FATIGUE AND ACCIDENTS: THE CASE OF FREIGHT TRANSPORT IN COLOMBIA

Nathaly M. Torregroza-Vargas, Universidad de los Andes, Grupo de Estudios en Sostenibilidad Urbana y Regional SUR, nathalytorregroza@yahoo.com

Juan Pablo Bocarejo, Universidad de los Andes, Grupo de Estudios en Sostenibilidad Urbana y Regional SUR, jbocarej@uniandes.edu.co

Juan P. Ramos-Bonilla, Universidad de los Andes, Departamento de Ingeniería Civil y Ambiental, jramos@uniandes.edu.co

ABSTRACT

Truck drivers are involved in an important number of road fatalities in Colombia. To identify variables that could be associated with accidents in which truck drivers are involved, a logistic regression model was constructed. The model had as the response variable a dichotomous variable that included the presence or absence of an accident during a specific trip. As independent variables the model included information regarding driver´s fatigue and road conditions. With the model, it was possible to determine the Odds Ratio of an accident in relation to several variables, adjusting for confounding. To collect the information about the trips that were included in the model, a survey among truck drivers was conducted. The results suggest strong associations between accidents (i.e., some of them statistically significant) with the number of stops done during the trip, and the average time of each stop. Survey analysis allowed us to identify the practices that contribute to generate fatigue and unhealthy conditions on the road among professional drivers.

A review of national regulations confirmed the lack of legislation on this topic.

Keywords: Truck Drivers, Road Safety, Fatigue, Logistic Model, Modeling Data Analysis

1. INTRODUCTION

Worldwide, road traffic accidents have risen in recent years, especially in developing countries (PIARC, 2003). Each year 110,000 people die in road accidents, and if the actual trend does not change, road accidents will become the fifth leading cause of death by 2030 (World Health Organization, 2011). In Colombia, fatalities by road accidents are the second leading cause of violent death (Instituto Nacional de Medicina Legal y Ciencias Forenses, 2010).

Professional drivers are a high exposed group and as a result, are at high risk of been involved in fatal road traffic accidents. Specifically, the working conditions of truck drivers may contribute to increase the accident risk dramatically if the regulations do not include a road safety perspective. Unfortunately, in developing countries this issue has not been properly addressed. This study analyzes the association between driver's fatigue and road accidents in Colombia, as a way to promote specific regulation focused mainly on hours of service and rest periods.

1.1 Driver fatigue

Fatigue is a bodily response that has the potential to affect people's mood. It is produced by long-term efforts, which may affect work performance. It can manifest itself in slow or erroneous reactions, loss of vigilance and alertness, a decrease in performance, and failure to anticipate and avoid an accident (Ramirez Cavassa, 2000). The symptoms are reflected in physical, mental and emotional behavior, generating impotence, somnolence, irritability, tension, sensory disturbance, tachycardia, headaches, sweating, and tremors (Ramirez Cavassa, 2000; University of Maryland Medical Center, 2011).

In the case of truck drivers, the driving time, resting time, and presence or absence of breaks along the trip are variables that have been associated with the risk of an accident in previous studies. A study conducted by Baas et al with a major survey of truck drivers in New Zealand, found that fatigue is involved in 5.1% of fatal road accidents (Baas et al, 2000). Pérez-Chada et al (2005), presented results from a cross-sectional study in Argentina showing that the mean hours of sleep during working days of truck drivers was 3.76, that 84.7% of work shifts were longer than 12 hours, that 43.7% of drivers reported frequent sleepiness while driving, and concluded that accident risk is associated with frequent snoring, daytime sleepiness and reports of sleepiness at the wheel. Hakkaken and Summala (2001) studied truck drivers in Finland and concluded that before an accident a driver fell asleep in 2% of cases, 4% of the drivers were drowsy, and 51% of the drivers had made an error in attention, anticipation or estimation. From a lorry and bus driver's study in Northern Sweden, Van den Berg and Landstrom (2006) showed that 14% reported sleeping while driving, 8% reported head nodding, and 40% of hazard events occurred to drivers who reported less than 6 hours of sleep before starting their shift. In the United States, Hanowski et al (2008) collected data from 62 commercial-vehicle drivers who worked for three trucking companies, and found 58 critical events between the 10th and 11th hour of their work shift. Furthermore, the mean sleeping time in this group was 6.28 hours, and when drivers experienced a critical incident they had slept less than their average overall sleep quantity.

1.2 Freight transport and accidents

Currently, road accidents are an important public health problem in Colombia. Road traffic accidents are the second cause of violent deaths in the country, after homicide (Instituto Nacional de Medicina Legal y Ciencias Forenses, 2010). In the country and during 2010, there were approximately 170,000 road traffic accidents, from which ~5000 were fatal, and ~35,000 victims suffered injuries (CFPV & Uniandes, 2012).

Data from the Ministry of Transport shows that in 2010, freight transport vehicles were involved 16% of the serious accidents occurred in that year, even though trucks are only 3.5% of the motor vehicle fleet circulating in the country (Ministerio de Transporte, 2011).

1.3 Hours of service regulation and employment situation

Several countries have implemented regulations regarding driving time and resting time, which are considered adequate strategies to reduce road traffic accidents. Jones et al., compared labor and transportation law of Australia, Canada, the United States of America, Switzerland and the European Union (Jones et al, 2005). Table I shows that despite some differences in terms of the hours allowed for driving and resting, legislation from several countries clearly regulates how much time a driver should both drive and rest, as a strategy to reduce fatigue induced accidents.

