9QE
P 63

M.L.I. Pokorny
D.H.J. Blom
P. van Leeuwen

ANANLYSIS OF TRAFFIC ACCIDENT DATA (FROM BUSDRIVERS)
- AN ALTERNATIVE APPROACH (I) and (II) -

NETHERLANDS INSTITUTE FOR PREVENTIVE HEALTH CARE / TNO
LEIDEN - THE NETHERLANDS

ANALYSIS OF TRAFFIC ACCIDENT DATA (FROM BUSDRIVERS) - AN ALTERNATIVE APPROACH (I)

M.L.I. Pokorny*, D.H.J. Blom** and P. van Leeuwen***

Netherlands Institute for Preventive Health Care / TNO
(Director: Dr. M.J. Hartgerink)
P.O. Box 124, 2300 AC Leiden - The Netherlands

ABSTRACT

The analysis of traffic accident data of busdrivers presented in these two papers, forms an integral part of a major project, focussing on the effect of the busdriver's task on the performer. The accidents were thought to be a possible indicator for this effect.
Data were obtained from the accident-archives of a bus company, together with additional information about the work organization, circumstances at the time of accident, etc. A total of 944 documented accidents of 197 busdrivers in a 5-year period were available. The analysis starts by presenting the accident frequencies found at the hours of the day that buses are in operation (from 5.00 to 1.00 hr.).
A measure of exposure is then introduced, being the total number of kilometers driven during each hour of the day, and accident rates are constructed for the same hour (number of accidents per 100,000 km). It is shown that part of the variability between the accident frequencies at various hours of the day can be explained by the different exposure. In the next part of the analysis the data are divided into different organizational groups, according to the type of shift (early - late - "broken" shifts). It is shown that the three shifts differ significantly with regard to their mean overall accident rate: Early: 3.39 acc/100,000 km; Late: 2.47; Broken: 3.08; $\chi^2_{(2)} = 16.03$ ($p < 0.001$). This result is quite interesting, because it can be regarded as an effect of the shift itself: These shifts were performed by all busdrivers on all buslines on rotating schedules, therefore each driver had the same conditions regarding shifts, buslines, kilometers driven, and the like.
The main difference between these shifts (apart from certain aspects of the broken shift) can be seen as their occurrence at a different stage of the day. It is shown that also *within* the three shifts a significant difference exists in the overall accident rates between groups, selected with regard to their starting hour: Within the early shift five groups could be selected (starting 5.00 hrs to 9.00 hrs respectively) with different overall accident rates ($\chi^2_{(4)} = 284.5$; $p < 0.001$); within the late shift four groups (starting 13.00 hrs to 16.00 hrs) rates differing with $\chi^2_{(3)} = 35.41$ ($p < 0.001$) and within the "broken" shift two groups (starting 6.00 hrs to 7.00 hrs) rates differing with $\chi^2_{(1)} = 32.8$ ($p < 0.001$).
Within all three shifts the following conclusion can be drawn: The earlier a driver started working the higher was the overall accident rate.

---

*Psychologist **Physician/Epidemiologist ***Statistician

KEYWORDS

Accident rate; busdriver; data-organization; duration of service; hour (day); shiftwork (discontinuous); traffic accidents.

INTRODUCTION

Since 1977 a major project on effect measurement of a task on the performer is in progress at the Netherlands Institute for Preventive Health Care / TNO, Leiden - The Netherlands.
This project is carried out by the first two authors of this paper, together with C.H.J.M. Opmeer, psychologist.
We shall give here a brief outline of this project, of which our accident analysis forms a more or less independent part.

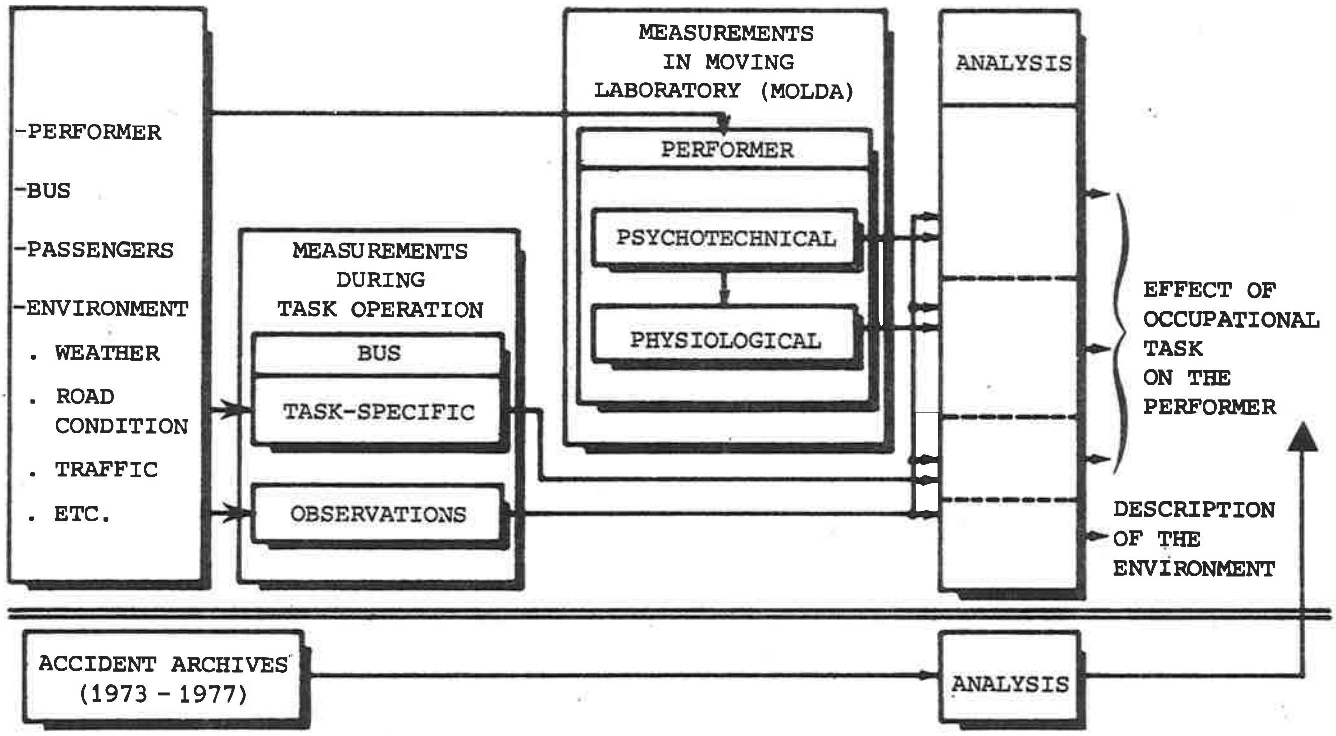

Fig. 1. Scheme of the total project

The main purpose of this study is the construction and testing of possibly useful methods to measure the effect of an occupational task on the performer. For practical reasons at the beginning of the project the task of a busdriver was chosen as input variable.
This task is carried out under different conditions of work by men of various ages. Therefore the experimental design includes three types of shift (early, late and "broken")[1], two different environmental conditions of service (urban vs. rural) and two age groups (younger vs. older busdrivers). Additionally, measurements are carried out under work-free conditions (day-off). Measurements under each of the above-named conditions are repeated once. This means that (together with one day for training) each subject is followed during a 3-week period (3 x 5 working days). The schedule of measurements is therefore: (3 x 2 + 1) x 2 for two age groups of ten subjects each.

