 mg/100 ml mark. (Accidents attributable or due to alcohol are defined as accidents that have a higher probability of occurrence as compared with accidents where the drivers involved had avoided alcohol altogether or had restricted themselves to a stipulated b.a.c., all other circumstances being equal).

This conclusion applies for certain parts of the United States, Canada and Czechoslovakia.
It is reasonable to assume that the situation would be found to be the same in the Netherlands.

1.2.3 The blood alcohol concentration at which the probability of accident involvement is greater than when sober

The investigation by Borkenstein et al. is distinguished by the size of the accident and control groups and by the way in which these groups were selected (See Table 1, p. 12).
In addition to blood alcohol concentration, a number of personal data were also registered for both groups, such as age, sex and driving experience, in order to be able to take effects of these factors into account.

Besides Borkenstein and his team, Goldberg and Havard (1966) and Allsop (1966) also provide detailed analyses of the findings of the study.
To obtain data on the blood alcohol concentration above which alcohol increases the likelihood of accident involvement, the probability of an accident has been calculated as a function of the blood alcohol concentration.
A unique and controversial finding of Borkenstein et al. is the lower accident risk at blood alcohol concentrations between 10 and 40 mg/100 ml as compared with concentrations lower than 10 mg/100 ml, the latter being defined as sober. (See Figure 1).

These findings are, however, based on group data and not on the differences per individual in the probability of accident involvement due to the b.a.c. As such they are of dubious validity, if there is an interaction between blood alcohol concentration and other variables influencing the accident risk. Thus the chance of an accident when sober does not have to be greater than that at a blood alcohol concentration between 10 and 40 mg/100 ml, if the other

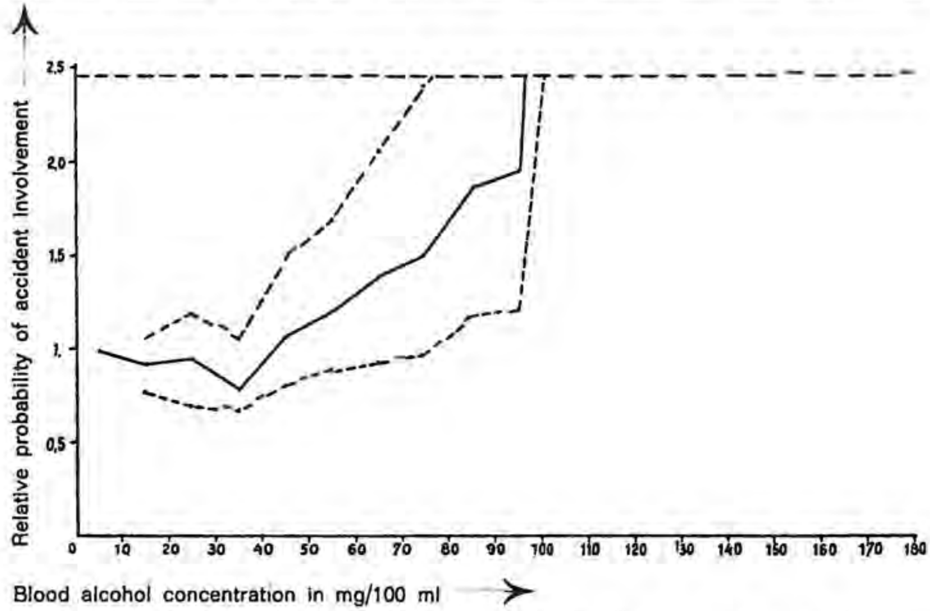

Figure 1. Relative probability of accident involvement owing to blood alcohol concentration. (Based on Borkenstein's. 1964, data). 95 % confidence limits according to Allsop, 1966.

Table 3. Distribution of estimated annual mileage classes over b.a.c. < 10 mg/100 ml and 10 mg/100 ml < b.a.c. < 40 mg/100 ml. (Data from Borkenstein, 1964, p. 223, table 36)

Est. annual mileage class	Alcohol class	< 10 mg/100 ml	10—40 mg/100 ml
5000 miles and under	Control group	1311 (21 %)	82 (15 %)
	Accident group	658 (31 %)	42 (24 %)
5001 miles and over	Control group	4969 (79 %)	475 (85 %)
	Accident group	1455 (69 %)	130 (76 %)
Total	Control group	6280 (100 %)	557 (100 %)
	Accident group	2113 (100 %)	172 (100 %)

relevant variables, such as driving experience, are such as to make the group concerned relatively less likely to become involved in accidents than other drivers with blood alcohol concentrations below 10 mg/100 ml.
Further analysis of the Borkenstein data supports this assumption. Table 3 gives a review.

Table 3 indicates that drivers with 10 mg/100 ml < b.a.c. < 40 mg/100 ml do have more driving experience than drivers with a b.a.c. < 10 mg/100 ml. This tends to be the case for both the accident and the control group of drivers in the Borkenstein study.
The point is moreover of minor importance, since at a 95 % confidence limit it is not possible to demonstrate statistically a difference between the accident risk at blood alcohol concentrations between 10 and 40 mg/100 ml on the one hand and less than 10 mg/100 ml on the other (Allsop, 1966). At a 95 % confidence limit no evidence therefore is available that as a function of a minor alcohol intake, leading to a b.a.c. < 40 mg/100 ml, the probability of being involved in traffic accidents is lower than while sober. This conclusion does not exclude the possibility that the reverse is true. It only states that this possibility has a low probability of being demonstrated factually.

With the same 95 % confidence limit it can be shown statistically that the risk of accidents is greater at blood alcohol concentrations in excess of 80 mg/100 ml than while sober.
It has to be borne in mind, however, there are indications that the assessed blood alcohol concentration is relatively too high for the control group. If this is true, than for a concentration lower than 80 mg/100 ml an increased risk could be demonstrated.
On the other hand, there are also other variables than the b.a.c. which contribute to the incidence of accidents.
On the basis of one factor analysis the conclusion is that for blood alcohol concentrations above 80-100 mg/100 ml a relation with the variables considered could not be statistically demonstrated, with the exception of sex, socio-economic status and age (Allsop, 1966).
The fact that a relation could not be demonstrated does not, however, exclude the possibility of the existence of such a correlation. The number of drivers with a blood alcohol concentration higher than 100 mg/100 ml included in the

Table 4. Distribution of estimated annual mileage classes over b.a.c. < 80 mg/100 ml and b.a.c. > 80 mg/100 ml. (Data from Borkenstein 1964. p. 223, table 36)