Table I - International regulations

European Union: CE561-2006	
Daily driving time	Max. 9 hrs. Twice a week max. 10 hrs.
Weekly driving time	Max. 56 hrs. 2 consecutive weeks max. 90 hrs.
Daily rest	At least 11 hrs. (Option: Two rest times with a duration 9 hrs and 3 hrs.)
Reduced daily rest	Max. 3 times/week daily rest could be between 9 and 11 hrs.
Weekly rest	45 hrs.
Reduced weekly rest	Min. 24 hrs and max. 45 hrs. Hours not taken must be replaced the following week.
Breaks	Option 1: Break of 45 min after driving for 4.5 hrs. Option 2: Two breaks with a duration of 30 min and 15 min minimum, in 4.5 hours of driving.
Australia: Road Traffic Regulations 1999	
Time windows (Periods) of work that determine regulations	Period 1: 5.5 hrs. Period 2: 24 hrs. Period 3: 336 hrs.
Driving time according with period	If Period 1: 5 hrs. If Period 2: 14 hrs. If Period 3: 144 hrs. For Period 3, driver should have at least 6 hrs working on duties outside the truck.
Breaks and rest time	If Period 1: One break of 30 min or 2 Breaks of 15 min. Period 2: One break of 10 hrs (min. 6 hrs outside the truck). Period 3: Out of the 336 hours, driver should rest 192 hrs (with a min. of two 24 hrs breaks outside the truck).
Canada: Commercial vehicle drivers' HOS regulations 1994	
Daily working time	Max. 14 hrs.
Daily driving time	Max. 13 hrs.
Weekly working time	Max. 70 hrs. 2 consecutive weeks max. 120 hrs.
Daily rest	Min. 10 hrs. Option: split into short breaks.
Reduced daily rest	Min. 8 hrs.
Weekly rest	Min. 36 hrs.

United States of America: 49 CFR 395	
Daily working time	Max. 14 hrs.
Daily driving time	Max. 11 hrs. in a 14-hour period
Weekly working time	If the employing motor carrier does not operates commercial motor vehicles every day of the week: 7/8 consecutive days: May not drive after 60/70 hrs. *Any period of 7 or 8 consecutive days may end with the beginning of an off-duty period of 34 or more consecutive hours that includes two periods from 1 a.m. to 5 a.m*
Daily rest	Min. 10 hrs.
Rest breaks	Min. 30 minutes in 8 hours
Weekly rest	A driver may restart a 7/8 consecutive day period after taking 34 or more hrs off duty. *A driver may not take an off-duty period allowed in this section to restart the calculation of 60/70 in 7/8 consecutive days until 168 or more consecutive hours have passed since the beginning of the last such off-duty period. If the driver takes more than 1 off-duty period during 168 consecutive hours, he or she must indicate which such period is being used to restart the calculation of 60/70 consecutive hours in 7/8 consecutive days*

The enforcement of these regulations is specified in detail in order to make them useful. The penalties for freight transport companies and drivers are severe. They include fines, immobilization of the vehicle, and even imprisonment and temporary withdrawal of the driving license (Department of Justice, 1985; National Archives and Records Administration, 2007; National Transport Commission, 2008; Federal Authorities of the Swiss Confederation, 2008; Europeas, 2009).

Colombia lacks the regulations previously described. In this framework, this study analyses the impact of driving time and resting periods on road traffic accidents, using a logistic regression model to determine the potential risks resulting from the lack of appropriate rest practices for professional drivers.

2. METHOD

To conduct this study, primary information regarding the truck drivers' characteristics and variables related to a reference road trip was collected using surveys among truck drivers. With this information, both basic and logistic regression models were used to determine the statistical associations of several factors with the risk of an accident. Below there is a detailed description of the methods applied in this study.

To conduct this study, primary information regarding the truck drivers' characteristics and variables related to a reference road trip was collected using surveys among truck drivers. With this information, both single variable relative risk estimates and logistic regression models were used to determine the statistical associations of several factors with the risk of an accident. Figure 1 shows a flow chart of the steps developed for this study. A detailed description of each step is included below

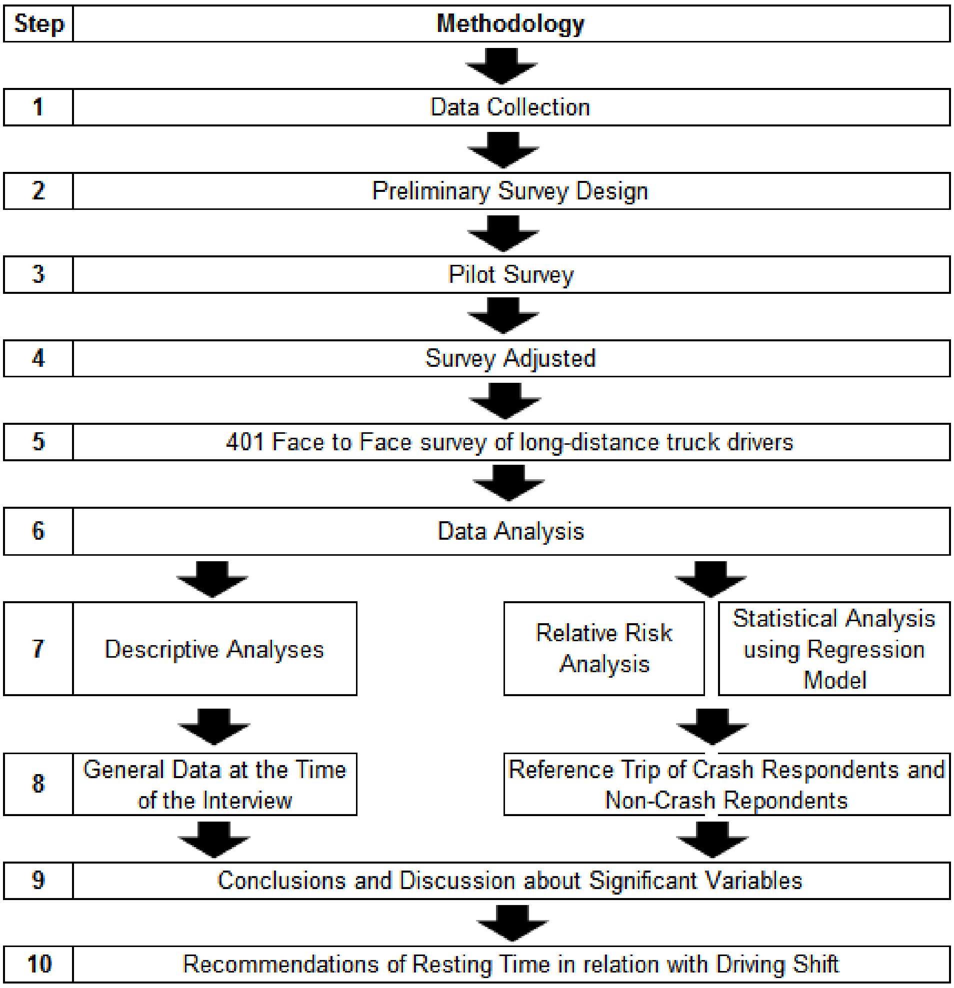

Figure 1 - Methodology to conduct this study

2.1 Drivers' survey

A face to face survey of long-distance truck drivers was conducted by a company specialized in transport surveys contracted for this study. Based on their knowledge and experience, drivers were selected and interviewed in rest areas nearby Bogotá, in roadways that communicate this city with the rest of the country. In these rest areas drivers usually eat, fix their trucks, or take breaks.

