ANALYSIS OF THE RELATIONSHIP BETWEEN OPERATOR CUMULATIVE DRIVING HOURS AND INVOLVEMENT IN PREVENTABLE COLLISIONS

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ABSTRACT

Long driving hours have a potential of causing fatigue, which is known as a contributing factor for collisions. This paper examines the influence of bus operator driving hours on the occurrence of preventable collisions by employing data from incident reports and operator schedules to evaluate the correlation between driving hours and operator involvement in collisions. Several methods of analysis including a statistical t-test, a comparative analysis, and an overrepresentation analysis are employed. The results show a discernable pattern of an increased propensity of collision involvement with an increase in driving hours. Based on the analysis, on average, bus drivers who are involved in preventable collisions drive over six hours more than the general bus driver population. According to the findings of this study, it is clear that the present regulation that limits drivers' on-duty time to a maximum of seventy hours per week should be revisited.

INTRODUCTION

There is a great deal of concern in the transit community that bus operator schedules can lead to fatigue and increased occurrences of bus collisions. Generally, fatigue increases with prolonging duty time. Agencies such as the Florida Department of Transportation (FDOT) that deal with regulating operations of transit systems have established rules that limit operator duty periods to limit fatigue. Operating rules are created to promote safe, efficient, timely, and customer-oriented transit operations. The FDOT Bus Transit Draft Rule 14-90.006(3) states that a driver shall not be permitted or required to drive more than 12-hours in any one 24-hour period or drive after having been on duty for 16 hours in any one 24-hour period. The rule allows the 12 hours of drive time to be spread out provided that 16 hours of on-duty time is not exceeded in any one 24-hour period. For example, worst case scenario, a driver might be on duty, driving for 8 hours and then take a 4 hour break and return to on-duty status for an additional 8 hours (4 hours driving and 4 hours non-driving). This would be considered as a maximum of 12 hours drive time and 16 hours on-duty time in a 24-hour period although a driver may not have rested for 20 hours. Rule 14-90.006 (3) further states that a driver shall not be permitted to drive until the requirement of a minimum eight consecutive hours of off-duty time has been fulfilled.

Obviously, the minimum eight consecutive hours of off-duty time stipulated in Rule 14-90.006(3) is not the net resting time. Part of the eight hour off-duty time may be used by drivers for activities such as traveling back and forth from work to home and running personal errands before and/or after sleeping. Regarding split duty, it is presumed that operators would use the break time for resting to rejuvenate before assuming a subsequent shift. However, operators have been observed to use the break time for activities such as running personal errands instead of resting. This may lead to tiredness as operators work for extended long hours.

Scientific literature strongly supports the fact that long hours of work lead to fatigue that can degrade performance, alertness, and concentration which increases safety risk. Several studies on the influence of operator schedule on collision occurrence have been conducted for other modes of transportation, particularly, the trucking industry. A literature search did not find similar research efforts for bus operators despite the concern that bus operator spread-hour schedules can lead to fatigue and hence increase a chance of crash occurrence. A thorough understanding of the correlation between transit collision occurrence and long duty hours caused by split schedules together is crucial in setting transit operating rules.

LITERATURE REVIEW

Fatigue and sleep are causal factors in thousands of crashes, injuries and fatalities annually *(1)*. At the 1995 National Truck and Bus Safety Summit, driver fatigue was identified as the leading safety issue in the industry *(2)*. Literature on the influence of fatigue on bus safety is scarce. However, there is a considerably large body of literature on the influence of fatigue on safety of other modes of mass transportation, particularly the trucking industry. This literature review section is therefore extended to include findings of previous research on the trucking industry. The literature review section starts by discussing literature that describe driver fatigue, continues by detailing previous studies relating to the influence of fatigue on truck drivers, and concludes by looking into available literature on bus drivers' fatigue.

Driver fatigue can be classified into two subcategories, sleep-related (SR) and task related (TR) fatigue on the basis of causal factors contributing to the fatigued state *(3)*. Sleep deficiency, extended duration of wakefulness and time of day affect SR fatigue. Certain characteristics of driving, like task demand and duration, can produce TR fatigue in the absence of any sleep-related cause *(3)*. However, TR fatigue is specifically subcategorized into active TR fatigue and passive TR fatigue. Generally, the causing factors of TR fatigue are the driving task and driving environment. In particular, active TR fatigue is caused by increased task load, high density traffic, poor visibility and the need to complete secondary task while the passive TR fatigue is due to under-load conditions, monotonous drive, extended driving periods and automated systems.

