EFFECTS FROM WORKING-HOURS, DRIVING AND REST PERIODS ON TRAFFIC SAFETY

Han VAN DER LOOP
Ministry of Transport, Public Work and Watermanagement
Den Haag - Holland

Michel MODDE
Traffic Test bv
Veenendaal - Holland

Ipe VELING
Traffic Test bv
Veenendaal - Holland

INTRODUCTION

Road freight transport causes major traffic safety problems in countries all over the world. In the Netherlands for example, trucks are involved in about 17% of all crashes in which one or more people are killed, while they account for only 6% of all kilometres driven. In short, about 230 people are killed in traffic accidents involving trucks and more than 2500 people are seriously injured each year in the Netherlands.

The prediction is that the situation will get worse. For example, when measured in ton-kilometres it is estimated that with unchanged policy the amount of freight transport carried out by trucks will be doubled in the Netherlands in 20 years time. Also, it is estimated that with unchanged policy the number of crashes in the Netherlands in which trucks are involved will be 50% higher in the year 2000 when compared to 1990 (Kayser and Roelofs, 1991).

Crashes are the result of numerous factors. An important contributing factor to the likelihood of crashes involving trucks may be fatigue of truck drivers, due to, for instance, long working hours and short rest periods. Indeed, it can easily be seen that from the economic point of view, the more kilometres are made by a truck, the more money is made. Therefore, employers can be inclined to press truck drivers to work as long as possible. Since truck drivers are able to make more money too by working longer hours, they are inclined to do so. In the interests of traffic safety, health and general well-being of truck drivers, a European agreement has been formulated regarding the maximum time that truck drivers are permitted to drive in a given period of time. Minimum requirements regarding the length of the rest periods in a given period of time have also been formulated. Both regulations apply to the crews of vehicles engaged in international road freight transport (AETR). In the Netherlands, a regulation also regarding the permitted maximum number of working hours has been enacted (i.e. Rijtijdenwet, Rijtijdenbesluit). These norms are the result of an agreement between the Dutch government and organisations of employers and employees.

A number of investigations has shown that both the European and the Dutch regulations are often violated. For example, Hamelin (1981) found in a survey of 200 truck drivers, that 11% of the rest periods in between two working days were 4 hours or less. Another 20% were between 4 and 6 hours. In the Netherlands, research from the Dutch Ministry of Transport (i.e. verkeersinspectie) has shown again and again that about 20 to 30% of the general population

of truck drivers is, at any given time, in violation of the regulations concerning working hours, driving periods and rest periods, whereas in other research it had been found that among international drivers, weeks of 70 working hours on average are no exception (van Ouwerkerk, 1987; Consent beleidsadvies, 1991). All in all, it can be concluded that the Dutch government considers the number of violations to be unacceptably high (RVI, 1989).

Several countermeasures are possible. However, although the current norms are the result of much debate and experience, there seems to be a lack of scientific research in which attempts are made to validate the correctness of the norms. Based on a review of relevant literature, two major conclusions can be drawn. The first conclusion is that there is a widespread consensus that long working and driving periods and short rest periods seriously impair traffic safety (Nairn et al, 1987). The second conclusion is that at present, it is not possible to conclude on a scientific basis at which periods of working, driving and rest the probability of an accident starts to increase. This lack of knowledge is partly due to the fact that this question has hardly been a focus of interest in quasi-experimental research. Another reason has to do with problems of generalisation of experimental findings from the United States. Stein and Jones (1988), for example, found in a study which used a case-control design that truck drivers who had spent six hours or more at the wheel, were overinvolved in accidents when compared to truck drivers who had driven less than six hours. However, in a comparative study of accidents involving trucks in the Netherlands, Europe and the United States, Tromp (1988) found major differences in the causes of traffic unsafety. Tromp (1988) concludes that one should be cautious in trying to generalize traffic safety research findings from the United States to (Western-) Europe and vice versa.

The fact that it is not possible at the moment to validate the current norms has led the Dutch Ministry of Transport and Public Works (i.e. Directorate General of Transport), to commission a study to investigate this topic from a traffic safety point of view. In this study, the question of primary interest was at which periods of working, driving and rest, ranging form short (i.e. one day) to long (i.e. one or two weeks), the probability of an accident involving trucks starts to increase.