To determine the number of interviews needed, a sample size calculation was made assuming that each truck has a driver and therefore the population of drivers is equal to the total number of registered truck. The number of trucks registered in Colombia for 2010 was 209.444. With an error of 5% and a significance level of 5%, a sample size of 384 surveys was estimated using simple random sampling. This estimate is also based on the most conservative value for prevalence (50%).

A pilot survey was tested in "*Altos de la Tribuna*" to identify wording problems and missing questions in the survey. Based on the results of the pilot survey, a structured survey consisting of 40 questions was constructed.

The survey was administered to 401 drivers, who were randomly selected by interviewing one in every three drivers who stopped in the rest zones selected for this study. To be included in the study, a driver should have been driving a truck with at least a two rigid-axles, which results in a vehicle with a gross weight up to 17 tons and a road capacity up to 9 tons (Ministerio de Transporte, 2009). When a driver was invited to voluntarily participate in the survey, the objectives of the study were explained before starting the interview.

Based on the results of the pilot survey, a structured survey consisting of 40 questions was constructed. The survey was designed to collect information regarding a “Reference Trip”. For drivers that had not been involved in an accident over the last three years, the “reference trip” was the last trip they had finished. For drivers that have had and accident over the last three years, the “reference trip” was the trip of the accident. The survey included questions regarding fatigue, and roadway characteristics of their “reference trip”. Based on this information, it was possible to build the models to compare the characteristics of a trip with an accident against the characteristics of a trip without accidents. Additionally, questions about their current employment situation, risk perception, drivers’ age, driving experience, vehicle type, and type of freight were ask. The main questions of the survey were:

a. Have you had a traffic accident in the last 3 years that resulted at least in vehicle damage?
b. Type of freight carried?
c. Gender and age?
d. Years of experience in freight transportation?
e. Type of Vehicle (number of axles), and vehicle year
f. Current employment situation? (Payment and contract type, employer, company size)
g. Roadway characteristics in the “reference trip”? (number of lanes, road conditions considering potholes and road signals, terrain type)
h. Driving time in the "reference trip”?
i. Resting period before the "reference trip"?
j. Number of breaks longer than 5 minutes taken during the "reference trip”?
k. Mean duration of each break taken during the “reference trip”?

2.2 Relative Risk estimation

A single variable relative risk estimation was conducted to determine the association of an accident event with the following variables: Time of rest before a shift, length of a shift, number of breaks during a shift, average time of breaks, number of lanes of the road, and terrain type.

The purposes of this analysis were: 1- To identify the reference category of all the categorical variables included in the logistic regression model. The reference categories selected were those that had the higher or lower relative risk (ie. Extreme values). 2- To identify the number of breaks that resulted in the lower risk within different categories of driving time. 3 – To determine how the relative risk of an accident changes according to driving time in combination with resting time before the trip.

The exposure variables analyzed and their categories are shown in Table II.

Table II - Categories of analysis for exposure variables

Variable		Time of rest before a shift	Length of a shift	Breaks	Average time of breaks	Number of lanes	Terrain Type
Categories	1	>8 hours	1-3 hours	Varied between 0 and 10, and no groups were created	<10 min	1	Flat
	2	6-8 hours	4-6 hours		10-20 min	2	Undulate
	3	4-5 hours	7-11 hours		21-30 min	>=3	Mountainous
	4	<4 hours	>=12 hours		31-40 min	-	-
	5	-	-		41-50 min	-	-
	6	-	-		>50 min	-	-
	7	-	-		No Breaks	-	-

Simple relative risks of an accident were estimated within the variables terrain type (i.e., using undulate terrain as the reference category), number of lanes (i.e., using =>3 lanes as the reference category), and time of the breaks (i.e., using 21-30 min as the reference category). Relative risks were calculated for all the categories within each variable, always using the same reference category.

For the remaining variables, the relative risk of an accident was estimated combining length of the driving shift and time of rest before the shift. Hence, within each category of length of the driving shift (e.g., >12 hours), a time of rest of >8 hours was selected as the reference category to estimate the RR of an accident in comparison to the other resting times. The same approach was used to combine length of the driving shift and number of brakes during the shift.

2.2.1 Logistic regression model

A logistic regression model was used to estimate the Odds Ratio (OR) of an accident (i.e.. odds of an accident divided by the odds of no accident), using as predictor variables resting time before the shift, the number and duration of breaks during the shift, characteristics of the terrain (i.e., flat, undulate, and mountainous), road conditions (i.e., poor, fair, good), and number of lanes (i.e., 1, 2, and >=3). The response variable of the logistic regression model was the presence or absence of an accident during a trip, represented as a dichotomous variable (1, 0). All the independent variables of the model were discrete variables included as dummy variables. The model determines the risk of an accident in a trip measured as the OR adjusted for several potential confounding variables. The statistical analysis was conducted using STATA version 11.

The model applied was:

$$\mathrm{Ln}\left(\frac{\mathrm{Probability\,Accident}}{1-\mathrm{Probability\,Accident}}\right)=\beta_0+\beta_1\mathrm{Prior}R\mathrm{est}+\beta_2\mathrm{Breaks}N\mathrm{umber}+\beta_3\mathrm{BreakTime}+$$
$$+\beta_4\mathrm{Road}T\mathrm{errain}+\beta_5\mathrm{RoadNumber}+\beta_6\mathrm{RoadConditions}+\varepsilon$$

In summary, the variables included in the logistic regression models can be classified in two groups: Variables associated with fatigue, and variables associated with the roadway. Table 3 shows these variables.