[1]This will be explained later on in this paper.

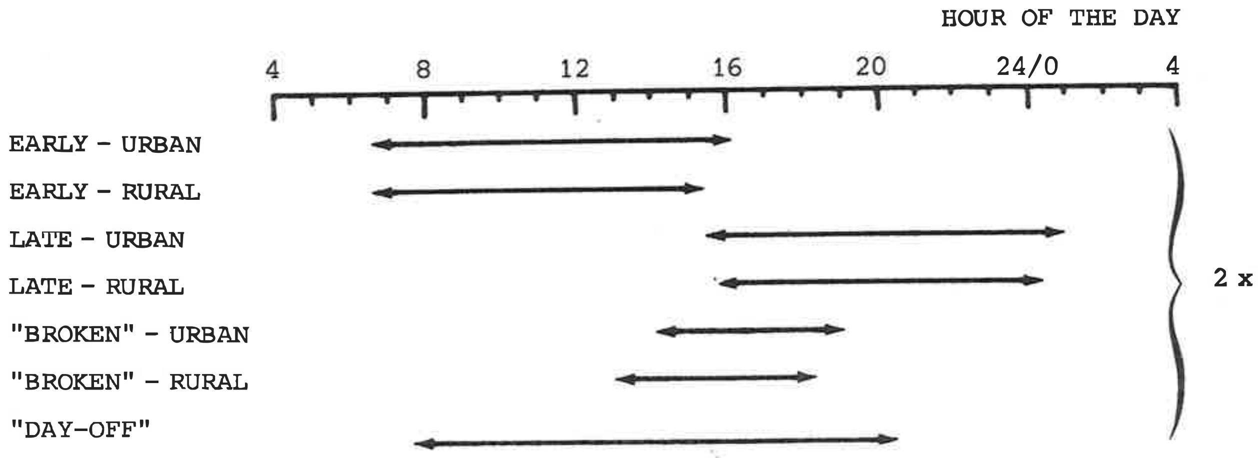

Fig. 2. Experimental design for one subject

Indicators used for estimation of the effect of the task include physiological, psychotechnical and task-specific measurements. We assume that the task has a cumulative effect on the performer and that this effect on the organism will last long enough to be measured some time after performing the task. Under this assumption the physiological and psychotechnical measurements can be carried out during a number of measuring blocks before the task, during some of the restperiods and after finishing the service. These measurements are done in a specially equipped moving laboratory (Mobile Laboratory for the Driving-task-effect Assessment: MOLDA) designed for this purpose. Of course the task-specific measurements are carried out during the taskoperation. Additional information to facilitate interpretation of the results is obtained by observation of events in and around the bus.
In these two papers we will concentrate on the accident analysis only; the other aspects of this study will be the subject of a different series of reports.

MATERIAL

One of the possible indicators for the influence of task performance under different conditions on the driver could be the number of accidents occurring under these conditions. Investigations of the archives of the buscompany where the experiments are taking place, revealed a good deal of information about all accidents that occurred in that company in the period 1973 through 1977. Additional information about workorganization, circumstances at the time of the accident such as busroute, direction, time of the day, type of shift etc., personal data of the busdriver (age, years of service etc.) could be collected for most of the 944 accidents. From various sources within the company we were able to obtain additional data which enabled us to analyse our material in more detail.
A total of 822 accidents was available for this detailed analysis (sometimes 742, when the hour of the day also is considered).
Here an accident is operationally defined as an event of damage to a bus or by a bus, which needed to be reported to the insurance company. In practice this means nearly all accidents of a bus, including the very minor ones.
The analysis of the accident data as presented here was possible because all drivers in this buscompany perform all duties on rotating schedules, therefore each driver has the same exposure regarding shifts, busline, kilometers driven, hours of service, etc. In other words - and this is important to note - they could be regarded as a homogeneous group with respect to exposure. In this paper (and the following one) only some of the results of our analysis and of the methods used will be presented. In due time the full report will be available on request.

HOUR OF THE DAY AND ACCIDENTS

It is clear that in order to analyse the impact of certain organizational or other aspects of the work on a busdriver one must be aware of possible influences of time itself and its related external factors (like traffic density, daylight or darkness etc.) and internal factors (like a possible effect of a circadian rhythm).
In the following Table and Fig. we present the relative accident frequencies at various hours of the day - between 5.00 hrs in the morning and 1.00 hrs at night - the time the bus services are operating.

TABLE 1 Accident Frequency per Hour of the Day

HOUR	ACCIDENT FREQUENCY	
	ABSOLUTE NUMBERS	RELATIVE (%)
5.00- 5.59 = 5	2	0.3
6.00- 6.59 = 6	10	1.3
7.00- 7.59 = 7	45	6.1
8.00- 8.59 = 8	68	9.2
9.00- 9.59 = 9	55	7.4
10.00-10.59 = 10	50	6.7
11.00-11.59 = 11	34	4.6
12.00-12.59 = 12	33	4.5
13.00-13.59 = 13	41	5.5
14.00-14.59 = 14	69	9.3
15.00-15.59 = 15	53	7.1
16.00-16.59 = 16	81	10.9
17.00-17.59 = 17	77	10.4
18.00-18.59 = 18	39	5.3
19.00-19.59 = 19	21	2.8
20.00-20.59 = 20	20	2.7
21.00-21.59 = 21	13	1.8
22.00-22.59 = 22	10	1.3
23.00-23.59 = 23	15	2.0
0.00- 0.59 = 0	6	0.8
TOTAL	742	100.0