1. METHOD

1.1. Design

The above formulated question has been examined with a case-control design. In this method, a crash sample is compared statistically with a comparison sample (i.e. cases and controls respectively). In research concerning traffic safety, the method usually consists of recording relevant information from a crash and then returning to the location of the crash at the same time and day of the week the crash occurred one or two weeks later. Subsequently, at the crash location one or more vehicles are randomly selected from the traffic flow and the relevant information from the selected vehicles is gathered. Following this procedure repeatedly for a great number of times, two samples of vehicles are obtained. These samples differ theoretically only in one aspect, namely that members of one sample were involved in a crash while members of the other sample were not. Thus, any statistically significant difference which is found for a given aspect between the two samples can be directly attributed to the probability of crash occurrence. For example, if the mean age of truckdrivers differs statistically significant

between the two samples, then it can be concluded that the age of a driver is correlated with the probability of getting involved in an accident. However, it is important to realise that by using this method, it is not possible to determine the absolute probability of getting involved in an accident, given a fixed value of an aspect which was shown to be statistically significant. Instead, this method provides a way to determine which aspects, compared to others, are associated with the occurrence of accidents. In other words, from the data collected with this method, it can be concluded which values of aspects are overinvolved in the occurrence of accidents and which values of aspects are underinvolved (it should be noted however that given a hypothesis, quasi-experimental designs such as this one allow to infer causal relationships).

1.2. Cases and controls

To be included in one of the two samples, both case and control-vehicles had to meet several requirements. With regard to the case (crash) vehicles, the requirements were the following:

1. The accident in which the crash vehicles were involved, had to have taken place outside suburban areas, in order to minimize the probability of getting crashes in the sample with minor severity.
2. The crash vehicle had to have Dutch licence plates and had to be registered in the Netherlands, in order to facilitate possible later communications with the driver or with the company that owned the truck.
3. The truck involved in the crash had to have a gross vehicle weight of at least 3500 kilograms.
4. Immediately following the crash, professional help had to be necessary, for example by the fire brigade or by an ambulance. This criterium was also included in order to minimize the probability of getting crashes in the sample with minor severity, which, consequently, would diminish the validity of the study.
5. It had to be obvious that the accident was not due to very bad weather conditions, like extreme heavy fog.

For each crash vehicle the first two controls were to be (randomly) selected, meeting the following requirements:

1. The control vehicles had to be on the same location (i.e. roadway), as the crash vehicle, travelling in the same direction.
2. The control vehicles had to be on that location on the same day of the week as the crash vehicle was, but only one week later.
3. The first control vehicle had to be on that road half an hour before the crash occurred the week before, while the second control vehicle had to be on that road half an hour after the crash.
4. The control vehicles both had to have Dutch license plates and had to be registered in the Netherlands, also in order to facilitate later communications if needed with the drivers or with the companies who owned the vehicles.
5. Selection of both the control vehicles was not to take place during very bad weather conditions, in order not to create dangerous conditions for traffic.

1.3. Geographical area and period

The geographical area in which the investigation took place, was restricted -for practical reasons- to the regions Zuid-Holland, Overijssel, Gelderland and Flevoland. The period in which the study took place, was from October 1st 1989 to June 15th, 1990. From earlier accident statistics involving trucks, it could be expected that both the selected areas and the chosen period would generate sufficient data to carry out the investigation as planned.

1.4. Collected data

To perform all the necessary analyses, information from both cases and controls was collected on the following topics:

1. General information (e.g. date and time).
2. Information on the vehicle involved (e.g. kind of vehicle, the fact whether the vehicle was loaded or unloaded, the kind of load, its speed just prior to the accident etc.).
3. Information on the location and the situation at the time of the crash or the stopping of the control vehicles (e.g. weather conditions, kind of road, road surface, etc.).
4. Information on the driver (e.g. age, number of years driving experience, etc.).
5. Information on the working hours, driving periods and rest periods from the last 14 days.

With regard to crash vehicles, information was also gathered on the kind of crash and the circumstances in which the crash occurred.

