Motorcoach Driver Fatigue Study, 2011

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

December 2012

FOREWORD

This report describes the work, sleep, and performance of a sample population (N=84) of commercial motorcoach drivers. The drivers were studied individually for approximately a month while pursuing their normal work/rest schedules. The goal was to assess the degree to which active motorcoach drivers push the limits of motorcoach hours-of-service regulations and so expose themselves to non-24-hour work/rest cycles—cycles that would likely restrict sleep and impair performance. Operationally defined for the purposes of this study, non-24-hour work/rest cycles are characterized by duty start times distributed at various times around the 24-hour day. Drivers self-identified as driving for Charter, Tour, Regular Route, or Commuter Express operations. Drivers were, on average, middle-aged, overweight or obese, and predominantly male. With a few exceptions, no evidence was found that the participating motorcoach drivers exposed themselves to non-24-hour work/rest cycles. Duty start times were clustered in the morning, indicating a duty day synchronized to the normal circadian rhythm of awake/work during the day and asleep at night. Average time on duty per duty day was slightly more than 9 hours. Average total daily sleep time, though shorter for on-duty days, was in the recommended range of 7–9 hours for both on-duty and off-duty days. Drivers averaged 40–45 hours on duty per 7 days. There was evidence of a decrease in vigilance test performance and an increase in fatigue and sleepiness at the end as compared to the beginning of the duty day.

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16. Abstract

Eighty-four commercial motorcoach drivers participated in a month-long study of duty start time, total duty time, total sleep time per 24 hours, with sleepiness, fatigue, and performance measured as they were going on and off duty. Drivers worked their normal schedules of duty and rest for the average 31 days of participation. Drivers wore a wrist-watch actigraph to measure continuous sleep/wake history and kept a duty/sleep diary. They took a 5-minute psychomotor vigilance test (PVT) and rated their fatigue and sleepiness going on and off duty. The aim of the study was to determine motorcoach driver duty hours, sleep time, fatigue, and performance while operating within the limits of the Federal Motor Carrier Safety Administration motorcoach hours-of-service regulations. Motorcoach drivers actively working as drivers, fit to drive by their company's standards, and who volunteered to participate were enrolled. Drivers self-identified as driving for Charter, Tour, Regular Route, or Commuter Express operations. This was a sample of convenience. The sample was, on average, middle-aged, overweight, and predominantly male. From the data: 1) duty start times clustered in the morning; 2) average total duty time for duty days was slightly more than 9 hours; 3) average total sleep time per 24 hours was in the range of 7 to 9 hours, with less sleep during on-duty days and more sleep during off-duty days. During on-duty days, longer total duty times were associated with shorter sleep. Drivers performed worse on the PVT and reported increased sleepiness and fatigue at the end of a duty period relative to the beginning. These findings were in the context of an estimated average of 43 hours on duty per week. Thus, drivers in the sample on average started work in the morning, worked approximately 9-hour days, and slightly more than a 40-hour week, and obtained satisfactory amounts of sleep. On average, drivers did not push the limits of the hours-of-service regulations.

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SI* (MODERN METRIC) CONVERSION FACTORS

TABLE OF APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME	1,000 L shall be shown in m^3	
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE	Temperature is in exact degrees	
W	Fahrenheit	5 × (F-32) ÷ 9 or (F-32) ÷ 1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

TABLE OF APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE	Temperature is in exact degrees	
°C	Celsius	1.8C + 32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-lamberts	fl
		Force & Pressure Or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Acronym	Definition
ANOVA	analysis of variance
EEG	electroencephalogram
EKG	electrocardiogram
EMG	electromyogram
EOG	electrooculogram
FMCSA	Federal Motor Carrier Safety Administration
HOS	hours of service
KSS	Karolinska Sleepiness Scale
MP	mixed procedure
NTSB	National Transportation Safety Board
PSG	polysomnogram
PVT	Psychomotor Vigilance Task
REML	restricted maximum likelihood
RT	reaction time
SAS	Statistical Analysis Software
SD	standard deviation of the mean
TST	total sleep time

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EXECUTIVE SUMMARY

PURPOSE

The objective of this study was to determine if commercial motorcoach drivers work to the limits of the Federal Motor Carrier Safety Administration (FMCSA) hours-of-service (HOS) regulations. Data were collected on duty start times, total duty time per 24 hours, and total sleep time per 24 hours. Performance was measured and subjective fatigue and sleepiness were rated when going on and off duty. These measures were taken in the context of HOS regulations mandating that 8 hours off duty precede 10–15 hours on duty, effectively permitting work/rest cycles outside of the normal 24-hour cycle of being awake during the day and asleep at night. Work/rest cycles outside of the normal 24-hour cycle was, for the purposes of this study, defined as the presence of duty start times distributed at various times throughout the 24-hour day. If distributed duty start times were found, it was expected that they would be accompanied by truncated sleep, degraded performance, and increased subjective fatigue and sleepiness.