$\chi^2_{(19)} = 313.4$ $p < 0.001$

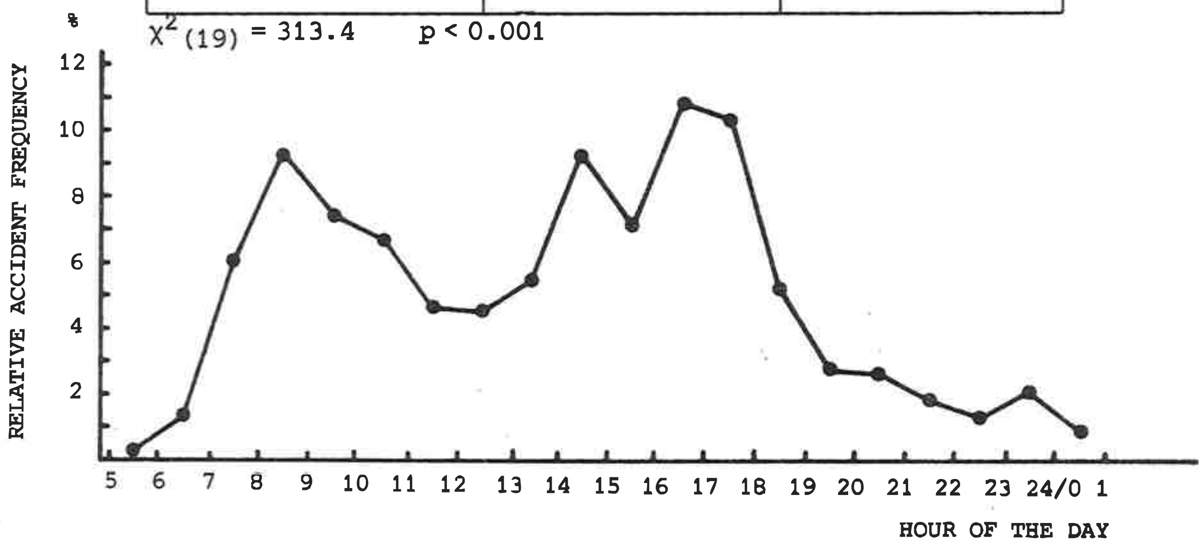

Fig. 3. Relative accident frequency per hour of the day (in %)

This picture is not very surprising: As already known the observed number of accidents during the different hours of the day is different ($\chi^2_{(19)} = 313.4$). The observed variability is related to the variability of the traffic density. Apparently accidents with buses follow the general pattern of all traffic accidents, as shown in many traffic accident statistics.

EXPOSURE

With entering the garage of the buscompany at various hours of the day one sees immediately the variability in the number of buses present at any time. Early in the morning, in the middle of the day and late at night the garage is more or less full. At the hours of greatest traffic density, however, the garage is completely empty. Of course the reverse can be said about the number of buses out on the road, the number of drivers at work and the resulting numbers of kilometers driven by them, or numbers of manhours, etc. The number of kilometers driven at each hour, on each line, in each service, etc., could be estimated[2] because these data were either actually available (kilometers per line) or could be estimated, using the structure of the services. The number of kilometers driven for each hour of the day is now used as an estimator of the exposure of the buses and drivers to the risk of incurring a traffic accident. In other words: When at a certain hour of the day many bus accidents are recorded this can be a mere expression of the large number of buses on the road during that hour, and does not necessarily reflect a greater accident risk at the same hour[3].

ACCIDENTS, HOUR OF THE DAY AND EXPOSURE

The rate of accidents per 100,000 km which occurred during the 5-years' registration period at each hour of the day was calculated.
In Table 2 and Fig. 4 we present these data.

TABLE 2 Accident Rates per Hour of the Day

HOUR	ACCIDENT RATE (ACC/100,000 KM)	HOUR	ACCIDENT RATE (ACC/100,000 KM)
5.00- 5.59 = 5	1.9	17.00-17.59 = 17	3.7
6.00- 6.59 = 6	1.5	18.00-18.59 = 18	2.1
7.00- 7.59 = 7	3.2	19.00-19.59 = 19	1.6
8.00- 8.59 = 8	3.9	20.00-20.59 = 20	1.8
9.00- 9.59 = 9	3.3	21.00-21.59 = 21	1.3
10.00-10.59 = 10	3.5	22.00-22.59 = 22	1.0
11.00-11.59 = 11	2.5	23.00-23.59 = 23	1.7
12.00-12.59 = 12	2.3	0.00- 0.59 = 0	1.2
13.00-13.59 = 13	2.3		
14.00-14.59 = 14	3.5	TOTAL (N = 742)	2.97
15.00-15.59 = 15	2.5		
16.00-16.59 = 16	3.7		

$\chi^2_{(19)} = 79.53$ $p < 0.001$

[2] For the exact methods used for calculation of the kilometers one can consult the full report (being published).

[3] The same type of measure for exposure was used for instance by Borkenstein comparing accident fatalities of various countries (Borkenstein, R.F. An overview of the problem of alcohol, drugs and traffic safety. In: Proceedings of the Seventh International Conference on Alcohol, Drugs and Traffic Safety. Melbourne, Victoria, 23-28 January 1977. Canberra, Australian Government Publishing Service, 1977).

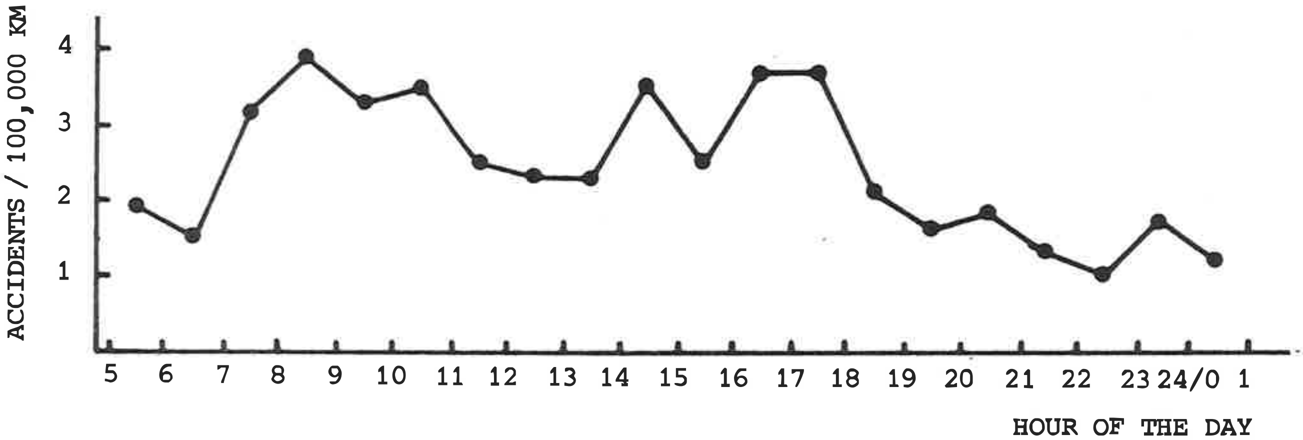

Fig. 4. Accident rates per hour of the day

When we compare Fig. 3 and 4 the overall variability of the relative accident frequencies (Fig. 3) is much greater than the overall variability of the accident rates at the different hours of the day. In other words we can conclude that a part of the variability can be explained by a different exposure of buses to the risk of getting an accident at different hours of the day, and we consider that any further analysis of differences between hours, duties, etc. needs to be based on accident rates per 100,000 km rather than on relative accident frequencies.

THREE DIFFERENT SHIFTS

As was stated in the introduction one of our experimental variables is the type of shift of the driver.
In the buscompany at issue three different types of shift can be distinguished:
1) Early shift: a shift with a mean duration of 8 hrs; starting between about 5.30 hours and 10.00 hours.
2) Late shift: a shift with a mean duration of 8 hrs; starting between 13.00 hours and 17.00 hours.
3) "Broken" shift: a compound shift, consisting of two parts. The first part starting at about 6.00 hours to 8.00 hours and lasting for about three hours; the second part starting between 13.00 hours to 15.00 hours and lasting for about five hours. This means that a person on a "broken" shift starts working early in the morning for a shorter part of his shift, is off duty for three to four hours and then starts working again in the afternoon for the second (longer) part of his shift.