Table III - Variables asked on survey and analyzed in the logistic model

Characteristics	Variable	Description
Fatigue	PriorRest	Resting time before the trip
	BreaksNumber	Number of breaks during the trip
	BreakTime	Average time per break
Roadway	RoadTerrain	Terrain type of the roads (flat, undulated, mountainous)
	RoadNumber	Number of lanes of the road (Single-lane, Two-lanes, Three-lanes or more)
	RoadConditions	Condition of the road (considering potholes and road signals) (Good, Poor, Fair)

3. RESULTS

A total of 401 drivers were interviewed, but 14 responded with inconsistencies. Thus, the results include information from 387 drivers.

3.1 Descriptive analyses

Table IV displays basic characteristics of the participating drivers, including employment status, as well as characteristics of the vehicles they drive. The results are divided between drivers involved in an accident over the last three years, and drivers not involved in an accident over the same period of time.

Table IV - Basic characteristics of both drivers and vehicles. (*) Characteristics of the driver at the time of the interview

Variable	Category	Driver involved in an accident		Driver not involved in an accident	
		Number	%	Number	%
Age (Years Old)	< 20	1	1%	0	0,0%
	20-30	20	27%	45	14%
	31-40	24	32%	101	32%
	41-50	16	22%	104	33%
	51-60	11	15%	51	16%
	> 60	2	3%	12	4%
Truck Driving Experience (Years)	< 2	1	1%	3	1%
	2-5	7	9%	31	10%
	6-20	38	51%	139	44%
	21-30	17	23%	88	28%
	> 30	11	15%	52	17%
Employer	chargers (freight generators)	14	19%	41	13%
	freight companies	33	45%	187	60%
	individual owners of trucks	21	28%	52	17%
	their own vehicle	6	8%	33	11%

Company size (Number of trucks)	Micro (1 Veh)	9	12%	68	22%
	Small (2-20 Veh)	27	36%	91	29%
	Medium (21-200 Veh)	17	23%	70	22%
	Large (>200 Veh)	21	28%	84	27%
Freight Type	Containers	29	39%	187	60%
	Bulk	32	43%	89	28%
	Hazardous	13	18%	37	12%
Vehicle Type	Two-axles truck	24	32%	87	28%
	Three-axles truck	16	22%	70	22%
	Four-axles truck	12	16%	48	15%
	Two-axles truck trailer	7	9%	42	13%
	Three-axles truck trailer	15	20%	66	21%
Type of payment	Based on distance of the trip	1	1%	11	4%
	Based on days or hours worked	0	0%	4	1%
	Based on weight of freight	5	7%	29	9%
	Based on number of trips	35	47%	162	52%
	Fixed salary	28	38%	72	23%
	Independent	5	7%	35	11%

The variables showed in Table 4 correspond to the characteristics of the driver at the time of the interview and not at the time of the accident. Therefore they were not included in the model. The drivers are classified as involved or not involved in an accident based on their driving experience over the last three years.

Half of the drivers interviewed were between 20 and 40 years old, which was similar for both groups (i.e., involved and not involved in an accident). In terms of driving experience, both groups had a similar percentage of drivers with experience below 5 years.

More than half of the drivers worked for freight companies, followed by drivers that worked for individual owners of trucks and chargers (freight generators). Few drivers owned the truck they drove. In terms of the size of the company, similar percentages of drivers work for small and large companies. Containers were the type of freight carried by the highest percentage of drivers. However, drivers involved in an accident had a higher percentage of bulk freight trucks (43%), while drivers not involved in an accident had a higher percentage of container trucks (60%).

3.1.1 Working and resting periods

Driving time before an accident, and resting time prior to the trip in which an accident occurred, were determined for the 74 drivers involved in an accident. Figure 1 details the distribution of driving time and resting time prior to a trip for these drivers.