Desmond and Hancock *(4)* and Gimeno *et al*. *(5)* points out that driver fatigue can be produced by active or passive TR fatigue. Active fatigue is the most common form of TR fatigue that drivers experience *(4)*. Gimeno *et al.* *(5)* relate active fatigue to mental overload (high demand) driving conditions and passive fatigue with under-load conditions. Typical environment of high task demand situations include high traffic density, poor visibility, or the need to complete an auxiliary or secondary task (i.e. searching for an address) in addition to the driving task *(3)*. Passive fatigue is produced when a driver is mainly monitoring the driving environment over an extended period of time when most or the entire actual driving task is automated. Passive fatigue may occur when the driving task is predictable. Drivers may start to rely on mental schemas of the driving task which results in a reduction in effort exerted on the task *(5)*. Under-load is likely to occur when the roadway is monotonous and there is little traffic *(3)*. Most researchers of driver fatigue have been directing their focus towards sleep deprivation or circadian rhythm effects, but require drivers to perform driving tasks in automated environments and monotonous highway conditions. This confounds the effects of SR and TR fatigue. May and Baldwin *(3)* points out that driver fatigue does produce performance decrements in driver simulation and on-road driving tasks.

Most studies that have investigated the influence of long hours of driving on safety for trucks have examined the presence of sleepiness and fatigue in truck drivers. McCartt *et al*. *(6)* conducted face-to-face interviews with 593 long-distance truck drivers at rest areas and inspection points. The study found the following six factors had influence on drivers falling asleep at the wheel: (1) greater daytime sleepiness (2) more arduous schedules with more hours of work and fewer hours off-duty (3) older, more experienced drivers (4) short, poorer sleep on road (5) symptoms of sleep disorder, and (6) greater tendency to night-time drowsy driving. Based on the findings of the study, the authors further suggested limiting drivers' work hours enable drivers to get adequate sleep to reduce sleepiness-related driving by truck drivers. Feyer and Williamson *(7)* conducted a controlled experiment whereby they examined twenty seven professional truck drivers who completed a 12-hour 900 km trip under three different settings – relay trip, a working-hour regulated one-way single trip, and a one-way (flexible) trip with no working hours' constraints. The results of their study indicated indifference in fatigue for the three different settings. However, the study suggested that the fatigue patterns were more related to pre-trip fatigue levels.

A study by Park *et al. (8)* evaluated safety implications of truck drivers' schedules from one United States less-than-truckload firm. It used schedules of 5,050 collision-involved and non-collision drivers collected for two years (1984 and 1985). The authors used the survival theory to examine the influence of driving time on crash occurrences. Crash risk was found to be associated with hours of driving, with risk increases of 30% to 80% compared to the first hour of driving. The results of this study also indicated that time of day (night and early morning schedules) and irregular schedules are associated with elevated crash risk in the range of 20% to 80%. In another similar study, Park and Jovanis *(9)* analyzed data from three trucking companies, each with different types of operations namely, primarily truckload operations, another exclusively less-than-truckload operation, and the third running a mix of operations. The study reported a non-linear increase in crash odds after the 6th hour of driving. According to the study, the odds ratios increase from 50% to over 200% in the 10th and 11th hour. While the above two cited results indicate a correlation between crash risk and time on task, a study by Barr *et al. (10)* found no relationship between driver fatigue and length of driving duty of local and short-haul truck drivers. Instead, the study found that fatigue was related to time of day, especially the early morning time period between 6:00 and 9:00 am.

Only three studies were found to have examined the influence of fatigue on city buses. Santos *et al. (11)* evaluated daytime and nighttime sleep, as well as daytime and nighttime sleepiness of professional shift-working bus drivers in Brazil. The study revealed that the sleep of shift-working bus drivers was shorter and more fragmented when it occurred during the day than at night. A thesis by Howarth *(12)* investigated differences in self-reported sleep length and aspects of fatigue for a sample of transit bus operators in the northeastern United States who were working split and straight shift schedules. The study used questionnaires which were distributed to 149 bus operators in Hartford, Connecticut. The results demonstrated expected relationships between sleep length and before/after-work measures of fatigue. In another questionnaire study, Briggs *et. al (13)* conducted a study that identified a number of fatigue factors relevant to metropolitan bus drivers in Australia. The study conducted a questionnaire survey of 249 bus drivers and focus groups participants. Two factors i.e., unrealistic scheduling that causes drivers to be unable to take breaks and lack of managerial support were found to be the main causes of fatigue.