Est. annual mileage	Alcohol class	< 80 mg/100 ml	> 80 mg/100 ml
5000 miles and under	Control group	1418 (20 %)	9 (9 %)
	Accident group	729 (31 %)	34 (20 %)
5001 miles and over	Control group	5548 (80 %)	94 (91 %)
	Accident group	1630 (69 %)	135 (80 %)
Total	Control group	6966 (100 %)	103 (100 %)
	Accident group	2359 (100 %)	169 (100 %)

Borkenstein study was in fact small, something which makes the statistical demonstration of correlations rather difficult. Neither would it be correct to exclude the possibility of any relation on the basis of the results at present available, since the method of analysis applied does not take all possible interactions into account. This can result in the effect of variables being counteracted. A number of variables were after all found to influence the accident risk besides the blood alcohol concentration itself, and these variables were not always identical in the accident group and the control group.
For instance, within the blood alcohol concentration group 0 < 80 mg/100 ml there were found indications for a difference between the different b.a.c. classes as regards driving experience. See Table 3. Analoguous differences were found on further analysis of the data from Borkenstein's report between the b.a.c. > 80 mg/100 ml and b.a.c. < 80 mg/100 ml groups, e.g. less driving experience in the latter group. Table 4 gives an illustration.

These differences indicate that the group with blood alcohol concentrations over 80 mg/100 ml is less likely to be involved in accidents than the group with concentrations above that figure owing to variables other than the blood alcohol concentration.
If this is the case, the blood alcohol concentration at which the accident risk is greater than when sober will in actual fact be higher than 80 mg/100 ml, as driving experience in the total population at risk increases.

The applicability of 80 mg/100 ml as a critical limit is determined by the degree to which the groups studied can be considered representative for all (American) drivers, e.g. concerning driving experience. The same can be said of the other elements which also contribute to the incidence of (alcohol) accidents. Whether these conditions are the same and whether the drivers studied by Borkenstein are any different from the general American driving population, or those of other countries, cannot be fully ascertained, as sufficient data are not available. In general it can be stated that the establishment of an identical maximum allowable b.a.c. for drivers in different countries cannot be justified by the results of the Borkenstein study. The reason is that differences between countries in driving conditions (especially at night) and differences in the driving population at risk (specifically driving experience) that also contribute to the incidence of (alcohol) accidents, are co-determinants for the accident risk as a function

of the blood alcohol concentration of drivers, even if this accident risk is relative to that while sober.
For the Netherlands a reasonable assumption is to state a critical b.a.c. lower than 80 mg/100 ml for drivers: driving experience, averaged over the total population at risk is lower, and driving conditions, specifically at night, are worse.

If one ignores these differences between countries regarding the probability of accident involvement in relation to blood alcohol concentration and assumes that the relative number of non-sober drivers in the Netherlands is not smaller than in the United States, Canada or Czechoslovakia (1 in 10, see Table 1, p. 12), it can be calculated that if drivers could limit their drinking to the 80 mg/100 ml level this would result in some 15,000 fewer accidents per year for the Netherlands (6 % of the total number of accidents yearly, according to Borkenstein's data; see: Goldberg and Havard, 1966).
Since after drinking the risk of a fatal accident increases at least twice as sharply as that of accidents of a less serious nature (Tables 1 and 2), these 15,000 accidents would include at least 300 fatalities.

1.3 Characteristics of 'alcohol accidents'

1.3.1 Type and seriousness

Compared with the total number of accidents, 'alcohol accidents' are distinguished by the 'type' of accident which occurs: the relatively more frequent occurrence of collisions involving only one driver. See 1.3.2, however. They are also distinguished by their results: relatively serious accidents with deaths and serious injuries. (See Table 1 and Borkenstein et al., 1964; Schlenkert, 1960; Arnold, 1959; Anon., 1966).
Measures to reduce the number of non-sober drivers will accordingly not only bring the total number of accidents down but will specifically cut the number of serious accidents.

1.3.2 Time and place

The number of 'alcohol accidents' as a percentage of the total number of accidents is disproportionately great between 21.00 hrs and 03.00 hrs in comparison with other times. In the same way the percentage of 'alcohol accidents' during weekends, including Friday evenings, is also out of proportion with the rest of the week.
The 'peaks' on weekdays occur at a different time in the night (21.00—24.00 hrs) than those on weekends (24.00—03.00 hrs). (See Willet, 1964; Cassie and Allan, 1961; Bjerver et al., 1955; Arnold, 1959; Schlenkert, 1958; Plymat, 1955). Froentjes and Verburgt (1962) give a breakdown of the number of 'alcohol accidents' over the twenty-four hours for the Netherlands, their figures serving

to confirm the findings in other countries regarding the percentage represented. 'Alcohol accidents' occur mainly during the 'quiet' night hours. Jeffcoate (1958) found a relatively higher percentage of single-vehicle accidents during the night (21.00—24.00 hrs) than in the rest of the twenty-four-hour period. On the basis, therefore, that positive blood alcohol concentration will occur mainly at night, drivers 'under the influence' will accordingly run a greater risk of single-vehicle collisions than those who are sober.

The greater seriousness of the 'alcohol accidents' could be explained in a similar way by making a distinction between place of occurrence and related differences in driving conditions and behaviour, e.g. obstacles on the roadside, vehicle speed.

1.4 Characteristics of drivers involved in 'alcohol accidents'

Most of the investigations made so far into the relation between the characteristics of drivers and the occurrence of 'alcohol accidents' have not taken into consideration other driver characteristics than the one considered which might also influence the accident risk. It was for instance found that the difference in the risk of 'alcohol accident' involvement could be explained by the effects of more relevant variables such as driving experience and age (Borkenstein, 1964).

Only a study of the influence of a combination of several factors on the probability of involvement in an 'alcohol accident' will enable the obtaining of more definite data on the effect of each of the factors individually.

1.4.1 Age

Compared with the age structure of the population as a whole, a disproportionate number of 30 to 50-year-olds appear to become involved in 'alcohol accidents'. (Bloch, 1962; Cassie and Allan, 1961; Goldberg, 1955; Froentjes and Verburgt, 1961).

The age structure of the population is not, however, a valid basis for comparison, since it fails to take into account possible differences in the number of drivers between age groups. It is for instance reasonable to assume that the 30—50 age bracket will include a relatively large number of driving licence holders. But even the possession of a driving licence is not an adequate criterion, in view of the difference in the amounts of driving actually done by the different age groups. The 30—50 age group is in fact the one with the greatest mileage. (SWOV, 1966; Munden and Quenault, 1966). Table 5 gives data for Britain and the Netherlands.

Up to the present no data have been available regarding 'alcohol accidents' calculated on the basis of mileage driven, either in comparison with other accidents or per age group.

