Transactions on the Built Environment vol 16, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509

# Effect of driver fatigue on truck accident rates

F.F. Saccomanno, M. Yu, J.H. Shortreed
*Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1*

## Abstract

A preliminary statistical link is established between truck driver fatigue and truck accident rates, where fatigue could be a contributing factor. Two criteria are used to identify driver fatigue in the police accident report: fatigue reported as a primary cause of the accident, and fatigue as inferred from the report using indirect measures, such as "driver being at-fault in a single vehicle accident". Truck accident rates are estimated for different fatigue criteria and linked to factors such as, hours of driving per day without rest, driving at night, and driving in remote areas. Significantly higher fatigue accident rates were obtained for driving longer than 9.5 hours per day without rest, for driving at night, and for driving in remote areas. These factors were found to have a cumulative effect on fatigue-related truck accident rates.

## 1 Driver Fatigue as a Safety Concern

Truck accidents typically result in a disproportionately large number of deaths and personal injuries. A major cause of these accidents is driver fatigue. In the 1950's, Prokop and Prokop reported that of 569 truck drivers surveyed 18% acknowledged to having fallen "asleep at the wheel" at one time or another in their careers (cited in McDonald, 1984). In a similar study carried out about two decades later, Tilley reported that of 155 truck drivers surveyed 64% were subject to some form of fatigue on a regular basis, and that about 10% of these drivers actually acknowledged to having been involved in at least one accident while affected by fatigue (cited in McDonald, 1984). A recent American Automobile Association study suggested that driver fatigue occurs on a routine basis on highways in the United States, especially where trucks are considered.

To reduce the incidence of driver fatigue in truck accidents a number of jurisdictions have introduced regulations limiting the hours of continuous driving to a maximum of 10 to 12 hours per day (Yu, 1994). The effectiveness of these types of regulations, however, has not been well established or researched, due in large part to a failure to establish a good empirical link between driver fatigue and accident propensity for different driver attributes and different driving conditions. In the absence of such a link, drivers will inevitably be guided by economic considerations to ignore fatigue-based regulations (Trimac, 1991). A clear and objective understanding of the link between fatigue and accident involvement is necessary, therefore, to develop effective fatigue mitigating strategies, that will be subject to industry-wide compliance and enforcement.

To establish such a link between driver fatigue and truck accident rates three steps need to be taken: 1) gaining a thorough understanding of the nature of driver fatigue and of the conditions under which it arises, 2) establishing objective and reliable methods for measuring fatigue, and 3) establishing a good empirical relationship between fatigue and truck accident involvement. The study reported in this paper applies this three step process to Ontario truck accident and exposure data.

## 2 Defining and Measuring Driver Fatigue

Grandjean (1988) *defines fatigue* in general terms as a "loss of efficiency or a disinclination to any kind of effort"; this disinclination can be muscular and/or mental in nature. Three types of fatigue are considered to have a special effect on truck driving performance: industrial, cumulative and circadian fatigue.

**Industrial fatigue** arises from working continuously over an extended period of time without proper rest. This type of fatigue is very likely to be the main cause of fatigue-related truck accidents. In their study of industrial fatigue in truck drivers, Mackie and Miller (1980) found that in over 65% of cases, truck accidents took place during the second half of a trip, regardless of trip length. The changeover from "less than expected" to "more than expected" numbers of accidents was found to take place at about 5 hours of continuous driving. On the basis of this evidence, the authors concluded that truck drivers were more predisposed to experience accidents during the latter stages of each trip and this was due in large part to the onset of industrial fatigue. A similar finding was reported by Matousek (1982), who recommended the scheduling of at least one rest stop for every 8 hour shift of continuous work. To be effective in reducing industrial fatigue, Matousek went on to suggest that each rest stop should be longer than 20 minutes in duration.