It is important to recognize that the operational characteristics of city buses differ from those of other modes of mass transportation and trucking industry. Unlike trucks for example, routes are scheduled during peak hours because that is the time when buses get more riders. Also, city buses use mostly city streets while trucks mostly ride on highways. Buses stop more frequently than trucks. In addition to the driving task, bus operators in most agencies have to do other tasks such as collecting fares, validating identity cards, etc. Based on the above reasons, one may argue that the findings regarding the influence of operator fatigue on the safety of vehicles other than city buses may not apply to bus operators. This study therefore examines operator schedules and bus collision records to determine if there is a correlation between the two.

DATA COLLECTION

This study employed data from four transit agencies in the state of Florida. Two large and two small agencies were selected. The agencies were selected based on their willingness to participate and availability of electronic incident report databases that could be exported to a Microsoft Access database. The four agencies were then ranked based on the number of buses they operate. Jacksonville Transit Authority (JTA), and Lynx (the transit agency in Orlando) were categorized as large size agencies as they operate a fleet of more than three hundred buses. StarMetro and Regional Transit System (RTS), transit agencies for Tallahassee and Gainesville, respectively, were ranked as small size agencies. They each operate a fleet size of less than 100 buses. Table 1 shows a list of agencies used for this study. Two types of data were collected, bus collisions and operator schedules. The following two sections describe the collection of these two data types.

TABLE 1 Transit Agencies Used in the Study

Agency Name	Location	Fleet size	Number of operators
Jacksonville Transit Authority (JTA)	Jacksonville	129	268
Lynx	Orlando	274	396
Regional Transit System (RTS)	Gainesville	80	148
StarMetro	Tallahassee	93	160

Bus Collision Data

Transit agencies maintain records of all incidents that occur when transit vehicles are in service. Incident reports considered for this study were for the years 2007 to 2009. For the purpose of this study, the incidents are divided into collisions, also referred to as "crashes", and non-collision incidents (typically, on-board passenger injury). A stepwise review of the reports was therefore employed. First, the reports were reviewed to identify collision incidents, i.e., bus crashes with other vehicles, bicycles, pedestrians, or with fixed objects. Then the data were further screened to obtain only collisions that were coded as preventable. It is worth noting that preventability of crashes was determined by each transit agency, not the authors of this manuscript. Typically, transit agencies have safety panels that review each collision by examining crash reports filed by the police officer, incident reports filed by bus operators, and if available, video tapes captured by the video cameras mounted on the buses. If the panel determines that a bus operator could have done something to prevent the crash from occurring, the crash will be coded as *preventable*, otherwise it will be considered to be *non-preventable*. It is important to realize that not all crashes that drivers are cited to be at fault are preventable and vice versa.

All non-preventable collisions were excluded, as were collisions which were neither coded as non-preventable nor preventable. Further examination was done to eliminate any preventable collisions that were perceived as having been caused by factors other than fatigue. Pertinent collision attributes such as operator information, time of crash, date of crash, and type of crash were collected to enable additional analysis.

Operator Schedule Data

Operator schedule data was collected in two steps. First, schedules of all operators in each of the participating agencies were collected to establish the distribution of operator driving schedules for all drivers. This set of data is also referred to as comparison data in this paper. A record of each bus operator included total days worked per day, driving hours, and time of reporting on and off duty. It was not possible to collect three years worth of data for all bus operators in the four agencies. Two weeks were therefore randomly selected within the study period of between year 2007 and year 2009 to constitute comparison data, i.e., schedules for all operators. One week was selected from a month with the lowest number of preventable crashes and another week from the month with the highest preventable crash occurrences. Second, schedules of operators who have been involved in collisions that were coded as *"preventable"* were collected. A two-week schedule prior to the day of collision was collected for each operator who was involved in a preventable collision. Schedule attributes that were collected include number of hours worked each day, the amount of split hours if any, and begin and end of duty time. Figure 1 shows an example of a weekly schedule. From the pay code, details of the schedule such as sick days, holidays, and administrative work could be depicted and excluded from driving hours. Also, split times could be computed from multiple on and off duty times during the same day.

Run	207	Card #	94463
Job Title			
Hire Date	06/25/2002		

TIME CARD Date	Pay Code	IN	IN Ex	OUT	OUT Ex	Reason	Schedule	Run#	Shift/ Pay Expr	Reg Hours	OT-1 - OT-2	Daily Total
09/22/2008 Mon	3 [SICK]							207 - RUN	002	8.00		8.00
09/23/2008 Tue	3 [SICK]							207 - RUN	002	8.00		8.00
09/24/2008 Wed		06:32 AM	E 8	10:19 AM	L 4		(6:40AM - 10:15AM)	207 - RUN	002-CR	3.58		
		02:27 PM	E 13	07:10 PM	G 5		(2:40PM - 7:15PM)	217 - RUN	002-IK	4.92		8.50
09/25/2008 Thu	6 [ADMN]							207 - RUN	002	8.00		8.00
09/26/2008 Fri	6 [ADMN]							207 - RUN	002	7.50		7.50
								tals:		40.00	0.00	40.00