1.5. Procedure

Crashes which occurred in the geographical area described during the defined period and which met the criteria listed before, were reported as soon as possible to the Rijksverkeersinspectie by the Dutch police. In most cases this was done only moments after the crash was reported to the police. As soon as the Rijksverkeersinspectie was notified that an accident had happened, a representative went to the location of that crash, to collect information. If all the necessary information could not be gathered at that moment, the company who owned the truck was visited within a couple of weeks after the crash.

Exactly one week after the crash two representatives of the Rijksverkeersinspectie went to the location of the crash. At the location two trucks which met the listed criteria mentioned before, were randomly selected from the traffic flow, one half an hour before the crash and the other half an hour after the crash. From those vehicles, all necessary information was collected in the same manner as with the case vehicles.

2. RESULTS

During the investigation, data of 193 crashes involving trucks were collected, as well as data of 386 control-vehicles. After preliminary examination, 186 case-vehicles and 378 control vehicles were found to be sufficiently qualified for further analysis.

Out of the 186 case (crash) -vehicles, 55% was involved in a crash with property damage, 36% was involved in a crash which resulted in personal injury of at least one of the persons

involved, while in the remaining 9% of the traffic accidents at least one of the persons involved was killed.

From an analysis of the data, it could be concluded that the matching of case- and control-vehicles was performed successfully. That is, no major differences were found between the two samples with regard to month, day of the week, hour of the day and type of road. Further, analysis of the crash data showed that the acquired accidents could be considered to be a fairly representative sample of all crashes involving trucks, that occurred during the period of the investigation.

2.1. Driving periods, working hours and rest periods

Table 1

Comparison of the crash sample with the control-sample, in terms of the number of hours driven per week and the number of hours worked in that week other than those driven.

Number of hours worked apart from driving	Number of hours driven	Crash sample (N=144) %	Control sample (N=324) %
≤ 14	≤ 28	11	28 s[1]
≤ 14	> 28	26	24 ns[2]
> 14	≤ 28	26	25 ns
> 14	> 28	37	23 s
total		100	100

1 "s" means significant at level $p < 0.01$
2 "ns" means not significant at level $p < 0.05$

Analysis of the data showed that the number of hours driven didn't have an effect on the probability of an accident, as one would expect from the literature. That is, for shorter periods of time (i.e. one or two days), no effect at all was found, while for longer periods of time (i.e. one or two weeks), only small effects were found, but sometimes in the opposite direction from what was expected. For example, truck drivers who had been driving more than 35 hours per week but less than 42 hours, were found to be overinvolved in the occurrence of accidents, while truck drivers who had been driving more than 42 hours per week were found to be underinvolved.

The explanation for these findings was found in the number of hours worked by truck-drivers, apart from driving. It was found that long periods of driving indeed increased the probability of an accident when accompanied by long periods of working. If, however, long periods of driving were accompanied by short periods of working or vice versa, no increase was

found on the probability of an accident. Short periods of driving in relation to short periods of working decreased the probability of an accident, as could be expected from the literature.

Table 2

Comparison of the crash sample with the control sample, in terms of the number of hours worked in the last seven days.

Hours worked (excl. breaks)	Crash sample (N=143)	Control sample (N=321)
≤ 30	7	19 s
31 to 40	18	23 s
41 to 55	50	38 s
≥ 55	25	20 s
total	100	100

Table 3

Comparison of the crash sample with the control sample, in terms of the number of hours worked during the last 24 hours, in relation to the number of years of driving experience.

Number of years of driving experience	Number of hours worked during last 24 hours	Crash sample (N=143) %	Control sample (N=321) %
< 5	< 6	4	4 ns
	6 to 10	15	9 s
	≥ 10	19	10 s
≥ 5	< 6	11	18 s
	6 to 10	23	32 s
	≥ 10	28	27 ns
total		100	100

Analyses of the data involving the number of hours worked show that the length of the period worked does have an effect on the probability of an accident. That is, truck drivers who have been working for longer periods, were found to be overinvolved in the occurrence of

accidents. Regardless of driving experience this is true for longer periods (i.e. seven days, table 2), while for shorter periods of time (i.e. one day), this result was especially found for truck drivers with less than five years of driving experience (table 3).