Table 5. Mileage accounted for by different age groups (as percentage of distance covered by passenger cars)

Netherlands	(SWOV, 1966)	Britain	(Munden and Quenault, 1966)
18—19	0.68	19	1.55
20—24	2.87	20—24	8.47
25—28	5.69	25—29	11.02
29—34	15.13	30—39	24.93
35—39	15.31	40—49	24.97
40—44	15.56	50—59	20.30
45—54	26.67	60—69	7.58
55—64	14.47	70 and over	1.18
65 and over	3.62		
	100 %		100 %
1963 figures		1961 figures	

What is known, however, is that the 30 to 50-year-olds do not form an exceptionally dangerous age group, on the basis of the total number of accidents per mile driven. The accident risk for persons over 50 is practically the same as that for the 30—50 age group; that for younger persons is higher (SWOV, 1966; Munden and Quenault, 1966; Häkkinen, 1966).
Borkenstein's study showed that it was chiefly young people up to 25 and those with total mileage of less than some 1000 miles, together with drivers over 70, who were involved relatively more often in 'alcohol accidents'. The 30—50 age group can consequently also be considered as relatively the least dangerous in this respect too.

1.4.2 Driving experience

The accident risk per mile driven becomes less with growing driving experience. This experience could also have a similar effect on the probability of being involved in an 'alcohol accident'.

Borkenstein found evidence to support this assumption, at least up to blood alcohol concentrations below 80 mg/100 ml. Above that level no relation could be demonstrated between driving experience and the probability of 'alcohol accident' involvement. Over 80 mg/100 ml the probability of an accident therefore increases with rising blood alcohol concentrations for experienced and inexperienced drivers alike.
The main reason for this lack of correlation seems to be that the less experienced driver is also the less ready to drive with a b.a.c. > 80 mg/100 ml (See Table 4, p. 18). The probability of finding a statistically significant relation between driving experience and 'alcohol accident' rate then is low, by a 'restriction of range' in the variation of driving experience over blood alcohol concentrations.

1.4.3 Marital status, sex, occupation, education

The literature provides indications that some social groups are disproportionately represented in 'alcohol accidents'; these indications, however, are not consistent. For instance, Waller (1966) concludes that divorced persons run a greater risk of an 'alcohol accident' per mile driven, while according to Goldberg (1955) the risk is greater for married persons.
Borkenstein, however, (1964) concludes that married persons are less likely to have accidents through drinking.
There are data available which appear to suggest that women drivers are involved in fewer accidents per mile driven than their male counterparts (Van der Burgh, 1966), but as far as 'alcohol accidents' are concerned the opposite would appear to be the case (Borkenstein, 1964).
Up to the present, however, data are lacking on the difference in the circumstances under which sober or non-sober male and female drivers drive, and also about the characteristics of sober and non-sober men and women drivers which could also influence the risk of involvement in 'alcohol accidents'. It is not therefore possible at present to furnish any definite information as regards the difference in 'alcohol accident' risk for men and women.

A large number of classifications are possible based on occupation. A relation often is apparent between the classification for occupation and education or socio-economic status. An entirely unambiguous social classification has yet to be developed, as can be seen from the following selection taken from the literature:
'Professional + technical', 'Clerical, skilled' and 'Laborer' (Waller, 1963), but also 'Professional and higher administrative'; 'Managerial and executive'; 'Lower non-manual', 'Skilled manual'; 'Semi-skilled manual'; 'Unskilled' (Willet, 1964); 'Ouvriers qualifiés du secteur privé'; Ouvriers spécialisés du secteur privé'; 'Manoeuvriés'; 'Commerçants (petits commerçants)'; 'Salariés agricoles'; 'Agriculteurs'; 'Artisans' (Bloch, 1962) etc.
One finding of at least some significance is that the numerical representation of the lower socio-economic groups in the total number of 'alcohol accidents' is disproportionately great in relation to the whole population.
The interpretation of this finding is not clear. It cannot be explained by the relatively greater proportion of drivers in this group, or by the average mileage of the group being higher, since mileage declines with declining incomes. See Table 6. The possibility cannot therefore be excluded that in the lower socio-economic groups a relatively larger number of persons drive 'under the influence': if police officers report all socio-economic status groups equally, especially when drivers are found to have been drinking.
In the Netherlands a study has been made to ascertain the occupations of drivers required to submit to blood tests (Froentjes and Verburgt, 1962).
The findings of this study lead to the conclusion that blood samples are taken principally from professional drivers (i.e. truck, van etc. drivers). If it is assumed that the number of 'blood test cases' coming before the courts provides an indication representative of the total number of 'alcohol accidents' and 'alcohol offences' involving drivers of the groups considered, it is nevertheless unwarranted to conclude that professional drivers are more prone to 'alcohol accidents' since as a group they cover a greater mileage. See Table 6.

Table 6. Distances covered by business vehicles and private cars. (Source: C.B.S. 1966)

	1963	1965
Business vehicles	22,300	22,500
enterprises	28,600	29,600
self-employed persons	18,400	18,700
employers	25,300	26,000
employees	20,100	21,200
Private cars	12,600	13,000
Owners' incomes		
up to *f* 10,000	11,600	11,900
f 10,000—*f* 15,000	13,800	13,600
f 15,000—*f* 20,000	14,700	15,000
f 20,000 and over	15,800	16,100

1.4.4 Type of road user

Besides drivers of motor vehicles other non-sober persons also use the road. This is evident from the blood alcohol concentrations found in pedestrians and cyclists involved in accidents (Rutley, 1966). The non-motorized victims of accidents are sometimes found to have drunk more than the motorized ones (Leipzig, Germany, Arnold, 1959), sometimes not (Middlesex, Britain, Rutley, 1966).
Although it is obvious that non-sober cyclists, moped riders and pedestrians can be a danger on the road, little has been done so far to ascertain the accident risk due to alcohol for other categories of road users besides drivers.

In a study by McCarrol and Haddon of 50 pedestrians killed in road accidents it was found that three out of every four of these pedestrians were not sober; a percentage that is somewhat higher than that for drivers killed on the roads, (60 %, see Table 1, p. 12). In the control group 34 % non-sober pedestrians were identified; for drivers the corresponding percentage is somewhat lower (26 %, see Table 1). These findings indicate that in comparison with drivers, the number

Table 7. Percentage of fatal accidents attributable to non-soberness for drivers and pedestrians. (Based on data by McCarrol and Haddon, 1963)

	Accident group		Control group		Fatal accidents attributable to non-soberness in % of accident group
	d	p	d	p	
Sober	14	13	161	132	
Non-sober	20	37	56	68	d: $\left[\frac{100}{34} \times \left(20 - \frac{56 \times 14}{161}\right)\right] = 80\ \%$
Total	34	50	217	200	p: $\left[\frac{100}{50} \times \left(37 - \frac{68 \times 13}{132}\right)\right] = 60\ \%$

d = drivers; p = pedestrians

of non-sober pedestrians is somewhat higher, also when they are involved in fatal accidents. Information on the number of drivers and the number of pedestrians whose involvements in fatal accidents can be attributed to alcohol is given in Table 7. The data are based on the two studies by McCarrol and Haddon mentioned in Table 1. Table 1 also gives information on the method of analysis of these data.