TIME CARD Date	Pay Code	IN	IN Ex	OUT	OUT Ex	Reason	Schedule	Run#	Shift/ Pay Expr	Reg Hours	OT-1 - OT-2	Daily Total
11/22/2008 Sat		05:20 AM*	E 80	08:20 AM*	E655		(6:40AM - 7:15PM)	76 -	001-DD	2.00		2.00
11/24/2008 Mon		06:40 AM*		07:15 PM*			(6:40AM - 7:15PM)	76 -	001-DD	11.58		11.58
11/25/2008 Tue		06:40 AM*		07:15 PM*			(6:40AM - 7:15PM)	76 -	001-DD	10.42	1.16	11.58
11/26/2008 Wed		06:40 AM*		07:15 PM*			(6:40AM - 7:15PM)	76 -	001-DD		11.84	11.84
11/27/2008 Thu	1 [HOLI]							76 -	001	8.00		8.00
11/28/2008 Fri	1 [HOLI]							76 -	001	8.00		8.00
								tals:		40.00	13.00	53.00

FIGURE 1 Example of Raw Data of Bus Operator Schedule.

DATA ANALYSIS

Descriptive Statistics of Preventable Crashes

Time of day

The distribution of preventable collisions by time of day is depicted in Figure 2. The fewest collisions occurred between midnight and 4 AM, a reflection of reduced routes and exposure late at night. Preventable collisions happened more often in the afternoon between the hours of 1 PM and 7 PM (56%) with the greatest number of collisions occurring between the hours of 1:00 and 3:00 PM (26%).

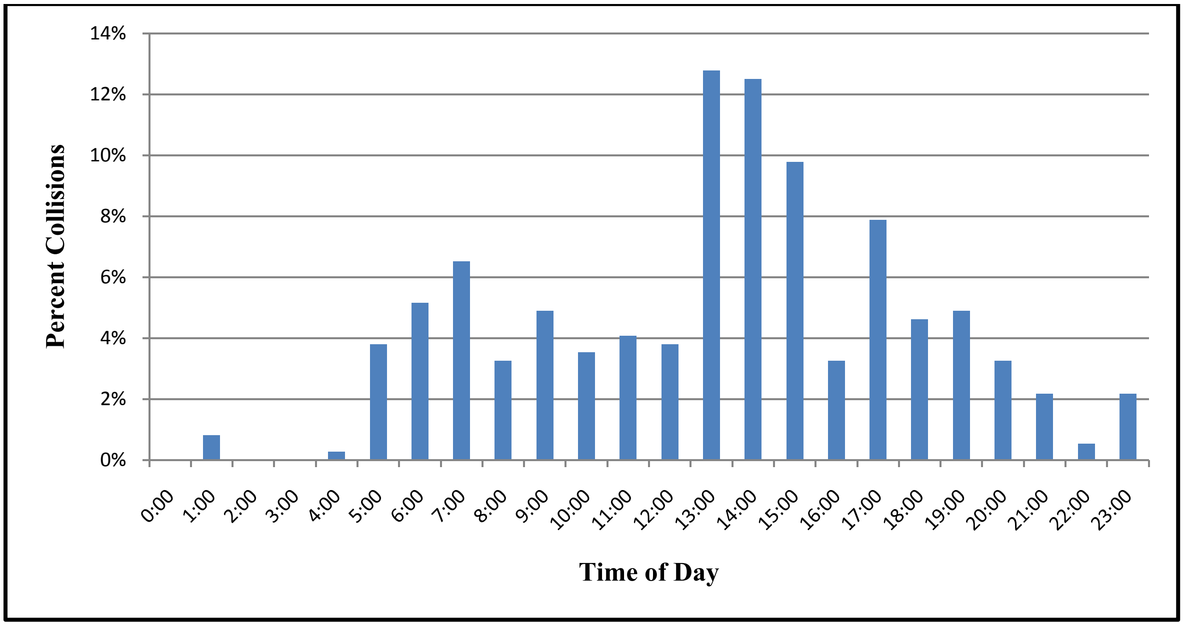

FIGURE 2 Bus preventable collisions by time of day.