**Cumulative fatigue** arises from working for too many days on any protracted, repetitive task without any prolonged break. This type of fatigue manifests itself most often in a loss of alertness caused mainly by familiarization and boredom. Long distance truck driving, where shipments can take several days to complete, is especially susceptible to the onset of cumulative fatigue. Mackie and Miller (1985) suggested that cumulative fatigue is most problematic in journeys of six or more consecutive days. To reduce the incidence of cumulative fatigue, Matousek (1982) recommended periodic task rotation in order to regain interest in a particular activity such as driving, eg. drivers can be assigned to loading and unloading activities, or to paper work at the shipping depot, etc.

**Circadian fatigue**, the third type of fatigue affecting truck drivers, is caused by deviations from unique bio-rhythms in the body ... a physiological pre-disposition to work that favours regular daytime schedules over irregular nighttime work. Circadian fatigue is perhaps the most difficult to identify under normal driving conditions, because it is strongly influenced by a wide range of factors, such as, living habits, medical history of the driver, time of day, seasonal factors, availability of sunlight, etc. A survey of truck drivers subject to irregular hours of work found that 50% of accidents involving fatigue took place between midnight and eight in the morning (Mackie and Miller, 1985). Since only 19% of truck shipments were scheduled during this period, fatigue-related accident rates at night were reported to be 7 times higher than the daytime rates for similar road and traffic conditions. The main reason for these differences in accident rates was given as circadian fatigue. In his study of fatigue, Matousek (1982) noted that for many workers morning is the most productive time of the day, and that this productivity drops off sharply by evening and into the early morning hours before dawn.

Any empirical study attempting to establish a link between driver fatigue and truck accidents must first establish acceptable procedures for *measuring fatigue*. The most acceptable procedure for measuring fatigue is to monitor brain activity over an extended period of time using electroencephalography. In this approach, brain waves are classified into different rhythms, each rhythm reflecting a unique pre-disposition to certain types of response. For example, beta rhythms in the range 14-30 Hz reflect increased alertness or arousal reaction. (Grandjean, 1988) Light frequency can also be used to measure fatigue on the basis of subject response (eye flickers).

Using this procedure, researchers have found that perception/reaction time varies with the number of stimuli received. Reaction/perception time in a driving context includes the recognition of danger (for example an obstruction on the roadway ahead), decision on suitable response (whether to apply the brakes or to steer clear of the hazard) and finally, action taken (applying the brakes and coming to a controlled stop before impact).

## 3 Methodology

The detailed electroencephalography approach was not available for this study. Nevertheless, accident and exposure data were available that could yield indirect measures of driver fatigue, and provide some preliminary statistical evidence concerning the link between driver fatigue and truck accident rates, where fatigue is identified as a possible causal factor.

In this study, three relationships were tested to demonstrate the effect of driver fatigue on fatigue accident rates:

1. Regional factors (reflecting industrial and circadian fatigue)
2. Hours of driving (night or day) without rest (reflecting industrial fatigue)

and 3. Driving in night or day conditions (reflecting circadian fatigue)

Large truck accidents (at least one truck involved) were extracted from 1988-89 Ontario police reports for a sample of highway sections. These accidents were classified as fatigue accidents on the basis of two criteria:

a) Direct evidence on fatigue as reported by the police. Two conditions need to be satisfied: 1) single vehicle truck accidents where the driver was reported as being "at fault", **and** 2) the primary cause of the accident was ascribed by the police to truck driver fatigue. These accidents have been designated as "**fatigue-suspected**" accidents.

b) Less restrictive evidence that fatigue could be a contributing factor. Only one of two conditions in (a) needs to be satisfied.