Due to various reasons (e.g. the small sample used) the significance of data in Table 7 is only relative. The data suggest that the importance of alcohol as a cause of accidents is greater for drivers than for pedestrians. In other words, the blood alcohol concentration above which the probability of accident involvement is greater that when sober, will possibly be higher for pedestrians than for drivers. More data are needed to verify this hypothesis.
There is a complete lack of data on drinking by cyclists and moped riders and the resultant accident risks.

1.4.5 Drinking habits

The problem of 'alcohol and road safety' used to be ascribed chiefly to occasional and 'social' drinking. There are indications, however, that the number of 'alcoholics' involved in 'alcohol accidents' is disproportionately high.
Thus Smith et al. (1962) found that 6 % of the persons involved in 'alcohol accidents' were receiving treatment at clinics for alcoholics, while the percentage to be expected on the basis of the total population was 2 %. Bjerver et al. (1953) found 32 % in a similar study when they had expected no more than 14 %. Goldberg (1955) concludes that 45 % of the persons reported by the police for driving 'under the influence' had already been convicted of a similar offence at some time in the preceding ten years and/or were or had been receiving treatment in a clinic, as opposed to the 9 % to be expected on the basis of the total population.
These findings cannot be explained by stating that alcoholics drive more. They are involved in 'alcohol accidents' more frequently per mile driven than other persons who are not registered as alcoholics (Schmidt et al., 1962).
No statistically demonstrable differences can otherwise be shown between these groups in the number of non-alcohol accidents per mile driven (Schmidt et al., 1962).

Other drinking habits such as frequency, times, places, and types of drinks would also appear to be of importance for the occurrence of 'alcohol accidents'. Thus the probability of an accident was found to be relatively the greatest after drinking in the morning, with the drinking of beer in particular increasing the accident risk (Borkenstein, 1964).

These data are not very informative in themselves, since here too interaction has to be taken into account. It was found, for instance, that regular drinkers ran a relatively smaller risk, which can be explained by the fact that this group also had relatively more driving experience.
Characteristics such as driving experience and driving conditions (e.g. night driving) are also relevant for the explanation of the higher accident liability

of 'alcoholics', although these have not been taken into consideration in the studies carried out so far.

It is not easy to calculate how many 'alcohol accidents' could be prevented if alcoholics could be kept out of the driving seat. A rough estimate can be made based on the assumption that the probability of encountering an alcoholic increases with the blood alcohol concentration observed in traffic. Blood alcohol concentrations higher than 150 mg/100 ml would only rarely be found in non-alcoholics (Goldberg and Havard, 1966).
In 35-50 % of the total number of 'alcohol accidents' drivers with a b.a.c. > 150 mg/100 ml are involved (See Table 2, columns 1, 5, 9, 13).
This estimate ties up with Goldberg's finding (1950) regarding the share of alcoholics in the total number of 'alcohol accidents' (45 %). Of the total number of accidents attributable to non-sober driving, in about 50 % drivers with a b.a.c. > 150 mg/100 ml are involved (See Table 2, columns 4, 8, 12, 16).
On this basis it appears worth while to investigate whether it would be possible to screen drivers with a b.a.c. > 150 mg/100 ml ('alcoholics') out of road traffic, at least as drivers. The conditions under which this countermeasure could be effective are discussed under 2.4.

1.4.6. The number of 'alcohol accidents and convictions' in the past

In 1964 the number of convictions under Section 26 of the Netherlands Road Traffic Act totalled 5840, or 55 % of the total number of convictions under the Act.
In 1963 the number of recidivists under Section 26 was 1649, or 31 % of the total number of convictions under that Section. The percentage of recidivism for traffic convictions not involving alcohol was found to be 17 %.
Corresponding ratios have been found in Germany, where a comparison between 1000 persons convicted of 'alcohol traffic offences' with 1000 others convicted of traffic offences where alcohol was not involved revealed that twice as many persons had already been convicted before in the first group as in the second (Händel, 1962).
Table 8 provides a survey of recidivism in alcohol traffic offences in the Netherlands from 1956 to 1963 (See p. 26).

Similar data compiled elsewhere indicate lower recidivism percentages for 'alcohol traffic offences', 7 % being found for Canada (Coldwell and Grant, 1962), 9 % for Sweden (Goldberg, 1955) and 10 % for Britain (Willet, 1964).
It is reasonable to assume that differences in the registration records adopted affect to some extent the percentages arrived at. In the Netherlands a note is made by the police officer at the time of every accident and every offence in traffic if the person(s) concerned is (are) sober or not, in so far as this can be detected from behavioural signs.

The statistics on recidivism do not take into account the period within which convictions or accidents are repeated; e.g. no distinction whatsoever is made between the repetition of an offence or accident within six months or within twenty years. Over 90 % of the 'alcohol convictions' result in the persons

Table 8. Recidivism in traffic offences in general and those attributable to alcohol in particular

	Year	Number of persons convicted			Number of previous offences					
		Total	of whom with previous convictions		1	2	3	4	5	6 or more
			Number	% of total						
Total number of persons convicted under Road Traffic Act	1956	7791	1590	20	1090	339	98	37	12	14
	1957	7834	1716	22	1150	360	129	46	13	18
	1958	7929	1790	23	1161	400	137	53	16	23
	1959	7703	1830	24	1149	380	160	71	40	30
	1960	8414	1977	23	1225	416	172	78	48	38
	1961	8839	2149	24	1298	467	204	89	44	47
	1962	9349	2222	24	1378	449	210	91	55	39
	1963	9559	2397	25	1437	518	243	103	48	48
Under Section 26	1956	5609	1368	24	936	292	86	31	11	12
	1957	5400	1455	27	950	319	116	45	11	14
	1958	5101	1463	29	943	328	115	44	15	18
	1959	4950	1477	30	928	305	132	59	28	25
	1960	5078	1562	31	952	335	147	63	38	27
	1961	5161	1633	32	930	388	165	75	39	36
	1962	5356	1655	31	979	364	172	68	44	28
	1963	5271	1649	31	943	372	186	72	36	40

concerned losing their driving licences for a period, so that when investigating recidivism over e.g. a ten-year period it has to be borne in mind that the actual period during which convictions can be repeated is in fact shorter, at least if it is assumed that banning a person from driving guarantees that he will not drive. On this basis the data now available accordingly result in the actual degree of recidivism regarding Section 26 of the Road Traffic Act being considerably underestimated.