Day of week

Of 222 recorded preventable collisions examined from four Florida agencies, the majority occurred on a weekday (81%) with 14% occurring on a Saturday, and only 5% happening on a Sunday, perhaps a reflection of reduced exposure (Figure 3). Examination of the incident reports revealed that most of the bus collisions that occur on Saturday happen at night and involve buses that shuttle patrons to events such as football and basketball games. The highest number of collisions occurs on Wednesday, followed by Monday and Tuesday.

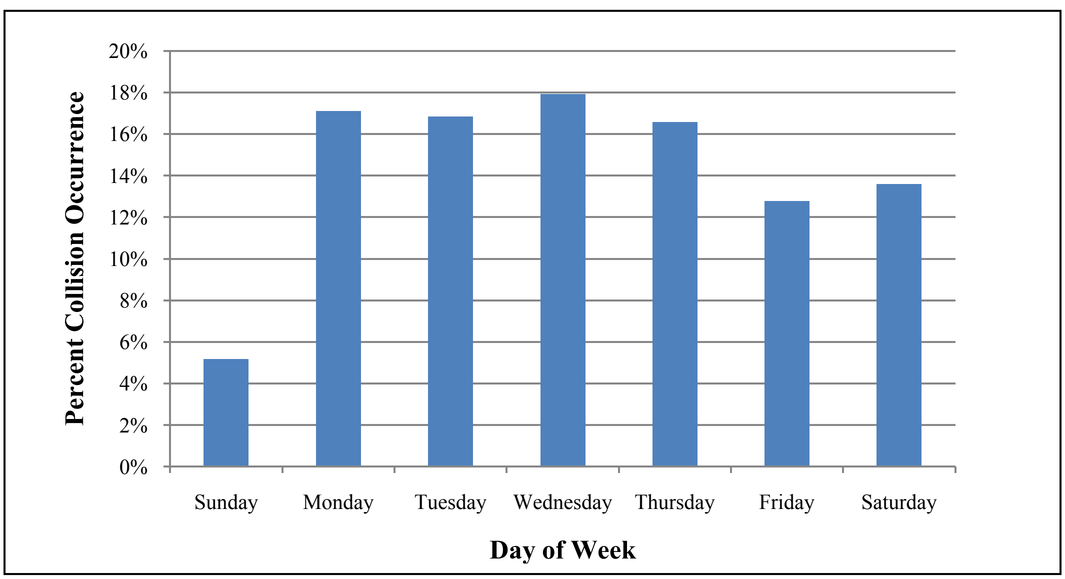

FIGURE 3 Preventable bus collisions by day of week.

Descriptive Statistics of Operator Schedules

The study design used in this study was based on a similar study that was done in the airline industry by Goode *(14).* Goode compared the distribution of pilot work schedule parameters for accidents to that for all pilots. The analysis presented herein compares schedules of bus operators who were involved in collisions to all operators. Schedules for all drivers were extracted for two consecutive weeks which were randomly chosen for each agency. The schedules of drivers who were involved in preventable collisions in those randomly selected weeks were removed from the dataset of all driver schedules. The 95% confidence interval for the combined mean weekly driving time for operators involved in preventable collisions was computed. A total of 222 collision occurrences were examined as summarized in Table 2. The results show a combined mean driving time of 49.8 hours for driving periods containing no split-time intervals, with a 95% confidence interval of 48.7-hr to 50.9-hr. This suggests a 95% likelihood that a bus driver who is involved in a collision would have driven more than 45 hours seven days prior to the collision. For operator weekly driving times containing split-time intervals, a combined mean driving time of 53.7 hours with a 95% confidence interval of 52.3-hr to 55.0-hr was computed indicating a 95% chance that a bus operator involved in a preventable collision would have driven more than 50 hours per week, including split times.

TABLE 2 Average Weekly Driving Hours of Operators Involved in Preventable Collisions and All Operators

Weekly average driving hours without splits								
Location	Average		Std. Deviation		Minimum		Maximum	
	Involved	All Drivers	Involved	All Drivers	Involved	All Drivers	Involved	All Drivers
Gainesville	49.22	40.24	7.36	2.70	35.75	32.10	68.55	60.50
Jacksonville	49.94	46.39	7.58	6.99	36.77	32.60	70.00	64.22
Orlando	50.02	43.90	7.54	9.09	31.25	6.25	68.68	65.02
Tallahassee	49.71	41.26	10.71	3.71	16.90	27.00	70.00	56.00
Combined	49.81	43.52	8.64	7.50	16.90	6.25	70.00	65.02
Weekly average driving hours with splits								
Location	Average		Std. Deviation		Minimum		Maximum	
	Involved	All Drivers	Involved	All Drivers	Involved	All Drivers	Involved	All Drivers
Gainesville	50.43	42.26	7.54	3.71	35.75	32.10	69.88	60.50
Jacksonville	54.34	51.79	8.46	10.90	39.95	32.60	71.56	85.67
Orlando	54.62	47.89	9.66	12.62	31.25	6.25	83.45	80.22
Tallahassee	53.35	46.73	11.82	9.41	30.50	27.00	81.35	70.50
Combined	53.67	47.65	9.85	11.06	30.50	6.25	81.35	85.67