Hours of driving profiles for night and day were estimated from the reported hours in the Ontario Commercial Vehicle Survey (CVS,1988) for each highway section containing a survey station. The CVS data provides information on commercial vehicle attributes at 72 representative stations located throughout the provincial highway network (42 southern region and 30 northern region stations). Used in conjunction with information on average annual daily traffic on each CVS section (obtained from the Ontario Traffic Volume Information System database), the procedure yields basic estimates of highway section hours of driving profiles (night and day) for all trucks in the traffic stream, ie. percentage trucks versus hours of driving from last rest stop. From these profiles, the 85th percentile hour was obtained on each CVS section (ie. the hour exceeded by 15% of all trucks in the traffic stream). **In using the CVS data to obtain section-specific 85th percentile hours of driving values, the basic assumption made is that conditions prevalent on the day of the survey at each CVS highway section remain in effect on the same section over the entire year.**

Analysis of Variance (ANOVA) and simple linear regression techniques were used to test the significance of the relationship between fatigue truck accident rates (for either of the two fatigue criteria defined

Transactions on the Built Environment vol 16, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509



above) and factors reflecting both industrial and circadian fatigue. Since the Ontario CVS data does not permit a tracking of shipments over several days, the effect of cumulative fatigue on accidents could not considered in this analysis.

## 4 Discussion of Results

Northern highway sections in Ontario are characterised by long stretches of remote two lane roads, where traffic volume are low, where trucks comprise a significant share of traffic, and where opportunities for rest along the route are limited. Southern highway sections, on the other hand, are characterised by shorter line haul distances, higher traffic volumes with lower percentage trucks and an increased opportunity for rest along the route. Conditions in the northern region appear to be more conducive to the on-set of industrial fatigue, and higher associated accident rates where fatigue is a contributing factor.

"Fatigue-suspected" accident rates for each CVS highway section were estimated for northern and southern regions. To increase the number of cases for analysis, accident and exposure data for both 1988 and 1989 were combined into a single data base.

The results of a simple one-way ANOVA (fatigue-suspected accident rates by region) are summarised in **Table 1**. An average fatigue-suspected accident rate of 0.237 accidents per million vehicle-kilometres was estimated for the northern region, which can be compared to a value of 0.114 accidents per million vehicle-kilometres in the southern region. These results suggest that conditions prevalent along more remote highway sections (longer distance driving, boredom) could be contributing to higher fatigue-suspected truck accident rates.

Fatigue-suspected accident rates were also estimated province-wide (northern and southern regions combined) for different hours of driving, expressed as the 85th percentile hour on each highway section. Fatigue-suspected truck accident rates do not increase uniformly at all hours of driving. A significant discontinuity (sharp increase) in the accident rate relationship was observed at 9.5 hours. Below the 9.5 hour value, fatigue-suspected truck accident rates were found to be relatively insensitive to changes in the hours of driving. The ANOVA results in **Table 2** suggest that significantly higher accident rates take place on sections where the 85th percentile hours of driving exceeds 9.5 hours. An average fatigue-suspected rate of 0.109 truck accidents per million vehicle-kilometres was obtained for less than 9.5 hours of driving, which can be compared to an average rate of 0.235 accidents per million vehicle-kilometres for hours of driving that exceed 9.5 hours; a difference that was found to be statistically significant at the 1% level.

The combination of geographic region and hours of driving in a two-

Transactions on the Built Environment vol 16, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509


way ANOVA suggested an additive effect on fatigue-suspected truck accident rates. This result confirms that factors reflecting increased industrial fatigue (in this case remoteness of northern highway sections and increased hours of continuous driving) individually contribute to significantly higher fatigue-suspected accident rates.

The effect of circadian fatigue on truck accident rates was considered by estimating single vehicle accident rates for night and day conditions and for different hours of driving (85th percentile less than or equal to 9.5 hours and greater than 9.5 hours). As indicated in **Figure 1**, significantly higher single vehicle accident rates were obtained for nighttime driving for both hours of driving categories. Introducing both day and night driving and hours of driving together in the ANOVA yielded higher accident rates at night, especially for more than 9.5 hours of continuous driving. These results indicate that circadian fatigue (expressed in terms of day and night conditions) has an additive effect on single vehicle accident rates, when combined with hours of driving (an indicator of industrial fatigue). An average single vehicle accident rate of 0.419 accident per million vehicle-kilometres was obtained for more than 9.5 hours of driving at night, as compared to an average rate of 0.058 accident per million vehicle-kilometres for less than 9.5 hours of continuous driving during the day, a 7 fold increase.