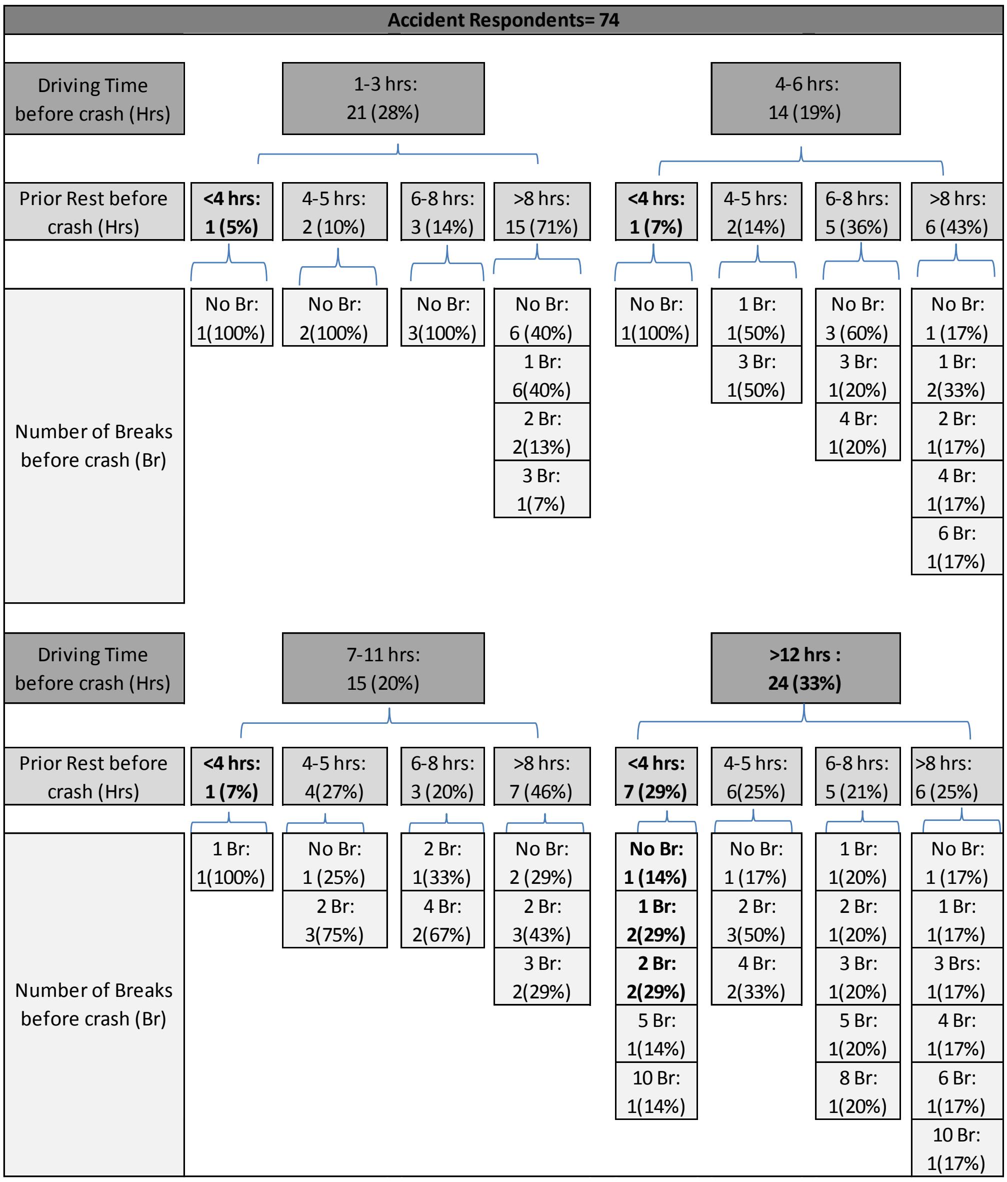

Figure 2 - Working and prior sleep time of accident respondents

Figure 2 shows the prior rest taken by drivers during the shift in which an accident happened.

Thirty three percent (33%) of the drivers involved in an accident had been driving for 12 hours or more when they crashed, and among this group, 29% had slept less than 4 hours before the trip (Figure 1). Thus, this group drove longer with less hours of sleep. The high percentage of drivers with less than 4 hours of sleep before the accident was a distinguishing feature of this group in comparison with the other driving time groups. Furthermore, more than half of this group (72%) took less than two breaks during the work shift.

Overall, more than half of the drivers that had an accident had driven for 7 or more hours.

Figure 3 shows information regarding driving time and resting time before the trip, for drivers that were not involved in an accident. Although there was a large percentage of drivers that had driven more than 12 hours (56%), among this group a small percentage (9%) had rested less than 4 hours before the trip, and 53% had rested for more than 8 hours. Furthermore, among the group that had rested more than 8 hours in shifts of >12 hours, 67% took 3, 4, 5 and 10 breaks. The data displayed for drivers in the category 1-3 hours should be taken with caution, since this group only includes 5 drivers.

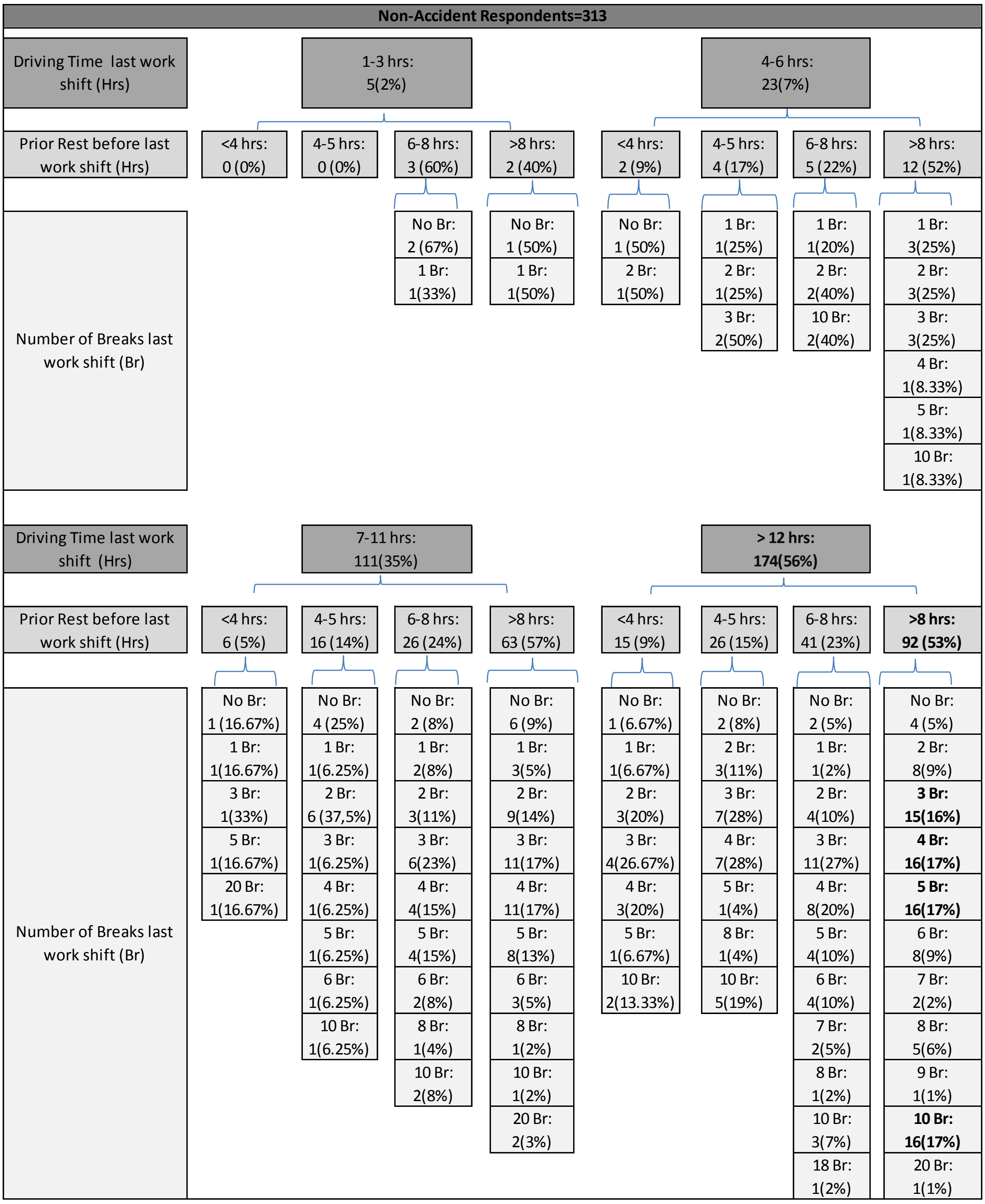

Figure 3 - Working and prior sleep time of non-accident respondents

3.2 Preliminary risk analyses

The relative risk for accident occurrence is 2.69 times higher for a flat terrain compared to undulated terrain. The relative risk of an accident is 3.04 times higher when driving in a single-lane road in comparison to a three or more lanes road. Using a prior resting period of 8 hours as reference, the relative risks of an accident when rest is less than 4 hours, between 4 to 6 hours, and 6 to 8 hours were 1.81, 1.39, and 1.05, respectively. Selecting as the reference category an average time per break between 21 and 30 minutes, the relative risk of an accident of breaks between <10, 10-20, 31-40, 41-50, >50, and no breaks were 1.72, 2.42, 1.04, 3.33, 2.60 and 5.56, respectively.