For each shift separately the number of kilometers driven is available. This enabled us to calculate accident rates for these shifts separately. These rates are given in Table 3.

TABLE 3 Accident Rates of the Early, Late and "Broken" Shifts

SHIFT	ACC/100,000 KM
EARLY	3.39
LATE	2.47
"BROKEN"	3.08

N = 822 $\chi^2_{(2)} = 16.03$ $p < 0.001$

Apparently, the early shift gives the highest accident rate, the late shift the lowest, while the broken shift gives an intermediate value. These differences are statistically significant ($\chi^2_{(2)} = 16.03$, $p < 0.001$). As we have seen above the bus-drivers can be regarded as one group, having all the same exposure to types of shift etc. Therefore it can be concluded that the differences of accident rates between the shifts are probably related to the type of shift itself, rather than to differences between the drivers.

DIFFERENT SUBGROUPS WITHIN THE EARLY, LATE AND "BROKEN" SHIFTS

Pursuing this line of investigation and keeping in mind the different overall accident rates, we took into account that the main difference between these shifts (apart from some special characteristics of the "broken" shift) is their occurrence at a different period of the day. In the previous paragraph we mentioned that, for example, the early shifts started between 5.00 and 10.00 hours, so not all at the same time. In fact five subgroups could be selected within the early shifts, the first group starting between 5.00 and 6.00 hours, the second starting between 6.00 and 7.00 hours, the third between 7.00 and 8.00 hours, the fourth between 8.00 and 9.00 hours and the fifth between 9.00 and 10.00 hours.
In the same way subgroups with a different starting hour could be selected within the late shifts (four subgroups starting from 13.00 to 14.00, 14.00 to 15.00, 15.00 to 16.00 and 16.00 to 17.00 hours respectively) and within the "broken" shifts (two subgroups starting from 6.00 to 7.00 hours and from 7.00 to 8.00 hours respectively).

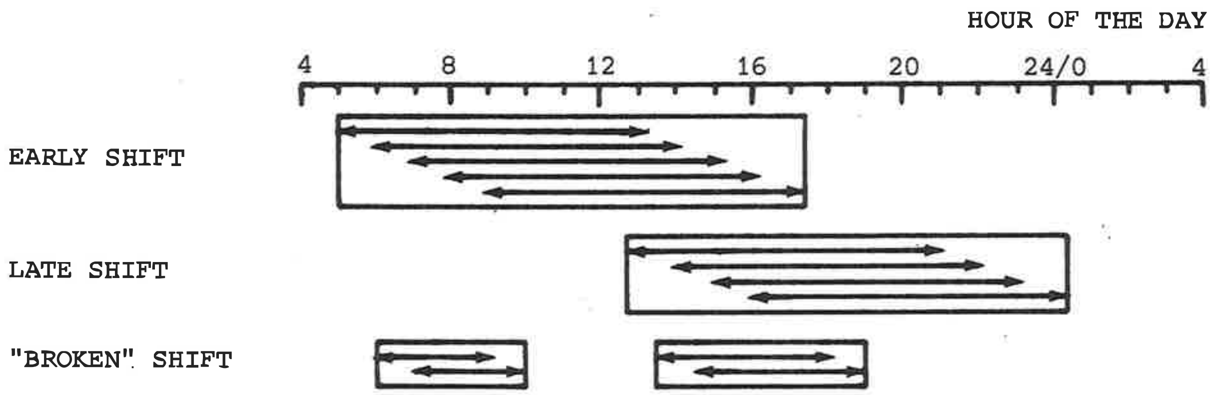

Fig. 5. Subgroups within the early, late and "broken" shifts

Investigation of the overall accident rate of all these subgroups of the shifts proved rewarding. The overall accident rates for each subgroup separately were calculated. The results are shown in the Table 4 and Fig. 6.
Within each shift subgroups differ statistically highly significant with regard to their overall accident rates: The five groups of the early shift differing with $\chi^2_{(4)} = 284.5$ ($p < 0.001$); the four groups of the late shift with $\chi^2_{(3)} = 35.41$ ($p < 0.001$); and the two groups of the "broken" shift with $\chi^2_{(1)} = 32.8$ ($p < 0.001$).

TABLE 4 Accident Rates of the Subgroups with Different Starting Hour. Early, Late and "Broken" shifts

STARTING HOUR OF SUBGROUP[4]		5	6	7	8	9
EARLY SHIFT	number of accidents	75	180	51	14	16
	kilometers driven	782300	2775500	3032800	2499700	1333500
	accident rate	9.58	6.48	1.68	0.56	1.19

$\chi^2_{(4)} = 284.5$ $p < 0.001$

STARTING HOUR OF SUBGROUP		13	14	15	16
LATE SHIFT	number of accidents	51	63	83	37
	kilometers driven	1136100	2116100	4135400	2491500
	accident rate	4.48	2.97	2.00	1.48

$\chi^2_{(3)} = 35.41$ $p < 0.001$

STARTING HOUR OF SUBGROUP		6	7
BROKEN SHIFT	number of accidents	96	50
	kilometers driven	2131100	2904800
	accident rate	4.50	1.72

$\chi^2_{(1)} = 32.8$ $p < 0.001$

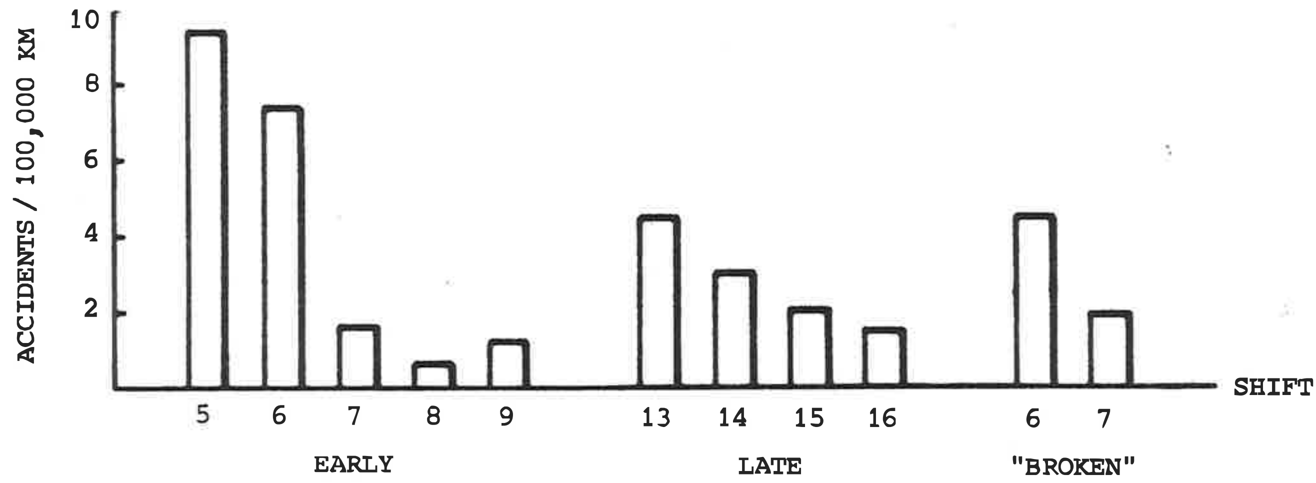

Fig. 6. Accident rates of the subgroups within the early, late and "broken" shifts

Two conclusions can be drawn at this stage:

1) The starting hour of the shift is strongly associated with the accident risk of that shift.
2) The earlier one started working within a certain type of shift, the higher was the overall accident rate.