A two-way ANOVA was carried out to assess the sensitivity of the fatigue criteria used in explaining the relationship between accident rates and hours of driving. Fatigue-suspected accident rates were found to differ significantly from single vehicle truck accident rates for the same hour of driving values ($F = 7.94$ for 2 Degrees of Freedom). While the nature of the fatigue criteria was found to affect the accident rate estimates, the choice of fatigue criteria did not alter the basic conclusion that higher accident rates took place at higher hours of driving ($F=5.33$ for 2 DoF). The interaction effect between hours of driving and fatigue criteria was not found to be statistically significant ($F=1.20$ at 4 DoF). Again the largest discontinuity in fatigue accident rates for hours of driving took place at 9.5 hours.

## 5 Conclusions

The results of this preliminary statistical analysis of Ontario truck accident data support the assertion that higher levels of driver fatigue (both industrial and circadian) result in significantly higher truck accident rates. The effect of both types of fatigue on accident rates appears to be cumulative in nature.

Notwithstanding concerns about limitations in the data and the measures used to reflect fatigue in these data, this study has provided some basic statistical evidence that truck driver fatigue poses a special problems for truck safety, and this issue needs to be addressed in a more in-depth manner.

## 6 References

Grandjean, E. *Fitting the Task to the Man.* Taylor and Francis. London, UK, 1988.

Mackie, D.H. and Miller, J.C. Effects of Irregular Schedules and Physical Work on Commercial Driver Fatigue and Performance, *Human Factors in Transport Research*, Academic Press Inc. London, UK, 1980.

Matousek, M. *Measures Against Errors in the Building Process*, Swiss Federal Institute of Technology, Zurich, Switzerland, 1982.

McDonald, N. *Fatigue, Safety and the Truck Driver*, Taylor and Francis Inc. Philadelphia, PA, 1984.

Trimac Consulting. *Owner Operator Costs and Earnings Comparison in Canada/US Transborder Trucking*. Final report for Transport Canada, T8080-1-6099, Calgary, Canada, 1991.

Yu, M. *Effect of Driver Fatigue on Commercial Vehicle Accidents*, Unpublished M.A.Sc. Thesis, Department of Civil Engineering, University of Waterloo, Canada, 1994.

---

**Table 1. Analysis of Variance of Fatigue-Suspected Accident Rates by Region**

| Category | # Sections | Sum | Average | Variance |
|---|---|---|---|---|
| Northern Region | 30 | 7.112 | 0.237 | 0.013 |
| Southern Region | 42 | 4.770 | 0.114 | 0.006 |

ANOVA Summary:

| Source of Variation | SS | df | MS | F (P-value) |
|---|---|---|---|---|
| Between Groups | 0.267 | 1 | 0.267 | 29.6 (0000) |
| Within Groups | 0.631 | 70 | 0.009 | |
| Total | 0.898 | 71 | | |

Transactions on the Built Environment vol 16, © 1995 WIT Press, www.witpress.com, ISSN 1743-3509



**Table 2. Analysis of Variance of Fatigue-Suspected Accident Rates by Hours of Driving (85th Percentile)**

| Category | # Sections | Sum | Average | Variance |
|---|---|---|---|---|
| LE 9.5 Hours | 40 | 4.370 | 0.1093 | 0.0062 |
| GT 9.5 Hours | 32 | 7.512 | 0.2347 | 0.0121 |

ANOVA Summary:

| Source of Variation | SS | df | MS | F (P-value) |
|---|---|---|---|---|
| Between Groups | 0.2800 | 1 | 0.2800 | 31.70 (0.000) |
| Within Groups | 0.6183 | 70 | 0.0088 | |
| Total | 0.8982 | 71 | | |

**Figure 1. Single Vehicle Truck Accident Rates by Night and Day for Different Hours of Driving.**