With respect to rest periods, it was found that the number of hours rested in a given period is associated with the probability of getting involved in an accident. The results indicate that truck drivers who rested less than 12 hours a day (excluding any weekend days), were overinvolved in the occurrence of accidents.

2.2. Other factors

Apart from the number of working and rest hours, analysis of the data showed that other factors appear to be significantly correlated with the occurrence of accidents. An overview of these factors is presented in Table 4, in which the focus is on the particular characteristic to which they belong.

Table 4

Factors that correlate significantly with the probability of an accident.

Factor	Underinvolved	Overinvolved
vehicle characteristics	- tractor without a trailer - unloaded tractor and trucks	
driver characteristics	- aged more than 25 years - five years of driving exp. or more - in possession of truck driver licence for 10 years or more	- aged less than 25 - less than five years of driving exp. - in possession of truck driver licence for less than 10 years
road-, traffic- and trip-characteristics	- little traffic	- a wet road - heavy traffic - last resting period spent in truck - next resting period expected to spend in truck - a high speed

From this table, it can be concluded that tractors without trailers are underinvolved in the occurrence of accidents, as are unloaded tractors and trucks. In addition, several driver characteristics are found to be associated with the occurrence of accidents, all of which are heavily correlated. With respect to these driver characteristics it can be concluded from the analysis of the data that the number of years of truck driving experience can be looked upon as the most dominant factor with regard to the occurrence of accidents.

It was also found that certain conditions and other aspects like a wet road, heavy traffic, the fact whether the last or next rest period was (to be) spent in the truck and driving prior to the accident with a high speed, were all overinvolved in the occurrence of accidents, while the condition of little traffic was underinvolved.

Finally, all factors that were found to be significantly correlated with crash-involvement have been analyzed, in order to determine the relative contribution of each factor. From this analysis, a number of independent factors emerged, which together explained 5.6% of the variance in the occurrence of accidents. The factor that explained most of the variance (i.e. 2.6%), was labelled "driver characteristics" (i.e. age, number of years of driving experience), and was followed by a factor that consisted of working and rest periods over longer periods of time (i.e. one and two weeks). This factor explained 1.8% of the variance. Other factors concern the "quality" of the last and next place to rest, vehicle and situational characteristics and working and rest periods over short periods of time. This latter factor only explained 0.1% of variance. Compared to the 1.8% of working and rest periods over longer periods, this is little (it should be kept in mind that the percentages of 1.8 and 0.1 respectively do not relate to the percentages of accidents caused by these factors but, instead, are related to the correlation between these factors and the occurrence of accidents).

3. DISCUSSION

The results of this study confirm the main conclusion found in the literature concerning working hours and rest periods. That is, a significant relationship exists between the length of the working hours and rest periods of truck drivers and traffic safety. With regard to these factors, two major conclusions can be drawn from the results of the present study.

The first conclusion concerns the relationship between working and driving periods on one side and traffic safety on the other. As stated in the previous chapter, in the present study it was found that driving and other working activities have similar influences on the occurrence of traffic accidents. This result means that for example four hours of driving has the same influence on traffic safety as only two hours of driving combined with two hours of other working activities (provided that the two hours of driving occur after the two hours of working).

The conclusion that can be derived from these findings is obvious: from a traffic safety point of view it is highly important that relevant regulations do not only state the maximum number of hours per period truck drivers are permitted to drive, but also, and in fact even more important, the maximum number of hours per period that they are permitted to work.

The second conclusion concerns the relative importance of the maximum number of working hours per period that is permitted and the minimum number of rest hours per period that is required. As shown, working and rest periods over longer periods (i.e. one or two weeks) explain far more variance in the occurrence of accidents than working and rest periods over shorter periods (i.e. one or two days). Therefore, from a traffic safety point of view, it can be concluded that the longer the period, the more important it is to define and enforce safe norms regarding working, driving and rest periods.

Table 5

Cross-table of the dichotomized accident factor and the dichotomy yes or no accident.

		Accident	No accident
accident factor	less than or equal to norm	a	b
	greater than norm	c	d

With regard to those 'safe' norms, a final remark should be made in this paper. When comparing the two samples with regard to the number of hours worked, the data from this study make it possible to calculate the number of hours worked (i.e. norm) which discriminates as much as possible between the two samples.