An attempt to interpret this result is made at the end of next paper.

---

[4]Starting hour "5" means: Starting between 5.00 and 6.00 hrs, etc.

ANALYSIS OF TRAFFIC ACCIDENT DATA (FROM BUSDRIVERS) - AN ALTERNATIVE APPROACH (II)

M.L.I. Pokorny*, D.H.J. Blom** and P. van Leeuwen***

Netherlands Institute for Preventive Health Care / TNO
(Director: Dr. M.J. Hartgerink)
P.O. Box 124, 2300 AC Leiden - The Netherlands

ABSTRACT

In the previous paper the different overall accident rates were discussed *between* various shiftgroups with different starting hours. This paper is focussed on differences *within* these groups. Of course the same type of construction of traffic accident rates is used as in the first paper (number of accidents / 100,000 km), but now the pattern of these rates during the different hours of the day and the different hours of service is analysed. It will be recalled that the various hours of the day had different accident rates. Analysis of the data from above mentioned groups (with different starting hours) now shows that every group had at the same time of the day a very different accident rate.
Therefore, it can be concluded that the hour of the day itself (and related external factors like traffic density, etc., and internal factors such as circadian rhythm effects, etc.) seem *not* to have a substantial influence on the accident risk, according to our data.
On the other hand it is shown that characteristic patterns in accident rates exist in the starting hour groups (subgroups of the shifts). These patterns are related, again, to the starting hour of the shift (pattern-level) and to the type and duration of the shift itself (pattern-form).
Summarizing the conclusions it can be said that, in our material, the major part of the variability between bus accident risks during the day can be explained by:
1. Differences in exposure (number of kilometers); 2. Starting hour of the shift;
3. Type of shift and duration of service.

KEYWORDS

Accident rate; busdriver; data-organization; duration of service; hour (day); shiftwork (discontinuous); traffic accidents.

THE HOUR OF THE DAY

It will be recalled that different accident rates were associated with the different hours of the day (Fig. 4 and Table 2 of the first paper). On the other hand we have shown that the three shifts - and also within these shifts their various

---

*Psychologist **Physician/Epidemiologist ***Statistician

starting-hour-subgroups - had different overall accident rates.
Let us consider for instance the difference between early and late shifts. (Early shift: 3.39 acc/100,000 km. Late shift: 2.47 acc/100,000 km. N = 822.) An obvious explanation could be that after 19.00 hrs a generally low level of accident rates exists, whereas a large part of the late shifts is performed in that period of the day. This may be part of the explanation, but let us now consider some of the subgroups. We take, for instance, the late shift subgroup starting between 16.00 and 17.00 hrs. The major part of this group's services takes place after 19.00 hrs; the overall accident rate of this subgroup is low indeed, 1.48 acc/100,000 km. However, when we take together the early subgroups starting between 8.00 and 9.00 hrs and between 9.00 and 10.00 hrs, it must be said that these services are completed before 19.00 hrs, performed in a period with generally high accident rates, and not yet in operation in the very early hours, also with low accident rates. Their overall accident rate is 0.78 acc/100,000 km, while the mean overall accident rate during the period between 7.00 hrs and 19.00 hrs (arbitrarily chosen) is 3.21 acc/ 100,000 km. We can see now that a low mean accident rate can be found not only at evening time, but also during the day in certain specified groups. Whereas other groups at that same period of the day have much higher accident rates, for instance the starting-hour-subgroups 5 and 6 (starting between 5.00 and 7.00 hrs) of the early shifts together have a mean accident rate of 7.16 acc/100,000 km (See Fig. 1).

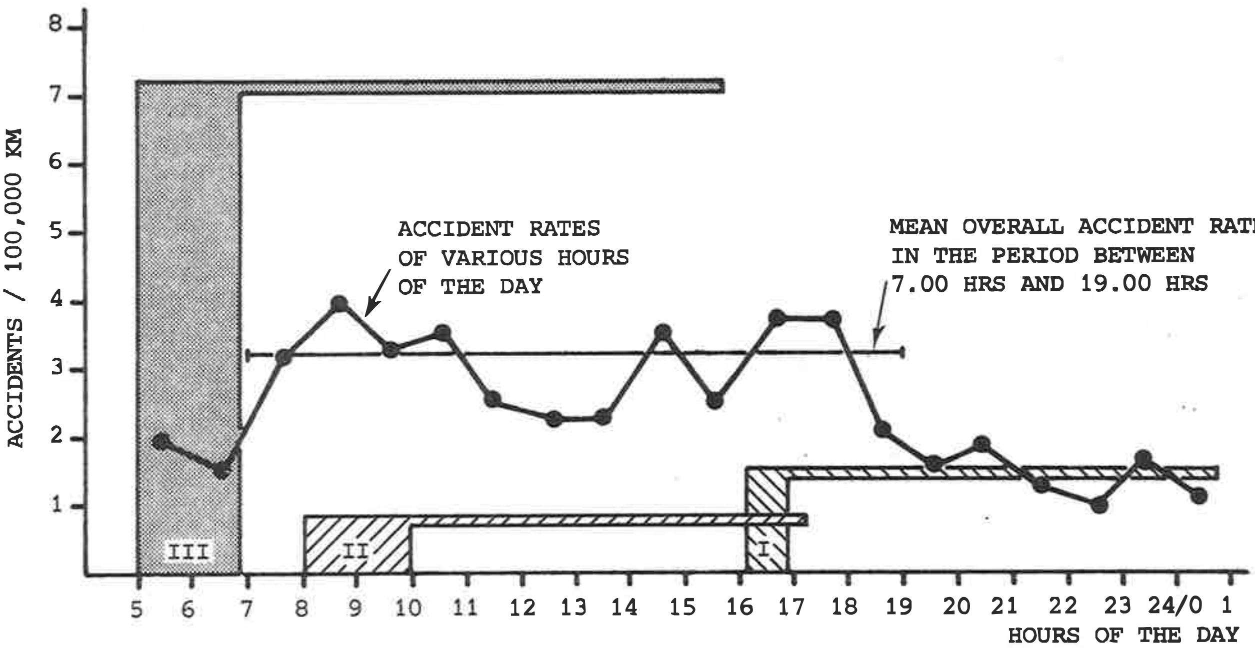

Fig. 1. Accident rates of various hours of the day; mean overall accident rate in the period between 7.00 hrs and 19.00 hrs and mean overall accident rate of late shift subgroup starting between 16.00 hrs and 17.00 hrs and early shift subgroups starting between 8.00 and 10.00, and 5.00 and 7.00 hrs

Mean overall accident rate of:
I = subgroup starting between 16.00 hrs and 17.00 hrs (late shift)
II = subgroups starting between 8.00 hrs and 10.00 hrs (early shift)
III = subgroups starting between 5.00 hrs and 7.00 hrs (early shift)

These and other[1] possible examples illustrate our general conclusion that the influence of time of the day on accident risks becomes very unclear when other

[1]For instance Table 4 in the first paper.

parameters like type of shift and starting hour are introduced.
Therefore it is our conclusion that the pattern of accident rates over the hours of the day is a very compound parameter, where time of the day itself (and related external factors like traffic density, daylight or darkness, etc., and internal factors such as a possible circadian rhythm effect etc.) seems to be only one of the possible components.