Table V shows the analysis of the combined effect of number of breaks and length of the trip on the risk of an accident. A combination between number of breaks and work shift indicates that 1 break makes a higher impact on risk reduction for longer trips in comparison to shorter trips, as shown in Table V.

Table V - Relative risk of an accident considering the length of the driving shift and the number of breaks taken during the shift

Number of Breaks	Driving Work Shift			
	Period 1: 1–3 Hrs	Period 2: 4–6 Hrs	Period 3: 7–11 Hrs	Period 4: >=12 Hrs
0	0.80	1.00	1.69	3.50
1	0.75	0.50	1.13	9.33
2	1.00	0.13	2.52	3.50
3	1.00	0.29	0.82	0.72
4	N.A.	0.67	1.00	1.14
5	N.A.	N.A.	N.A.	1.17
6	N.A.	1.00	N.A.	1.08
8	N.A.	N.A.	N.A.	1.75
10	N.A.	N.A.	N.A.	1.00

Figure 4 shows that driving in shifts of 12 hours or more, regardless of the hours of sleep before the shift, had the largest relative risk of an accident. For the other shift lengths, the RR of an accident varied depending on the hours of sleep taken before the shift.

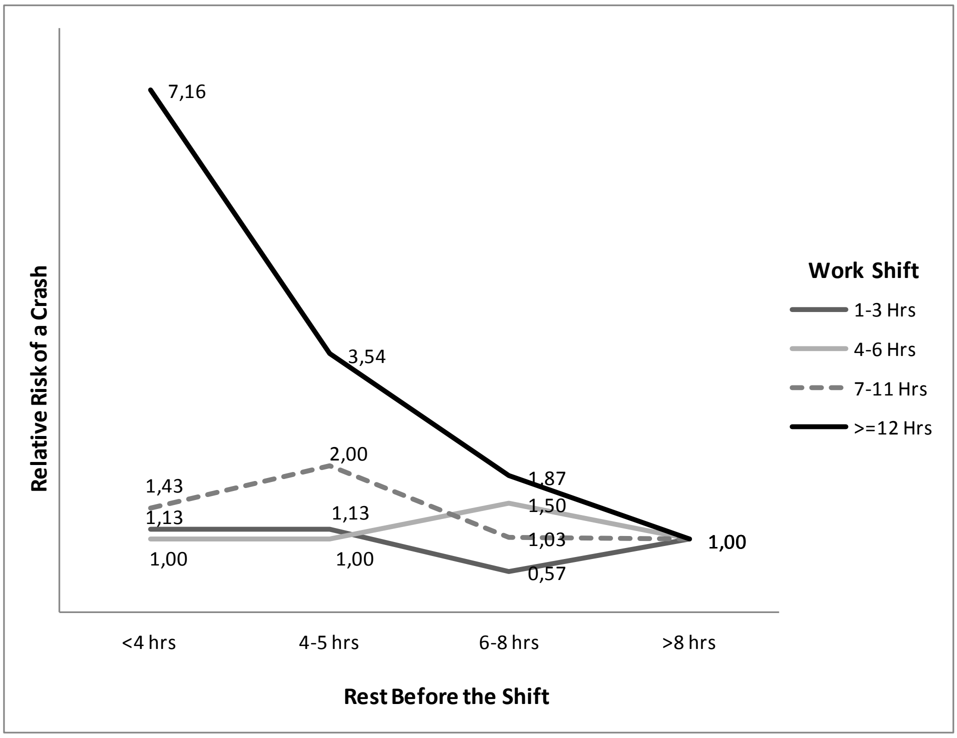

Figure 4 - Relative risk combining the duration of rest before the shift and driving time during the shift

3.3 Logistic regression model

The response variable of the model was occurrence or not occurrence of an accident, and the independent variables included were the number of breaks, the average time of each break, terrain type, number of lanes, and road conditions considering potholes and road signals. For this analysis, the number of breaks was divided into four categories, grouping the number of brakes that had similar risks of an accident. The individual risk of an accident for each number of breaks was estimated as odds of an accident using single variable logistic regressions. Based on this grouping criterion, the following categories were created: Category 1 (0 and 1 breaks), Category 2 (2 breaks), Category 3 (3, 4, 6, and 8 breaks), and Category 4 (5 and 10 breaks).

Table VI summarizes the results of the model. For each category the OR of an accident is displayed (based on the reference category for each variable). Table VI also shows the 95% confidence interval.

Table VI - Logistic regression model results. Note: *** p<0.01, ** p<0.05, * p<0.1

Variable	Category Meaning	OR	SE	z	P>|z|	95% CI	
PriorRest							
	< 4 hrs.	1.396137	.709206	0.66	0.511	.5158661	3.778498
	4-5 hrs.	1.200434	.5026321	0.44	0.663	.5283633	2.727368
	6-8 hrs.	1.091664	.4169855	0.23	0.818	.5163612	2.30794
	> 8 hrs (Reference Category)						
BreakTime							