That is, following table five, let 'a' be the number of crash-involved truck drivers who worked less than the norm that is to be calculated. Let 'b' be the number of non-crash-involved truck drivers who worked less than the norm and let 'c' and 'd' be the number of crash-involved and non-crash-involved truck drivers respectively who worked more hours than the norm. Then it can be argued that in this scheme, groups 'a' and 'd' in fact represent errors. That is, truck drivers who worked less than the norm conducted themselves safely but in group 'a' they were involved in a crash anyway.

On the other hand, truck drivers in group 'd' did not conduct themselves safely (i.e. worked for more hours than permitted), but this behavior didn't result in involvement in a crash. Then it can be argued that the norm which discriminates as much as possible between the two samples has to be the smallest value possible, when the product is taken of 'a' and 'd' minus the product of 'c' and 'b'.

The procedure involving the calculation explained above was followed and the values which resulted from the calculation were 12 hours maximum working time per period of 24 hours and 45 hours of maximum working time per period of seven days. Given the assumption that the minimum required rest period should be made complementary to the maximum number of working hours permitted (based on cycles of 24 hours), it can be calculated that the minimum number of rest hours required should be 12 hours per period of 24 hours and 75 hours per week (excluding 48 hours in the weekend). It should be realised that the calculated values are merely to be seen as possibilities instead of 'scientific truth'. However, it can be argued that implementation and a 100% enforcement of the calculated 'new' norms should decrease the number of traffic accidents involving trucks with -theoretically speaking- 14% a year. Thus, purely from a traffic safety point of view, if current legalisation of working and rest periods is to be discussed, the norms that were presented in this paper should be taken into careful consideration.

In summary then, from a traffic safety point of view three major points can be derived from the results of the present study.

Firstly, regulations should state the maximum number of working hours permitted per period and not just the maximum number of driving hours permitted per period. Since this is the case in the current Dutch legislation but not in the current European legislation, it means that the European legislation should be adjusted by stating the maximum number of working hours per period.

Secondly, the longer the period, the more important it is to define and enforce safe norms regarding working, driving and rest periods. Consequently, both in the Netherlands as well as in the rest of Europe, enforcement of the legislation should be emphasized for periods of one week instead of periods of one day.

Finally, purely from a traffic safety point of view, the following norms can be recommended: maximum 12 hours of working time per period of 24 hours and 45 hours maximum of working time per period of seven days, while in both cases truck drivers should be required to rest in the remaining hours. It can be calculated that in theory implementation and a 100% enforcement of these norms should decrease the number of traffic accidents involving trucks by 14% a year. Therefore, when national or international agreements are to be made, these norms should be taken into careful consideration. In general, it can be said that the longer truck drivers are at work the greater the probability is that they will become for them to get involved in a traffic accident.

BIBLIOGRAPHY

Consent beleidsadvies bv. Evaluatie-experimenten arbeidssystemen in het goederenwegvervoer. Amsterdam: Consent beleidsadvies bv, 1991.

Hamelin, P.. Les conditions temporelles de travail des conducteurs routiers et la sécurité routière. Travail Humain. 1981, 44. 5-21.

Kayser, R.E., and Roelofs, E.C.. Basisdocument Zwaar Verkeer. Veenendaal: Traffic Test bv, 1991.

Nairn, R.J. and partners. The role of fatigue in rural accidents. Hawthorn: Road Traffic Authority, 1987.

Ouwerkerk, F. van, Relationships between road transport working conditions, fatigue, health and traffic safety. Haren: Traffic Research Centre Rijksuniversiteit Groningen, 1987.

Rijksverkeersinspectie. Controleresultaten 1988. Den Haag: Ministerie van Verkeer en Waterstaat, 1989.

Stein, H.S. and Jones, I.S.. Crash involvements of large trucks by configuration: a case-control study. Washington: Insurance Institute for Highway Safety, 1987.

Tromp, J.P.M. Ongevallen met zware voertuigen. Een vergelijking van gegevens uit Nederland, Europa en de Verenigde Staten. Leidschendam: SWOV, 1988.