Further study is consequently desirable with a view to establishing the probability of an 'alcohol accident' or conviction as a result of a person's criminal or accident record. Besides the length of the period concerned, this study should also take into consideration drivers' mileages and other characteristics such as driving experience and age, since these can also influence the probability of being involved in an 'alcohol accident' or committing an 'alcohol offence' in traffic. A study of this type has been started in the meanwhile, under contract from the Institute for Road Safety Research (SWOV), by the Criminological Institute of Groningen State University. The aim of this research project is to provide information on the extent to which in different periods of time the same drivers are involved in 'alcohol accidents' or are convicted of 'alcohol offences' in traffic. To what extent this 'alcohol accident and conviction' stability increases with higher blood alcohol concentration of the driver will also be checked.
If this stability is sufficiently high, efforts would then be made to investigate whether conviction in respect of 'alcohol offences' on the road can be predicted on the basis of previous:

1. 'alcohol convictions' on the road and/or elsewhere,
2. convictions not involving alcohol on the road and/or elsewhere.

Only if the incidence of 'alcohol accidents' in different periods of time involves the same drivers in the majority of cases, can prediction of the number of these accidents expected in the future as a function of accident history and or as a function of other driver characteristics be successful.

2 Countermeasures

2.1 Adaptation of driving conditions

The possible influence of road conditions and vehicle design which might contribute to the occurrence of 'alcohol accidents' is still insufficiently understood, but it is reasonable to assume that measures of a general nature to improve road safety will also reduce the number and seriousness of 'alcohol accidents'.
Since it is chiefly during the night hours that non-sober driving occurs, and also in view of the fact that alcohol impairs vision, improvement of visibility conditions, e.g. lighting of roads, could well prove to be of particular value. It would be desirable to check to what extent road safety is improved through a reduction in the number of 'alcohol accidents' following the introduction of road lighting. Such data are not yet available.

2.2 Controlling the effect of alcohol in the body

On the assumption that the complete separation of driving and drinking is unlikely to pass beyond the realm of wishful thinking, an effective means of combating the danger of alcohol on the road would be to reduce or nullify the effect of alcohol in the body.

2.2.1 Food consumption

Froentjes (1962) has studied on the basis of clinical observations the degree of influence the intake of food has at different blood alcohol concentrations when eaten just before or during alcohol consumption. His results are shown in Table 9.
Froentjes did not find any statistically demonstrable differences in the degree of intoxication between those who had and those who had not eaten during or before drinking.
With regard to the medical assessment on the basis of equal blood alcohol concentrations, Froentjes' data indicate that whether or not one has eaten during

Table 9. Effect of food consumption on the degree of intoxication (Froentjes, 1962)

Blood alcohol concentration in mg/100 ml	With food: 2764 persons Degree of intoxication			Without food: 4783 persons Degree of intoxication		
	Not apparent	Slight	Distinct	Not apparent	Slight	Distinct
	%	%	%	%	%	%
100—149	33	51	16	34	50	16
150—199	16	48	36	17	50	33
200—249	7	44	49	7	42	51

or before drinking makes no difference to the assessment of one's behaviour (i.e. being under the influence or not).

Goldberg (1950) did find differences in the blood alcohol concentrations of persons who had and who had not eaten during or before drinking, when the amounts of alcohol consumed were the same.
At equal alcohol intakes, eating prior to or during drinking consequently appears to have a favourable effect on the blood alcohol concentration. It was also found that the medical assessment of the degree of influence did not differ.

2.2.2 Consumption of an antidote

Research has been carried out for some years in both the U.S.A. and Germany to find an agent that would result in quicker elimination of alcohol from the blood. The results to date have been disappointing. Most of the agents tested proved not to have any effect. Fructose and levulose resulted in a somewhat accelerated breaking down of alcohol in the liver, but doses of the size needed were found to produce unwanted side effects such as nausea (Institute for Road Safety Research (SWOV) unpubl.).

Up to now efforts have been concentrated on agents with an alcohol oxidizing effect. More encouraging results could perhaps be expected from an antidote working on the central nervous system. This could be the case in particular with lower blood alcohol concentrations (< 80 mg/100 ml), at which effect of alcohol appears to be primarily to encourage risk taking behaviour.
It should be borne in mind that an antidote can produce side effects or only partially moderate the effect of alcohol. Most of the drugs tested even act synergistically in combination with alcohol (Kielholz et al., 1967).

An approach of greater utility will be to do research on alternative luxuries which are less harming and more pleasurable than alcohol.

2.3 Changing drinking and driving habits

Self-evident measures to reduce the number of non-sober drivers include a change in drinking habits, by which drivers would not drink before driving, and a change in driving habits as a result of which driving after drinking would be decreased. Both behavioural patterns, and especially drinking habits, appear rather difficult to change.
Certain requirements have to be satisfied if driving habits are to be effectively influenced as far as alcohol is concerned.
In the first place there is the public's awareness of the danger of alcohol when driving and possible permissible alcohol limits. There are indications that drivers are still inadequately informed on these points (Borkenstein, 1964; Netherlands Road Safety Association, 1966).

Even when these data are generally known, the question still arises whether this would affect the behaviour of the individual. After all, most non-sober drivers still reach their destinations unharmed and do not come to the notice of the police either.
Most drivers consider themselves as possessing above average driving ability. It can be assumed that they do not consider themselves any less capable after a few drinks.
Besides the fact that undesirable behaviour has to be punished, there should also be an attractive alternative means of transport available, such as public transport in particular; punishment is as a rule only effective when a change in behaviour is rewarded at the same time (Duijker, 1966).
These conditions have frequently not been met, or only partly at best, during campaigns to reduce driving 'under the influence'.

Up till now campaigns to cut down the number of non-sober drivers have produced little or no results.
Thus around Christmas 1964 a large-scale and intensive shock campaign in Britain proved ineffective insofar as a reduction in the number of alcohol accidents could not be demonstrated. (Road Research Laboratory, 1965).

2.3.1 Measures by insurance companies

In the Netherlands, all-risks policies normally include a clause to the effect that the driver is not covered for damage caused by accidents which are proved to be due to alcohol.
A number of Swedish insurance companies only issue policies to persons who undertake to abstain permanently from all drinks with an alcohol content exceeding 2.25 (vol.) %.
Fewer claims are made on these companies than on other insurance companies. This approach could help to improve road safety if non-abstainers were to restrict themselves permanently to drinks of under 2.25 (vol.) % alcohol in order to cut their insurance premiums. It is not known whether this does in fact happen.