	< 10 min.	1.20594	.8585588	0.26	0.793	.2987583	4.867786
	10–20 min.**	2.662263	1.283468	2.03	0.042	1.034879	6.848768
	31-40 min.	1.023013	.9462294	0.02	0.980	.166943	6.268945
	41-50 min.	2.483055	2.006295	1.13	0.260	.5095891	12.09909
	> 50 min.	1.271705	.9411091	0.32	0.745	.2981713	5.423844
	No breaks	1.558622	1.001498	0.69	0.490	.4423829	5.491401
	21–30 min (Reference Category)						
TerrainType							
	Mountainous	1.271729	.5764968	0.53	0.596	.5230345	3.092139
	Undulated*	.5181426	.1947428	-1.75	0.080	.248043	1.08236
	Flat (Reference Category)						
RoadNumber							
	Three-lanes or more	.7875999	.4452326	-0.42	0.673	.2600872	2.385022
	Two-lanes*	.5039218	.1802027	-1.92	0.055	.2500191	1.015671
	Single-lane (Reference Category)						
RoadConditions							
	Fair	.6098488	.2222013	-1.36	0.175	.2985952	1.245551
	Poor	.5323367	.2194125	-1.53	0.126	.2373274	1.194057
	Good (Reference Category)						
BreaksNumber							
	2 Breaks	.473554	.234645	-1.51	0.131	.179308	1.250659
	3, 4, 6, 8 Breaks***	.15688	.075054	-3.87	0.000	.061423	.4006815
	5 and 10 Breaks***	.062324	.041092	-4.21	0.000	.01711	.2269212
	0 and 1 Break (Reference Category)						
	CONSTANT	0.28040	0.66384	0.42	0.673	1.02071	1.59151

The length of the driving shift was excluded from de model. The reason for this was that the coefficient of this variable suggested that short trips had a higher risk of an accident in comparison to longer trips, which is counterintuitive. We believe that since the occurrence of an accident interrupts the shift, the accident makes the shift shorter than planned. Thus, we are facing a potential problem of reverse causation, in which the response variable is inducing the predicting variable.

Looking at fatigue-related variables, the OR suggest that taking breaks between 31-40 minutes seems to have no difference in the odds of an accident in comparison to the reference category (21-30 min), and all other break lengths increase the odds of an accident in comparison to the reference category. However, the only significant OR was for break duration of 10-20 minutes, suggesting that the odds of an accident is 2.66 times higher for breaks between 10-20 minutes compared to the odds of an accident of breaks between 21-30 minutes, adjusting for all other variables.

For the number of brakes, Table 6 shows that in all cases, taking 2 or more brakes in a trip has a protective effect in comparison to trips that take 1 or no breaks. Furthermore, two categories of number of brakes showed significant reductions in the odds of an accident in comparison to the reference category of 1 or no breaks: Category 2, 4, 6, and 8 breaks and category 5 and 10 brakes, with the highest risk reduction observed for the category 5 and 10 breaks. In this last case, the odds of an accident is 0.06 times lower when taking 5 or 10 brakes in a trip in comparison to trips that take 1 or no breaks.

In terms of the number of lanes in a road, there seems to be a protective effect for an accident in roads of 2 and 3 or more lanes in comparison to roads with one lane, and this reduction was marginally significant for two lanes.

For terrain type, mountainous terrain showed a non-significant increase in the OR of an accident in comparison to flat terrain, and undulated terrain showed a marginally significant reduction in the OR in comparison to flat terrain.

Road conditions showed OR reductions of fair and poor roads in comparison to roads in good condition, but the estimates were not statistically significant.

Finally, time of prior rest to the trip showed that less time of rest increases the odds of an accident, but all the OR estimated were not statistically significant.

4. DISCUSSION

This is the first study conducted in Colombia that analyzes the association between truck driver´s fatigue and the occurrence of an accident. The study found statistically significant associations between the number of breaks taken during the shift, and their duration, with the occurrence of accidents. The results suggest that a larger number of breaks during a shift reduce the OR of an accident. However, the average length of the breaks to reduce the odds of an accident is less evident. The results suggest that the highest and significant risk is obtained with breaks lasting between 10-20 min in comparison to breaks lasting 21-30 min.

The analysis of time spent resting before a trip shows that the odds of an accident is the lowest when resting for >8 hours, but not statistically significant. Hanwoski et al (2007) found that drivers who reported a critical incident had significantly less prior sleep than the mean overall sleep quantity of the group studied.

Another characteristic observed among these drivers, is that those that drove for longer shifts and had less rest before the shift seem to have more accidents. Previous studies have found similar results. Gander et al (2006) found that 10.8% of drivers involved in accidents have been continuously awake for more than 12 hours and have slept less than 6 hours during the 24 hours before the accident. Blanco et al (2011) concluded that the risk of being in a safety-critical event generally increased as working hours increased.

As it was observed in the model, undulated terrain had a lower risk of accident in comparison to flat terrain, and similar results were obtained comparing poor and good condition of the road. In both cases, the protective effect could be the result of reduced speed and the perception by the drivers that the driving conditions had the potential for a accident occurrence, which made them paid more attention to prevent an accident.

The analysis of accident risk that combined the length of the driving shift with the number of breaks taken, suggests that there are optimal combinations for risk reduction. In this group of drivers, to reduce the RR of an accident, the number of breaks must be increased as the length of the drive increases. Blanco et al (2011) found that Longer trips are associated with greater levels of exposure, which means that a greater number of driving hours increased the risk of an accident if the event rate is constant, and that taking a break from driving significantly reduced the risk of being involved in a safety-critical event, and that the benefits of taking a break from driving ranged from 30 to 50 percent reduction in risk of safety-critical events. Furthermore, international regulation in this area demands more breaks as the shift length increases

One of the limitations of the model is that we lack information of some potential confounders for accidents, including the employment situation of drivers, vehicle characteristics, time of the accident, and weather conditions at the time of the accident. There could also be an issue of recall bias since divers that had been involved in an accident could have better recollection of the circumstances surrounding an accident in comparison to the drivers that had not been involved in an accident. However, an attempt to reduce recall bias was made by asking drivers who have not been in an accident to provide information of their last trip, because the circumstances and characteristics of this trip are the easiest to recollect. Since people involved in uncommon events, such as accidents, tend to recollect better the circumstances surrounding the event, we believe that drivers involved in an accident could have had a good recollection of the event considering the time window that was stipulated: three years.

Since reverse causation may have been a factor influencing the results obtained for the association between the duration of the driving shift and the occurrence of an accident, this area requires further study in the country.