DURATION OF THE SERVICE

From the point of view that the hour of the day as such is not a very useful parameter for comparing variable accident risks over the day, and also that the shifts and their subgroups are important explanatory variables, the logical step seems to be to consider hours of service within the subgroups for analysis of the influence of time and duration of service.

The Early Shift and its Subgroups

The early shifts start between 5.00 and 10.00 hrs.
We were able to calculate separate accident rates for each hour of service within three of the five subgroups, viz. the subgroups starting between 5.00 and 6.00, 6.00 and 7.00 and 7.00 and 8.00 hrs respectively. The data of these three subgroups are given in Table 1 and Fig. 2. During the services of these subgroups 80% of the accidents occurred and 59% of the kilometers were driven.

TABLE 1 Early shift. Accident Rates for Each Hour of Service within Subgroups Starting between 5.00 and 6.00, 6.00 and 7.00 and 7.00 and 8.00 Hrs Respectively

SUBGROUPS STARTING HOUR			DURATION OF SERVICE (IN HOURS)										
			1	2	3	4	5	6	7	8	9	10	TOTAL
5-6	A		4	5	16	10	9	9	9	4	8	1	75
	B		76300	86900	81400	91400	83500	94100	92600	92000	68100	15900	782300
	C		5.24	5.75	19.66	10.94	10.77	9.56	9.72	4.35	11.74	----	9.58
6-7	A		13	24	22	36	20	11	20	14	16	4	180
	B		301200	316200	316400	323700	325600	325500	326400	308800	193600	38000	2775500
	C		4.31	7.59	6.95	11.12	6.14	3.38	6.13	4.53	8.26	10.52	6.48
7-8	A		2	4	4	13	6	2	7	10	3	-	51
	B		347400	347000	355300	357900	358700	358600	357100	319300	206400	25000	3032800
	C		0.58	1.15	1.13	3.63	1.67	0.56	1.96	3.13	1.45	----	1.68

A: number of accidents occurred
B: number of kilometers driven
C: accidents per 100,000 km

As expected, the data show different levels for the three subgroups. But it is important to note that these different levels exist more or less throughout the duration of the whole service. On the other hand a certain pattern of the accident rates can be distinguished; this is even more clear, when the data are displayed along a duration-of-service-axis.
Our next problem is whether it is permissable to take the data of these three subgroups together for analysis of the effect of duration of service on the accident risks. For this purpose we calculated the expected number of accidents, taking into account the pattern of kilometers driven for each subgroup and each hour of service. (The principles of the method used can be found in I.N. Darroch and D. Ratcliff - Generalized iterative scaling for log-linear models. The Annuals of Mathematical Statistics, Vol. 43, No 5, October 1972.) Differences between observed and expected

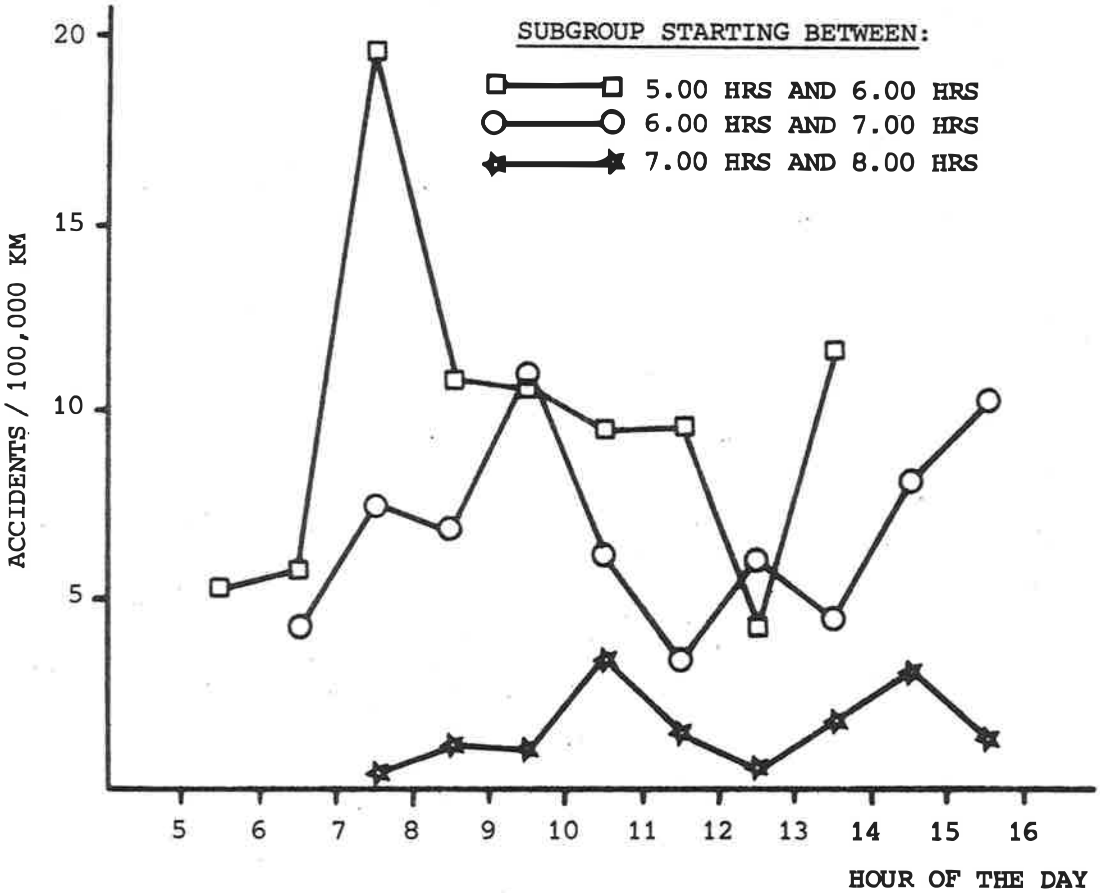

Fig. 2. Early shift. Accident rates for each hour of service within subgroups starting between 5.00 and 6.00, 6.00 and 7.00 and 7.00 and 8.00 hrs respectively on an hour-of-the-day-axis

numbers of accidents result in a χ^2 of 24.79 (with 16 DF).
The p-value of this χ^2 is between 0.05 and 0.10. This seems to reflect a slight difference between the subgroups data, but considering the separate cells of the 3 x 9 matrix it is obvious that only a few are in fact contributing to this χ^2-value. Therefore, we can conclude that the differences between the subgroup data are minimal, and we are allowed to take them together for consideration of the pattern of accident risks during the service.
For this pattern of the early shift accident rates we took the mean accident rate at a certain hour of service for the three subgroups.
These mean accident rates are simple arithmetic, unweighted means. The pattern of these mean accident rates is shown in the next figure (Fig. 3, see next page). We will discuss the characteristics of this pattern later on.