Inferential Statistics Analysis

A one-tailed two-sample *t*-test was used to determine whether the population of operators involved in preventable collisions predominantly work longer hours or if driving schedules with split-time intervals played a role in collision occurrences compared to the overall population sampled with similar schedules. The *t*-test results for driving hours without splits and with splits are summarized in Table 3. The results show that on average, drivers who were involved in preventable collisions drove over six hours more per week than that of the general population of drivers. The results of a one-tailed two-sample t-test revealed that a significant difference exists for all four agencies and for combined data. It is therefore evident from data that statistically, operators who are involved in preventable collisions drive more hours compared to the population of all drivers.

TABLE 3 *t*-Test Results

t-Test Results - Collisions for driving periods without splits						
Location	N		Mean Hours		T-Value	P-Value
	Involved	All Drivers	Involved	All Drivers		
Gainesville	23	132	49.22	40.24	-5.78	0.00
Jacksonville	80	172	49.94	46.39	-3.55	0.00
Orlando	47	296	50.02	43.90	-5.02	0.00
Tallahassee	72	77	49.70	41.26	-6.34	0.00
Combined	222	677	49.81	43.52	-9.71	0.00
t-Test Results - Collisions for driving periods with splits						
Location	N		Mean Hours		T-Value	P-Value
	Involved	All Drivers	Involved	All Drivers		
Gainesville	23	132	50.43	42.26	-5.09	0.00
Jacksonville	80	172	54.34	51.80	-2.02	0.022
Orlando	47	296	54.62	47.90	-4.24	0.00
Tallahassee	72	77	53.30	46.73	-3.76	0.00
Combined	222	677	53.67	47.70	-7.66	0.00

Comparative Analysis

Table 4 shows the proportion of driving periods of various lengths for preventable collisions and all operators. The first column shows the seven categories of driving hours. The second column shows the number of preventable collisions for each driving hour's category. Collision proportion as a ratio of number of preventable collisions for each category to the total number of preventable collisions is recorded in the third column. The forth column shows the proportion of the total number of preventable collisions for driving hours including split-time for each category. The fifth and sixth columns show the total driving hours in each driving hour category (drawn from all drivers schedule data) and the exposure proportion respectively, while columns seven and eight show similar data for total driving hours with splits for all drivers. Collision proportions relative to the exposure proportion for driving hours without splits and with splits are shown in columns nine and ten, respectively.

TABLE 4 Comparative Analysis of Weekly Driving Hours for Combined Data

Combined Agency Weekly Summary									
Driving Period (1)	Collisions (2)	Collision proportion (3)	Collision proportion (with splits) (4)	Driving Hours (5)	Exposure proportion (6)	Driving hours (with splits) (7)	Exposure proportion (with splits) (8)	Collision prop. Relative to Exposure prop. (without splits) (9)	Collision prop. Relative to Exposure prop. (with splits) (10)
0-40	17	0.08	0.05	8740	0.30	5928	0.18	0.26	0.29
>40-45	53	0.24	0.18	8778	0.30	7812	0.24	0.80	0.73
>45-50	59	0.27	0.17	5152	0.17	5088	0.16	1.52	1.06
>50-55	40	0.18	0.18	4368	0.15	4452	0.14	1.22	1.34
>55-60	25	0.11	0.15	1512	0.05	3060	0.09	2.20	1.61
>60	28	0.13	0.27	930	0.03	5922	0.18	4.00	1.45
Total	222	1.00	1.00	29480	1.00	32262	1.00	1.00	1.00

For the first two categories, i.e., driving periods below 45 hours per week, the proportion of drivers was higher than the proportion of preventable collisions. Collision proportions increased relative to the general population for driving hours exceeding 45 hours per week. Figure 4 shows the relationship between number of driving hours and the collision and exposure proportion. It is clear from Figure 4 that preventable collisions are more prevalent as the length of the driving period increases.