4.1 Conclusions and recommendations

Colombia lacks adequate regulations regarding the working conditions of truck drivers, including regulations to reduce fatigue. Furthermore, drivers have to face aggravating factors including non-formal work. Our research suggests that in Colombia there is a relationship between fatigue and road accidents among truck drivers, which requires intervention.

Based on the international regulations on this topic, combined with the results presented in this study (Figure 4, Table V, Table VI), we recommend the implementation of the following resting time in relation to the duration of the driving shift:

Table 1VII - Recommendation for prior rest and number of breaks

Shift length	Prior rest	Breaks	Average Duration per Break
At least 12 hours	At least 8 hours	At least 4	21 to 30 minutes

7 to 11 hours	At least 6 hours	3	21 to 30 minutes
4 to 6 hours	Not relevant	2	21 to 30 minutes
1 to 3 hours	Not relevant	1	21 to 30 minutes

ACKNOWLEDGEMENTS

The authors wish to thank PhD. MARIA ELSA CORREAL NUNEZ for her assistance on statistical models.

REFERENCES

Baas P H, Charlton S G, Bastin G T. (2000). Survey of New Zealand truck driver fatigue and fitness for duty. Transportation Research, Part F, Volume 3, Issue 4, Page 186.

Blanco M, Hanowski R, Olson R, Morgan J, Soccolich S, Wu S, Guo F. (2011). the impact of driving, non-driving work, and rest breaks on driving performance in commercial motor vehicle operations. U.S department of transportation. Federal motor carrier safety administration.

CFPV & Uniandes (2012). Anuario Estadístico de Accidentalidad Vial en Colombia, 2010 Corporación Fondo de Prevención Vial. Universidad de los Andes Bogotá.

Gander P H, Marshall N, James I, Quesne L. (2006). Investigating driver fatigue in truck crashes: trial of a systematic methodology. Transportation Research, Part F, Volume 9, Pages 65-76

Hakkanen H, Summala H. (2001). Fatal traffic accidents among trailer truck drivers and accident causes as viewed by other truck drivers. Accident Analysis and Prevention, Volume 33, Issue 2, Pages 187–196.

Hanowski R, Hickman J, Fumero M, Olson R, Dingus T. (2007). The sleep of commercial vehicles drivers under the 2003 hours-of-service regulation. Accident Analysis and Prevention, Volume 39, Pages 1140-1145.

Hanowski R, Hickman J, Olson R, Bocanegra J. (2008). Evaluating the 2003 revised hours-of-service regulations for truck drivers: The impact of time-on-task on critical incident risk. Accident Analysis and Prevention, Volume 41, Issue 2, Pages 268-275.

Instituto Nacional de Medicina Legal y Ciencias Forenses (2010). Forensis 2010 Datos para la vida. Volumen 12 no. 1. Diseñum tremens. Bogotá D.C.

Jones C, Dorrian J, Rajaratnam S, Dawson D. (2005). Working hours regulations and fatigue in transportation: A comparative analysis. Safety Science, Volume 43, Issue 4, Pages 225–252.

Ministerio de Transporte (2011). Bases de datos de accidentalidad en Colombia. Bogotá, Colombia.

Ministerio de Transporte (2009). Resolución 001782 de 2009. Bogotá, Colombia

Pérez-Chada D; Videla AJ; O'Flaherty ME et al. Sleep habits and accident risk among truck drivers: a cross-sectional study in Argentina. SLEEP 2005;28(9): Pages1103-1108

PIARC. (2003). Road Safety Manual: Recommendations from the World Road Association. France: Route 2 Market. Pages 6–17.

Ramirez Cavassa, C. (2000). Ergonomía y Productividad. En C. Ramirez Cavassa, Ergonomía y Productividad. 3rd Edition. Editorial Limusa. Page 60.

South Australia Regulations, SA. (1999). Road Traffic (Driving Hour) Regulations 1999 under the Road Traffic Act 1961. Australia.

Van den Berg J, Landstrom U. (2006). Symptoms of sleepiness while driving and their relationship to prior sleep, work and individual characteristics. Transportation Research, Part F, Volume 9, Issue 3, Pages 207–226.

ONLINE REFERENCES

Department of Justice. (1985). Motor Vehicle Transport Act. http://laws-lois.justice.gc.ca/PDF/M-12.01.pdf

Department of Justice. (1994). SOR/89-316. Commercial Vehicle Drivers Hours of Service Regulations, Canada, 1994. http://laws-lois.justice.gc.ca/eng/regulations/SOR-94-716/

Department of Justice. (2011). SOR/2005-313. Commercial Vehicle Drivers Hours of Service Regulations, Canada, 2011. http://laws-lois.justice.gc.ca/PDF/SOR-2005-313.pdf

European Union. (2006) Regulation (EC) No 561/2006 of the European Parliament and of the Council of 15 March 2006. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:102:0001:0013:EN:PDF

Europeas C D. (2009). Eur Lex. Analysing the penalties for serious infringements against the social rules in road transport, as provided for in the legislation of the member states. Brussels, 2009. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0225:FIN:EN:PDF

Federal Authorities of the Swiss Confederation. (2008). Ordonnance sur la durée du travail et du repos des conducteurs professionnels de véhicules automobiles. Switzerland, 2008. http://www.admin.ch/ch/f/rs/8/822.221.fr.pdf

Federal Authorities of the Swiss Confederation (2011). Ordonnance sur la durée du travail et du repos des conducteurs professionnels de véhicules automobiles. Switzerland, 2011. http://www.admin.ch/ch/f/as/2011/3905.pdf

National Archives and Records Administration. (2012). Electronic Code of Federal Regulation. Title 49: Transportation. 49 CFR 395. 72 FR 71270. United States of America, 2012. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4d1e08ca500bc581c35c5a74fb61b811&rgn=div5&view=text&node=49:5.1.1.2.38&idno=49#49:5.1.1.2.38.0.13.3)

National Transport Commission Australia (2008). Training in Fatigue Management. http://www.ntc.gov.au/viewpage.aspx?documentid=1616

University of Maryland Medical Center. (2011). Fatiga – Overview. http://www.umm.edu/esp_ency/article/003088.htm

World Health Organization. (2011). 2nd Global Status Report on Road Safety. http://www.who.int/violence_injury_prevention/global_status_report/flyer_en.pdf