The late shift and its subgroups

The same type of analysis is used for the late shifts. It will be recalled that four subgroups could be selected. During the services of these four subgroups 88% of the accidents occurred and 91% of the kilometers were driven. Our following figure and table (Fig. 4 and Table 2) show the accident rates for each hour of service and each subgroup. In the figure (Fig. 4) we present the data on an hour-of-the-day-axis.

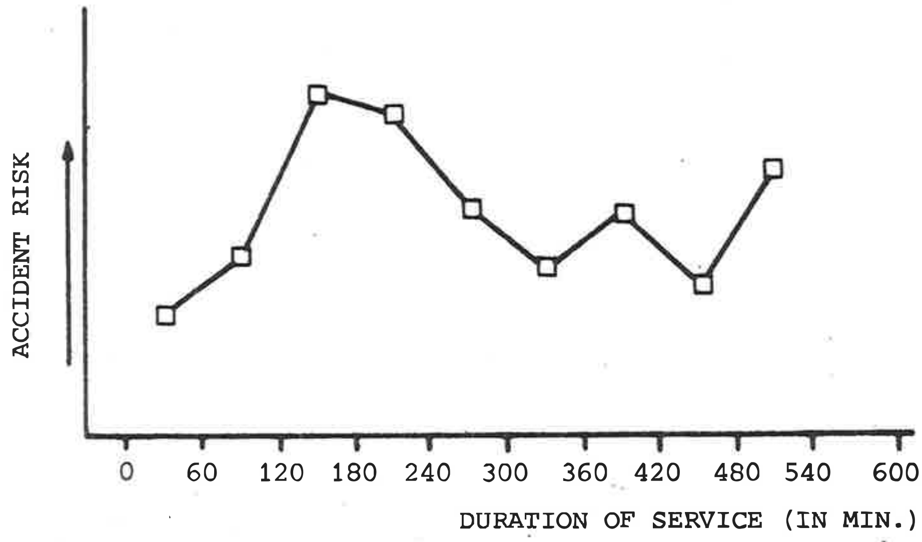

Fig. 3. Early shift. Pattern of the mean accident rates

TABLE 2 Late Shift. Accident Rates for Each Hour of Service within Subgroups Starting between 13.00 and 14.00, 14.00 and 15.00, 15.00 and 16.00 and 16.00 and 17.00 Hrs Respectively

SUBGROUPS STARTING HOUR		DURATION OF SERVICE (IN HOURS)										
		1	2	3	4	5	6	7	8	9	10	TOTAL
13-14	A	14	7	9	11	7	1	-	2	-	-	51
	B	116500	126800	128600	167100	183600	178100	138300	55500	26500	15100	1136100
	C	12.02	5.52	7.00	6.58	3.81	0.56	----	3.60	----	----	4.48
14-15	A	9	7	14	6	6	6	3	7	5	-	63
	B	184000	187500	241300	263600	271300	253800	237500	202800	181500	92900	2116100
	C	4.89	3.73	5.80	2.28	2.21	2.36	1.26	3.45	2.75	----	2.97
15-16	A	10	17	12	13	9	3	6	5	8	-	83
	B	327700	422700	462500	480200	496800	498500	474400	469500	456100	46900	4135400
	C	3.05	4.02	2.59	2.71	1.81	0.60	1.26	1.07	1.75	----	2.00
16-17	A	7	10	7	4	3	1	3	1	1	-	37
	B	225400	249500	258800	268000	273300	262400	259300	295600	399200	-----	2491500
	C	3.11	4.01	2.70	1.49	1.10	0.38	1.16	0.34	0.25	----	1.48

A: number of accidents occurred
B: number of kilometers driven
C: accidents per 100,000 km

Similar to the early shift a certain pattern of the accident rates can be distinguished in all of the different subgroups within this shift.
Analysis of differences between the data of the subgroups with regard to the pattern of the accident risks during the service is performed similarly to the early shift analysis. This resulted in a total χ^2 of 27.24 (24 DF, $p > 0.25$).
Consideration of the various cells of the 4×9 matrix shows a fairly equal and small contribution of all cells to this χ^2-value.
Therefore we are also allowed for the late shifts to take the data of the subgroups together for analysis of the pattern of accident risks during the service.
Calculation of the mean accident rates at each hour of service gives the following picture (Fig. 5), which will be discussed later on.

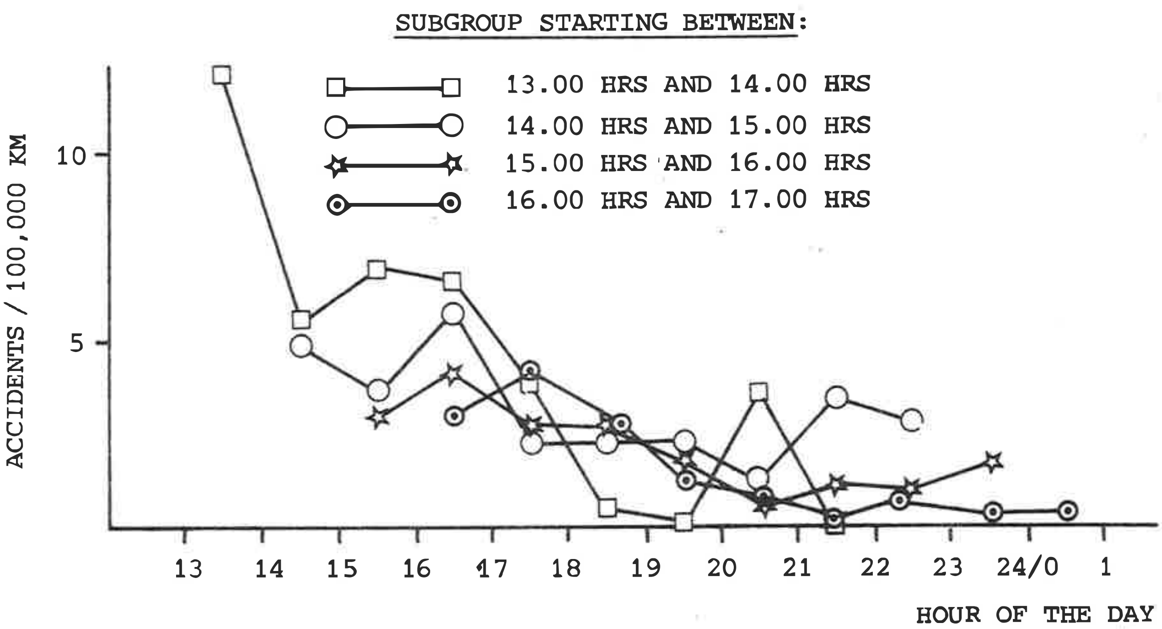

Fig. 4. Late shift. Accident rates for each hour of service within subgroups starting between 13.00 and 14.00, 14.00 and 15.00, 15.00 and 16.00 and 16.00 and 17.00 hrs respectively on an hour-of-the-day-axis