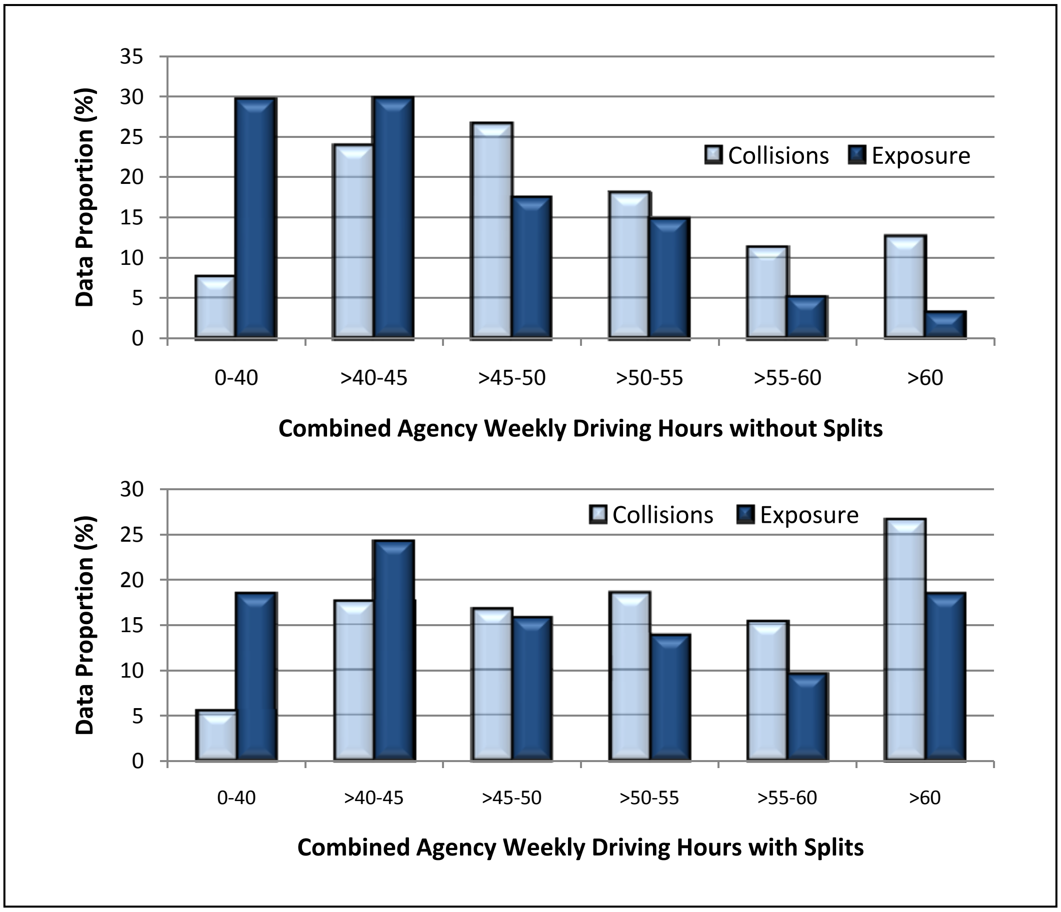

FIGURE 4 Comparative analyses for combined weekly hours.

Overrepresentation Analysis

The results of the comparative analysis were used to determine long driving hour's overrepresentation ratios for each driving hour duration category. The overrepresentation ratio was computed as collision proportions relative to the exposure proportions for driving hours (columns 9 and 10 in Table 4). The ratios are shown in Figure 5. According to Figure 5, the ratio of collision proportion to the exposure proportion increases with the length of driving hours for both split and non-split schedules. For the same categories, drivers driving straight hours, i.e., without splits were found to have higher propensity of being involved in preventable collisions. The overrepresentation ratio increases drastically from 2.20 to 4.00 from driving hour category of 55-60 hours to >60 hours for schedules with splits. The relative proportion of preventable collisions to exposure for driving hours with splits appears to decrease slightly for the >60 driving category from the 55-60 driving period. This is representative of fewer occurrences of total driving hours including split-time falling in the 55-60 driving period category. Consequently, a steady increase in the propensity for preventable collisions with longer hours on duty, including split-times, is evident.