The Canadian practice of refusing all-risk insurance to drivers who have been convicted for drunken driving and disqualified from driving for a period is also worthy of note (Surrell, 1962). Data are, however, lacking for an appraisal of these two measures on the basis of their effect in terms of fewer 'alcohol accidents', both involving insurance claims and otherwise.

2.3.2 Driver improvement meetings

What are known as 'driver improvement meetings' are held in some countries with the aim of 'educating' drivers who have been involved in a relatively large number of offences and/or accidents within a fairly short period of time. It is thought that discussions along these lines can result in improvement of such drivers' appreciation of the standards required and hence lead to them improving their behaviour on the road.
The results indicate that, in comparison with a control group, drivers who took part in these meetings were not involved in fewer accidents later on.
An improvement was, however, apparent in that they less freqently ignored traffic rules. It was, however, also found to be possible to bring about this improvement by just sending an official letter stating that in view of the number of traffic offences and/or accidents in which he had been involved the addressee had been listed as a candidate for an 'improvement course' (Coppin, 1964/1965).
The lack of any apparent effect on accident frequency may be explained by the fact that deliberate lack of care and attention cannot be proved in most accidents. Driving 'under the influence' may well form an exception, however, since it can result from a more or less deliberate prior decision.
It is accordingly possible that 'improvement courses' of the type referred to may have an effect on persons involved in alcohol offences and accidents.

A necessary condition for a reduction in the number of 'alcohol offences and accidents' to be expected a result of 'driver improvement meetings' is a relatively high stability of 'alcohol accident and conviction' involvement. If most of the 'alcohol accidents and convictions' are 'first' 'alcohol accidents and convictions', treatment of a small number of accident repeaters or 'habitual offenders', even if fully successful, will have but little effect on the total number of 'alcohol accidents and convictions'.
In the case of heavy drinkers moreover with little if any ability to restrict their alcohol consumption, more intensive therapies over longer periods will as a rule first be required to obtain the desired effect.

2.4 Standards to be met by drivers

The setting of general standards for suitability to drive implies that a number of drivers are excluded by selection.
The relatively minor utility of a general screening of drivers has been amply

demonstrated as a result of several studies. However, with regard to alcohol offences and accidents screening can be of greater value.
There are two possibilities in particular:
1. the advance exclusion of alcoholics from driving;
2. the removal from the roads of persons repeatedly involved in 'alcohol traffic offences and accidents'.

Besides for conditions of a more permanent nature, such as alcoholism, standards can also be set to govern temporary conditions in which drivers use the roads, in particular by stating a maximum allowable blood alcohol concentration for drivers in law.

2.4.1 Selection of alcoholics and recidivists

In the Netherlands measures are taken to prevent driving of alcoholics and habitual offenders.
Suitability to drive is assessed in the first place by a medical questionnaire including the question: 'Are you under treatment, or have you previously received treatment, owing to the use of alcohol or narcotics?'.
If this question is answered in the affirmative, the central licence-issuing authority can then proceed to obtain further information regarding the applicant's criminal record (from the official court records) or his physical and mental condition (by medical examination). His suitability to drive is then appraised on the basis of these data.
It is not known whether this method is always fully effective for the detection of alcoholics.
What is clear is that there are indications that too much reliance should not be placed on applicants' unsupported statements, including answers to questions such as those relating to alcoholism (Netherlands Health Board, 1965).
For post-selection either driving licences may be withdrawn or else the person involved may be required to undergo a new examination to assess his suitability and capability to drive. Some 5000 driving licences are withdrawn every year in this way.
Most of the cases concerned arise from recidivism with regard to Sections 26 or 36 of the Netherlands Road Traffic Act. Data on the effectiveness of this measure are not available in the form of a reduction in the number of traffic offences and accidents due to alcohol.

The exclusion of alcoholics and/or recidivists from driving would only have a positive effect on road safety if at least the following two conditions are satisfied.
1. Involvement in traffic offences and accidents attributable to alcohol must be a stable phenomenon, i.e. it must always be largely the same persons who prove to be involved in this sort of accident/offence (recidivists). Data on this are lacking, however, both in the Netherlands and in other countries.
2. It should be possible to make a reliable prediction of the rate of 'alcohol accident and/or conviction' involvement on the base of medical and psychological etc. characteristics of persons. An unsolved problem with regard to the identification of alcoholics is that inevitably a certain number of persons would unjustifiably be labelled as 'alcoholics', while others who should be would not

be, with the consequence that the former would be unjustifiably barred from driving while the latter would still be allowed to drive.

The effectiveness of the medical and/or psychological screening procedure appears to be quite low (see Schmidt, 1962; Smart, 1964; Netherlands Health Board, 1966).
The likelihood of being unjustifiably labelled as an 'alcoholic' also depends on the accuracy of the diagnosis. Not all deficiencies in liver function, for instance, are the result of excessive alcohol consumption.
Fundamental research is needed to enable consistently accurate diagnosis and consequently also treatment of the alcoholic.

2.4.2 Maximum allowable concentration of alcohol in the blood of drivers

Over recent years statutory regulations concerning the consumption of alcohol by drivers have been introduced in a large number of countries.
In Czechoslovakia it is forbidden for all drivers of motor vehicles. Yugoslavia, Norway and Switzerland ban drinking and driving for professional - i.e. truck, van, bus etc. - drivers. In Iceland, Norway, Sweden and Yugoslavia, persons found driving with blood alcohol concentrations over 50 mg/100 ml are liable to conviction. In Austria and Britain the limit is set at 80 mg/100 ml etc.
In some countries, where these regulations are not statutory, the limit is set by the courts.
In the Netherlands no statutory limit has been fixed for the blood alcohol concentration of drivers of motorized vehicles; in practice, however, the courts appear to take a concentration of between 100 and 150 mg/100 ml as the dividing line.

2.5 The enforcement of statutory countermeasures

In the Netherlands, but not only there, control over the behaviour of drivers is left as a rule to the personal understanding and initiative of the police officer on duty.
The behavioural rules stipulated by law which are most important for road safety are frequently relatively difficult to ascertain or to enforce, particularly in relation to offences under Section 26 of the Netherlands Road Traffic Act.
Then in addition it has to be borne in mind that assessing whether a driver is or is not 'under the influence' is a subjective matter based on the driver's behaviour and any smell of alcohol as judged a police officer and consequently as judged by the court.
As a consequence it is usually only the serious forms which are noted, and this again mostly restricted to situations where an accident has occurred, as is indicated by medical investigations of the alcohol concentration in the blood of arrested drivers (Froentjes and Verburgt, 1962).