PROCESS

Eighty-four motorcoach drivers who self-identified as working for Charter, Tour, Regular Route, or Commuter Express operations were studied for an average of 31 consecutive days, during which they maintained their normal work/rest schedule. To measure driver duty start times, duty break times, and duty end times, drivers kept a duty/sleep diary. To measure sleep/wake history, drivers wore an actigraph—a wrist-worn device recording arm movements in 1-minute increments from which a minute-by-minute sleep/wake history can be scored. To measure performance, drivers took a psychomotor vigilance task (PVT) going on and off duty, as well as before and after any mid-duty breaks. To measure subjective fatigue and sleepiness, drivers filled out the Samn-Perelli Fatigue Scale and the Karolinska Sleepiness Scale (KSS) going on and off duty and before and after any mid-duty breaks. Both scales were used because, in the scientific literature and in discussions with operational personnel, fatigue appears to be a slightly different construct from sleepiness. Baseline scores are not available for this study's population, making these tests useful for relative comparison across days and across shifts within days.

RATIONALE AND BACKGROUND

The HOS regulations for motorcoach drivers allow 10–15 hours on duty (10 hours driving) after 8 hours off duty. This cycle, if repeated—8 hours off, 10–15 hours on, 8 hours off, 10–15 hours on—would allow an 18–23-hour work/rest cycles that are not in sync with the normal 24-hour night/day sleep/wake synchrony. Functionally, this would mean getting up 1 to 6 hours earlier each day, i.e., a "backwardly rotating" schedule. It is unknown whether motorcoach drivers push the regulatory limits or operate well within them. If they do not push the limits then they likely are maintaining a 24-hour work/rest cycle in a normal diurnal phase alignment to the 24-hour day (awake and active during the day, asleep at night). Pushing the limits would manifest itself by duty start times distributed at various times throughout the day and night, resulting in sleep truncation and associated impaired performance, and increased fatigue and sleepiness. Additional issues have been raised by the National Transportation Safety Board (NTSB) regarding the safety of curbside (as opposed to terminal) pick-up and drop-off operations, particularly in the context of smaller bus companies. Using the NTSB definition, their curbside pick-up, and drop-off would fall within the boundaries of this study's Regular Route classification, though it is unknown whether the study sample included drivers involved in curbside pick-up and drop-off operations.

STUDY FINDINGS

The 84 motorcoach drivers who participated in this study were, on average, middle-aged, overweight, and male. It is not known if this sample is representative of the motorcoach industry. Drivers from FMCSA HOS-regulated companies were eligible for the study if they were fit for duty according to the standards of their company. Drivers volunteered to participate and gave written informed consent.

The average length of participation per subject was 31 days (range 20–48 days). Duty start times for the sample, derived from the duty/sleep diary, clustered in the early- to mid-morning hours with Regular Route and Commuter Express duty start times earlier than those of Charter or Tour. Overall, duty start times showed a normal circadian alignment.

Mean duty period for the sample was slightly more than 9 hours. Rarely did a duty period exceed the regulatory limit of 15 hours on duty.

The participants were on duty 65 percent of total studied days. In a rough calculation, total on-duty time averaged 43 hours per week. Based on actigraph data, mean TST per 24 hours for the drivers was in the recommended range of 7 to 9 hours. TST per 24 hours was longer for off-duty days than on-duty days, and for on-duty days, the longer the total duty time, the shorter the TST.

Participants demonstrated decreased PVT performance at the end of the duty period relative to the beginning. Similarly, participants reported an increased level of fatigue and sleepiness at the end of a duty period relative to the beginning.

CONCLUSIONS

Motorcoach drivers self-identifying as driving for Charter, Tour, Regular Route, or Commuter Express operations were studied for approximately a month as they went about their usual work/rest routine. Duty start times clustered in the early to mid-morning suggesting normal circadian synchronization to the 24-hour day. Total time on duty per duty day averaged slightly more than 9 hours and rarely exceeded the regulatory limit of 15 hours. Drivers were estimated to work 43 hours per week. Mean total daily sleep time was within the recommended range of 7–9 hours per 24 hours for the overall sample and for each operational subset. Drivers in the study sample appear to be working well within the limits of the current HOS regulations. In the present study, motorcoach drivers appear to effectively balance the demands of work, family, and community to sustain adequate amounts of sleep.

1. INTRODUCTION

1.1 Objective

The objective was to determine if commercial motorcoach drivers work to the limits of the Federal Motor Carrier Safety Administration (FMCSA) hours-of-service (HOS) regulations. Working to the limits of the current regulations would entail being on duty for 10 to 15 hours after 8 hours off duty for rest and sleep, and repeating this in a backwardly rotating 18–23-hour consecutive series of work/rest cycles. Working to the limits in this way could be expected to yield duty start times distributed at various times around the 24-hour day/night cycle, with additional associated findings of truncated sleep, impaired performance, and increased fatigue and sleepiness.