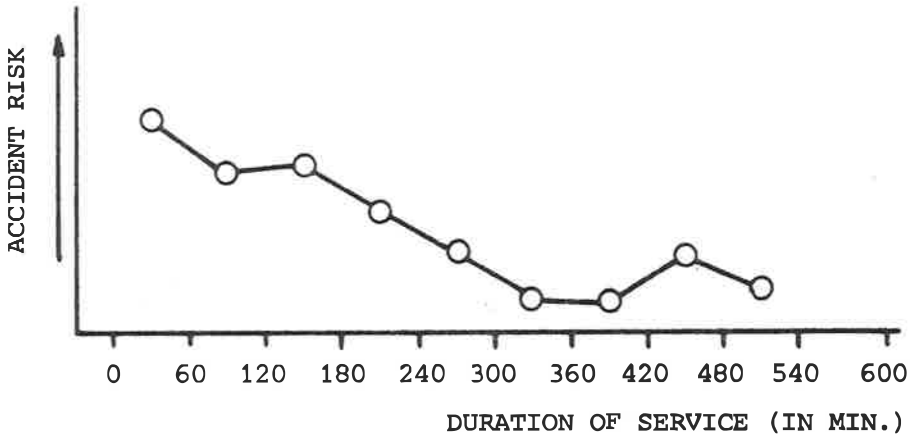

Fig. 5. Late shift. Pattern of the mean accident rates

The broken shift

With respect to the broken shifts it must be said, that duration of service of these shifts is not completely comparable with duration of service of the other two types of shift, because this service is discontinuous, as was shown in the previous paper. In this paper we will restrict the analysis to the continuous shifts with respect to effects of duration of service.

COMPARISON OF PATTERNS OF EARLY AND LATE SHIFTS

The next question is whether it is permissible to take these two shifts together for examination of the influence of duration of service on accident risks.
We compared again the observed and expected values at each hour of service for the early and late shifts, taking into account the differences between the starting

hours. The resulting χ^2 (with 8 DF) was 44.19 ($p < 0.001$) and our conclusion is therefore that each shift must be examined separately, due to large differences. Figure 6 shows the pattern of the accident rates for the early and late shifts.

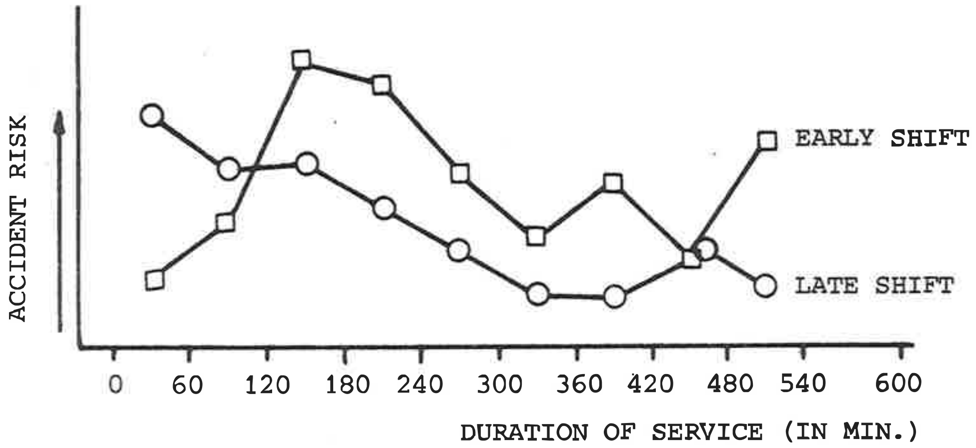

Fig. 6. Early and late shifts. Patterns of the mean accident rates

We conclude that two different patterns of accident rates during the service exist, dependant on the type of shift. Generally speaking higher accident rates in the late shift are found only at the beginning of the service, followed by a continuous fall, while in the early shift peak accident rates are seen at the third and fourth hour and slightly less at the end of service.

CONCLUSIONS

Summarizing the conclusions of the two papers it can be said that a different number of kilometers driven at the various hours of the day explain part of the variability in our material.
The results of the analysis presented in the previous paragraphs are confirmed by the analysis of variance[2] shown in the next table (Table 3). A very important explanatory variable is the type of shift. In the first paper the significant difference between the early, late and broken shifts was shown. This is confirmed here by the highly significant difference between early and late shift in our analysis of variance.
The following very important factor seems to be the starting hour of subgroups within each shift. Again this is confirmed in this analysis of variance.
This has brought us to the conclusion that the hour of the day as such does not seem to have a substantial impact on accident risks, but that a major part of the variability of bus accident risks during the day can be explained by type of shift and starting hour of the service. It will be recalled that the earlier one started working within the different shifts, the higher was the overall accident rate.
On the other hand different patterns of accident rates during the service were shown, dependant on the type of shift. Again, this is confirmed by the analysis of variance, where hour of service and interaction of type and duration of shift seem to be significant explanatory variables.

---

[2]The data used for the analysis of variance are: accidents per 100,000 km.

TABLE 3 Analysis of Variance[3]

	DF	MEAN SQUARE	F
TOTAL	62	14.178	
RESIDU	40	4.808	
MAIN EFFECTS:			
Shifts (Early vs. Late)	1	154.959	32.23**
Starting Hour	5	67.003	13.94**
Service Duration	8	12.079	2.51*
INTERACTION:			
Shifts x Service Duration	8	12.510	2.60*

*$p < 0.05$ **$p < 0.001$

DISCUSSION

The implications of these results for our project are quite interesting.
Assuming that accident statistics have a certain value as indicators for the effects of different tasks, we can conclude that the type of shift and even the different starting hour within each type of shift, do influence the effect of the task on the man.
We might interpret this result in the sense that the state of the organism before and/or at the beginning of the task can modify the task effect significantly at any particular time of the service. On the other hand it is possible that the attitude of the worker at the beginning of a task is important. These factors could be interpreted as having a relatively long-term influence.
Furthermore, the differences between the shifts with regard to the pattern of accident risks during the services, could be seen in our opinion as representing relatively short-term aspects of the task effect.
Possibly the results of the experimental part of our project will provide more insight into the underlying mechanisms involved.

[3]Program name: VARIAN. Original authors: Kwaaitaal and Roskam (University of Nijmegen, NL). Rewritten by J. Gerkema (NIPG / TNO Leiden, NL).