Accurate data on alcohol consumption by drivers cannot be obtained in this way, nor reliable information on the number of 'alcohol accidents' either. See also 1.1. and 2.3.

Most methods to record the alcohol concentration in the human body have the drawback of requiring a blood test. It would accordingly be desirable for an alternative method to be developed which would be scientifically acceptable, simple for the police to use and unobjectionable from the point of view of medical ethics. Of the existing possibilities, viz. the analysis of saliva, urine or breath, the latter technique appears the most promising (Goldberg and Havard, 1966).
As there is a lack of data on the correlation between blood alcohol concentration values as measured by blood tests, and as estimated by analyses of the breath, under field conditions, a blood test is required at present in the Netherlands in order to obtain conclusive results acceptable as evidence.

2.6 Sanctions against drinking and driving

The report of the Third International Conference on Alcohol and Road Traffic, held in London in 1962, gives a survey of the forms of punishment for traffic offences involving alcohol provided for in the legislation of different countries. The report of the Fourth Conference (Bloomington, USA, 1965) also includes further information on this aspect.

In the Netherlands - Road Traffic Act, Section 26 and Section 36, paragraphs 1 and 3 - driving under the influence of alcohol may be punished by imprisonment for a period not exceeding three months. If death or serious bodily injury has been caused, the punishment is a maximum of three or two years' imprisonment respectively. In addition a person convicted on these counts may be disqualified from driving for a maximum of five years.
Considerable variation is, however, evident in the punishment of persons

Table 10. Punishments for traffic offences resulting from alcohol consumption in different police districts in the Netherlands

District	Type of punishment imprisonment	fine	probation
's-Hertogenbosch	28 %	55 %	17 %
Arnhem	28 %	41 %	31 %
The Hague	51 %	33 %	16 %
Amsterdam	45 %	27 %	27 %
Leeuwarden	54 %	19 %	27 %

convicted of traffic offences resulting from alcohol, as can be seen from Table 10.

The establishment of a legal maximum allowable blood alcohol concentration for drivers of motor vehicles and the introduction of objective forms of enforcement are measures which should lead to greater uniformity in sentencing. The distinction made at present between the punishments for traffic offences involving alcohol which result in accidents and those which do not should also be lessened.
The probability of an accident rises progressively as a function of the blood alcohol concentration (See Figure 1, p. 16).

The influence of characteristics of the driver which could compensate in part the danger from alcohol decreases with increasing blood alcohol concentrations. From 80 mg/100 ml such influence is virtually negligible.

Differences in the consequences of 'alcohol accidents' are moreover also determined by chance circumstances not specifically related to alcohol consumption, such as the presence of dangerous obstacles along the road, and whether or not other vehicles are in the vicinity and the behaviour of their drivers.
From the road safety angle these facts do not provide any arguments in support of the present procedure, in which the sentence pronounced upon conviction differs according to whether or not the person concerned 'caused a (serious) accident'.

2.7 The effect of statutory measures

Data regarding the effect of statutory measures are available from Sweden, Austria and Czechoslovakia.

In Sweden (Andréasson, 1962) a compulsory blood test for drivers suspected of driving under the influence of alcohol was introduced in 1934.
Table 11 provides indications that the proportion of 'alcohol accidents' in the total number of traffic accidents in Sweden has fallen since 1935.
In 1941 the maximum allowable blood alcohol concentration was set at 150 mg/100 ml, while drivers found to have blood alcohol concentrations between 80 and 150 mg/100 ml were also made liable to conviction if there was also other evidence of drunkenness. A quite pronounced drop in the number of 'alcohol accidents' followed after that year, although this drop was perhaps due to the war.
The lowering of the limit to 50 mg/100 ml in 1957 has not had any visible effect. It is also possible, however, that the effect of the abolishment of liquor rationing in 1955 is incorporated here too. Moreover due account must also be taken of the possibility that the number of fatal accidents ('alcohol accidents' are often fatal ones) is not rising at the same rate as the increase in the total number

Table 11. 'Alcohol accidents' in Sweden. (See also Andréasson, 1962)

Traffic accidents involving motor vehicles recorded by police

Year	Total		'Alcohol accidents'			
	Number	Index	Number	Index	%	Index percentage
1935	10,820	100	581	100	5.4	100
6	12,382	114	600	103	4.8	89
7	14,128	131	673	116	4.8	89
8	16,504	153	809	139	4.9	91
9	16,314	151	794	137	4.9	91
1940	7,190	66	226	39	3.1	57
1	6,256	58	100	17	1.6	30
2	6,765	63	164	28	2.4	44
3	6,352	59	162	28	2.6	48
4	6,100	56	181	31	3.0	56
5	6,507	60	233	40	3.6	67
6	14,410	133	682	117	4.7	87
7	17,847	165	658	113	3.7	69
8	15,468	143	612	104	4.0	74
9	15,859	147	442	76	2.8	52
1950	20,427	189	622	107	3.0	56
1	24,561	227	784	135	3.2	59
2	29,510	273	933	161	3.2	59
3	31,914	295	982	169	3.1	57
4	40,651	376	1135	195	2.8	52
5	45,850	423	1369	236	3.0	56
6	49,227	455	1651	284	3.4	63
7	51,857	479	1478	254	2.9	54
8	56,575	523	1879	323	3.3	61
9	55,955	518	1818	313	3.2	59

of a accident following the growth in traffic flow over recent years. The relative reduction in the number of 'alcohol accidents' could then be less the result of statutory restrictions than of the greater traffic flow.

In Austria a law setting the maximum allowable blood alcohol concentration at 80 mg/100 ml came into force on 1 January 1961.
It can be seen from Table 12 that the proportion of 'alcohol accidents' in the total number of road accidents has fallen since the enacting of the law.