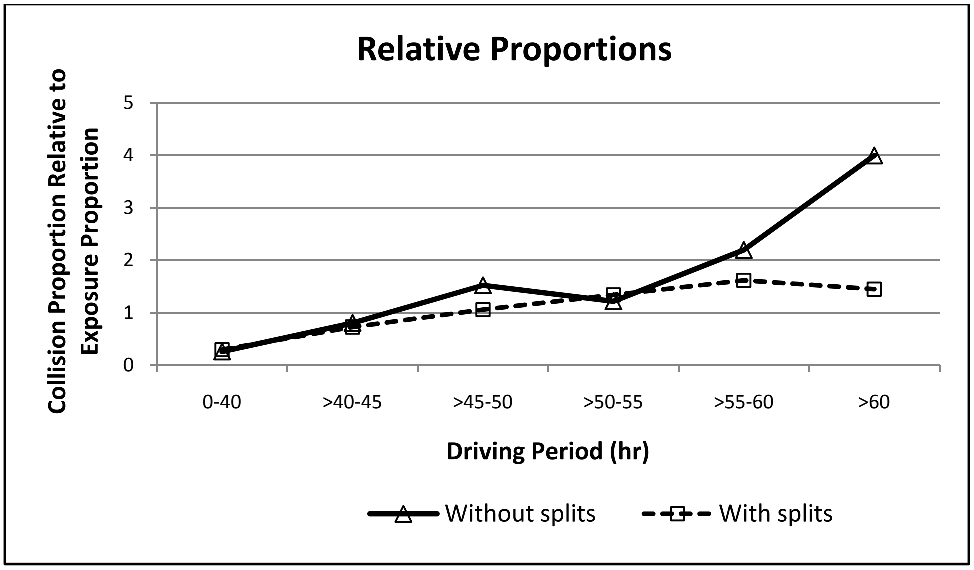

FIGURE 5 Drivers' driving hours and preventable collisions by length of driving.

CONCLUSIONS AND RECOMMENDATIONS

This study was conducted to examine the relationship between the number of driving hours of bus operators and the occurrence of preventable collisions. The study utilized incident and schedule data from four Florida transit agencies. Weekly schedules of transit operators were examined using several analysis methods including descriptive statistics, *t*-test inferential statistics, and graphical comparative analysis.

The results show an overall average of 49.8 hours for driving periods containing no split-time intervals, with a 95% confidence interval of 48.7-hr to 50.9-hr. For operator weekly driving times containing split-time intervals, a combined mean driving time of 53.7 hours with a 95% confidence interval of 52.3-hr to 55.0-hr was computed indicating a 95% chance that a collision would occur when an operator's total hours, including split-times, exceeds 50 hours. The results of the t-test analysis indicate that drivers who are involved in preventable collisions drive more than six hours per week than the general driver population. The results were statistically significant.

The results of the comparative analysis suggest that preventable collisions occur predominantly with drivers that have long driving schedules. The overrepresentation analysis further indicated that relatively, drivers driving over sixty hours per week without splits have higher propensity of being involved in a preventable collision. Based on the findings of this study, a discernible pattern was observed that shows that there is a correlation between preventable collisions and the length of transit operator driving hours. Present regulation limits bus operators to drive a maximum of seventy hours per week. In light of the findings of this study, a lower limit might be more desirable as the overrepresentation ratio was observed to spike after sixty hours of driving per week.

We recommend more data to be collected from agencies with varying size and geographical location, and that a survey of bus operators be conducted to collect information on how operators use their break time (for split shifts) and activities performed during the off-duty hours after and before beginning work. The questionnaire could be designed to also gather information on activities that are typically performed during the off-duty period that may include operators traveling from work to home, eating, sleeping, preparing for work, and traveling back to work from home. The amount of sleep that a bus operator gets would depend on the time it takes to perform off-duty activities. These anonymous surveys could use a diary technique to document start and end of each off-duty activity. General questions such as the distance from home to work, average hours of sleep per day could also be included in the questionnaire.

Suggestions for future research are plenty. A within comparison study is recommended for future research. In a within study, instead of comparing scheduled of drivers involved in collisions with those of other drivers, a comparison is made within the same group of drivers who are involved in collisions but the comparison set is extracted randomly from weeks that drivers are not involved in a collision. This could help in controlling differences between individual drivers. This study used the total number of driving hours as the only exposure measure. Further analysis is recommended that would include other exposure measures such as number of trips and mileage. Also, this paper did not consider time-on-task on a daily basis. This should be examined in future studies.

It should be noted, however, that the study reported herein did not consider other variables that in combination with long driving hours might influence the occurrence of bus collisions. We therefore recommend that future research should consider performing a statistical modeling analysis to analyze the interaction between a number of traffic, roadway, and driver characteristics that are known to influence collisions in order to determine if there are other factors that are stronger predictors of bus crash occurrences other than cumulative driving hours. Such variables may include traffic level, length of routes, type of shift (day or night), driver experience, and driving hours. Lastly, a reduction of weekly driving caps without implementing other fatigue reduction strategies may be simplistic. A more comprehensive strategy that includes limiting maximum weekly driving hours coupled with other fatigue management programs (FMPs) that include training, napping strategies, sleep disorder screening and treatment is desirable.

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