In Czechoslovakia the consumption of alcohol has been forbidden for all drivers since 1 January 1961 (See Table 13).
Here too, a reduction in the number of 'alcohol accidents' as a percentage of the total number of accidents is apparent, following the entry into force of the ban on alcohol for drivers.
It is not known whether perhaps other measures were also introduced after the entry into force of the law which might possibly have reduced the probability of 'alcohol accidents' or of other accidents with serious consequences, despite the higher overall accident total.
Even if such measures were introduced in the different countries it seems unlikely if this would always have been simultaneous with the introduction of

Table 12. 'Alcohol accidents' in Austria. (According to Breitenecker, 1962, and data supplied by the Austrian Ministry of the Interior, 1967)

Year	Total number of traffic accidents	% represented by 'alcohol accidents'
1959	73,374	5.2
1960	97,296	5.8
1961	75,443	4.8
1962	78,943	4.7
1963	84,377	4.7
1964	87,872	4.7
1965	91,635	4.3

Table 13. 'Alcohol accidents' in Czechoslovakia. (According to data furnished by the Czechoslovakian Ministry of the Interior, 1967)

Year	Total number of traffic accidents	% represented by 'alcohol accidents'
1958	28,930	9.9
1959	34,806	10.9
1960	38,550	10.1
1961	42,745	6.8
1962	45,964	7.5
1963	56,377	6.6
1964	66,575	7.7
1965	74,100	6.8
1966 (9 mths)	58,559	6.7

stricter legislation on drinking and driving. The abrupt fall in the number of 'alcohol accidents' following the entry into force of such legislation does not appear to be altogether attributable to the gradual increase in traffic flow.

To be able to assess quantitatively the effect of the measures taken, data would have to be available on the number of 'alcohol and non-alcohol accidents' to be expected if these countermeasures were not taken. These data could be provided assuming that the effects of all the factors relevant for the incidence and seriousness of 'alcohol and non-alcohol accidents' remain the same in the period after the countermeasure is established. This assumption is not realistic: for instance, with increase in time (traffic flow), the increase in the number of fatal accidents lags behind the increase in the number of non-fatal accidents.

For 'alcohol accidents', the proportion of fatalities is relatively high. As a consequence, even in the absence of countermeasures a decrease could be expected in the number of 'alcohol accidents', as a percentage of the total number of accidents, as a function of time. This artificial reduction in the number of 'alcohol accidents' would probably be less or absent, if one took the number of fatalities (alcohol and non-alcohol) involved instead of the total number of accidents.

Table 14. Reported 'alcohol' and 'non-alcohol' accidents in Austria before and after 1-1-61

Average reported number of accidents	Before 1-1-61	After 1-1-61	Total
Non-alcohol accidents	72,128	79,803	151,931
Alcohol accidents	4,207	3,851	8,058
Total	76,335	83,654	159,989

It is, however, rather difficult — if not impossible — for a police officer to detect non-soberness when the driver is dead. The only way to obtain this information is blood analysis in hospitals. Analysis of blood for alcohol concentration is not, however, generally part of routine medical examination in hospitals.

In order to be able to make a rough prediction of the effect to be expected of making a blood alcohol concentration of about 80 mg/100 ml the maximum legally allowable in the blood of motorists, a 'before and after' analysis of the data in Table 12 has been made. It must be borne in mind that the results of such an analysis are biased towards a favourable effect of the countermeasure.
Table 14 gives the number of 'alcohol accidents' and the number of 'non-alcohol accidents' per year, as an average for the 'before' period (1959—1960) and the 'after' period (1961—1965).

The average reduction in the number of accidents (R) in the 'after' period expressed as a percentage of the total number of accidents in the 'after' period can be calculated with the formula:

$$R = \frac{100}{n} \times \left(a_i - \frac{c_i \times a_o}{c_o} \right)$$

(See also Table 2)

where:

n = total number of accidents in 'after' period = 83,654
a_i = number of alcohol accidents in 'after' period = 3,851
c_i = number of alcohol accidents in 'before' period = 4,207
a_o = number of non-alcohol accidents in 'after' period = 79,803
c_o = number of non-alcohol accidents in 'before' period = 72,128

A difference of 0.964 % in the total number of accidents can be calculated between the period before and the period after the introduction of legislation making 80 mg/100 ml the maximum blood alcohol concentration allowable for motorists.
It should be realized that besides the countermeasure referred to, other factors are also relevant for the explanation of the difference noted. The calculated percentage therefore is an overestimation of the effect resulting from the introduction of such legislation.
The same method applied to the number of 'alcohol and non-alcohol accidents'

in the 'before' and 'after' periods in Czechoslovakia (Table 13) gives an estimated average reduction of 2 %. In this country any consumption of alcohol is forbidden for all road users and failure to this law is severely punished.

These data can not be generalized as there are differences between countries concerning driving conditions, characteristics of the driving population at risk, observance of the law by motorists and also enforcement of the law by the police.
The calculation of a correction for the decrease in 'alcohol accidents' as a function of time (e.g. increase in traffic flow), is not even possible as no data are available.

The conclusion is that only objective, systematically gathered data concerning the blood alcohol concentrations of drivers, including those involved in accidents, can provide valid information on the effectiveness of countermeasures. (Both research projects are now on the programme of the Institute for Road Safety Research (SWOV).

3 Summary

a. Research in the USA, Canada and Czechoslovakia indicates that at times and at places of accident occurrence, one in every ten drivers not involved in accidents, but passing the accident site, will not be entirely sober. No data are available for the Netherlands.

b. According to studies made in other countries, it will be found that alcohol has been taken in at least 12 % of all road accidents and in 40 to 70 % of those resulting in hospitalization or death. For the Netherlands data from the courts indicate 3 %. Valid data in the Netherlands are not available.

c. Research in the USA has revealed that the blood alcohol concentration of drivers at which the probability of accident involvement is statistically greater than when sober is no higher than 80 mg/100 ml. There are reasons for assuming that this level is not the same for different countries.

d. The enacting of legislation making the maximum allowable alcohol concentration in the blood of motorists about 80 mg/100 ml resulted in an estimated maximum reduction of 1 % in the total number of reported accidents in Austria.

e. A severely enforced prohibition of any use of alcohol for all road users resulted in an estimated maximum reduction of 2 % in the total number of reported accidents in Czechoslovakia.

f. An estimated 75 % (50 %) of the total number of accidents attributable to alcohol are due to blood alcohol concentrations over 100 mg/100 ml (150 mg/100 ml), according to data from the USA, Canada and Czechoslovakia.

g. A relatively large proportion of 'alcohol accidents' have serious consequences. Effective measures to reduce the number of fatalities would therefore specifically reduce the number of 'alcohol accidents'.

h. No research has yet been carried out either in the Netherlands or elsewhere on the relationship between drivers' characteristics and whether or not they tend to drive after drinking.

i. Although it is obvious that non-sober cyclists, moped rider and pedestrians can also be a danger in traffic, little research has been done up to the present on the accident risk due to alcohol consumption for categories of road users other than drivers. There are some indications that for pedestrians the blood alcohol concentration above which the probability of accident involvement is greater than when sober, is higher than for motorists.

j. Research on the behavioural effects of alcohol in driving situations, and specifically the influence of driving conditions upon this behaviour, is needed as a base for reducing the accident risk of non-sober driving.

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