1.2 BACKGROUND

Fatigue is defined *subjectively* by self-reporting and defined *objectively* by degraded performance. It is the product of the interaction of sleep loss, adverse circadian rhythm phase, workload, and individual differences (Balkin, 2011; Belenky & Akerstedt, 2011; Wesensten et al., 2004). Sleep loss and circadian rhythm are factors in the two-process model of sleep regulation (Borbély, 1982). The two-process model has been adapted to predict alertness and performance as a function of time awake and circadian phase (Van Dongen, 2004). The two-process model, thus, can predict the effects of extended work hours, night operations, and early starts on operational performance. Extended work hours, night operations, and early starts are permitted in motorcoach operations under current HOS regulations.

Normal total sleep time (TST) is not well characterized (National Sleep Foundation—http://www.sleepfoundation.org/article/white-papers/how-much-sleep-do-adults-need). The recommended range for adults (and the standard of reference for this report) is roughly 7 to 9 hours of sleep per day (National Sleep Foundation—http://www.sleepfoundation.org/article/how-sleep-works/how-much-sleep-do-we-really-need). This recommended range is substantially more than that achieved by a cross-section of middle-aged Americans, studied as part of the Coronary Artery Risk Development in Young Adults (CARDIA) study, which found that sleep measured over 3 days by actigraphy (Ancoli-Israel et al., 2003; see Section 2.3.2) averaged 6.1 hours of sleep per day ± 1.2 hours standard deviation (SD) (Lauderdale et al., 2006).

It is TST per 24-hour day that sustains performance (Mollicone, Van Dongen, and Dinges, 2007; Mollicone et al., 2008). Thus, performance-relevant TST includes both main sleep periods and naps. To accurately measure TST (main sleep period and naps, if taken) one must record sleep/wake history 24 hours per day. This is done in the laboratory using a combination of electrophysiological recording of electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG), and electrocardiogram (EKG) called polysomnography (PSG). It can be done unobtrusively in the field with the wrist-worn actigraph. Actigraphy is as accurate as PSG in determining TST per day (Ancoli-Israel et al., 2003).

At the time of this study, motorcoach drivers operated under FMCSA HOS regulations that limited them to 15 consecutive hours on duty after completing 8 consecutive hours off duty. A maximum of 10 of those on-duty hours could be spent driving. Motorcoach drivers could not drive after a total 60/70 hours on duty on 7/8 consecutive days without taking further time off. Under these rules it is possible to work backwardly rotating 18–23-hour days. Being on duty for 15 hours preceded by the mandatory 8 hours off duty yields a 23-hour day, which means the next shift would then begin 1 hour earlier than the previous shift. Being on duty for 10 hours preceded by the mandatory 8 hours off yields an 18-hour day, which would mean each successive shift would begin 6 hours earlier. This backwardly rotating schedule forces drivers to be out of sync with the normal 24-hour night/day sleep/wake cycle (Czeisler et al., 1999). By continuously changing the relationship of sleep opportunity and work duty day to the normal night/day 24-hour circadian cycle, deleterious direct effects on sleep and both direct and indirect effects on performance and subjective assessment of fatigue and sleepiness would be expected. The direct effects on sleep would be through sleep truncation by the off-duty period overlapping a period of rising circadian drive for wakefulness. The direct effects on performance would be through performance degradation by the work period overlapping a period of falling circadian drive for wakefulness. The indirect effects on performance would be through the truncation of sleep, as described above. The human circadian clock in the suprachiasmatic nucleus in the hypothalamus of the brain has an intrinsic period of slightly more than 24 hours. The clock can adjust to periods slightly shorter and slightly longer than 24 hours, but a 23-hour day is probably beyond the reach of the circadian clock's ability to adjust (Wright et al., 2001). Working such shortened cycles would have a negative effect on sleep, performance, and subjective state (Drake & Wright, 2011).

The motorcoach industry can be divided into four types of operations:

- Charter—to and from a destination during the same day.
- Tour—multiday trips.
- Regular Route—scheduled trips within or between cities.
- Commuter Express—trips to and from work (including airport express).

These categories closely fit the terminology used by the bus industry (http://www.buses.org/About-Us).

These types of operations may differ in duty-day timing, duration, and other metrics—differences that could be reflected in disruptions in sleep, performance, and subjective state. It should be noted that there is no accepted classificatory scheme for characterizing the types of motorcoach operations, but the Motor Carrier Safety Advisory Committee (MCSAC) took this on as a task at its January 2012 meeting.

2. METHODS

2.1 EXPERIMENTAL DESIGN

This was a naturalistic study of duty, sleep, performance, and subjective fatigue and sleepiness conducted in motorcoach drivers going about their normal routines of work, rest, and family/community activities and responsibilities. To study sleep, performance, and subjective state in relationship to duty status requires measures of sleep and performance, duty start and end times, timing and length of breaks, and self-reported measures of subjective state. The study was designed to collect these objective data in actual motorcoach operations. Further, the study aimed to better describe the types of shifts that exist in current motorcoach operations. In this effort, motorcoach drivers were continuously studied using actigraphy and sleep/work diaries. Participants also completed a 5-minute psychomotor vigilance task (PVT) and rated their subjective fatigue and sleepiness at specific intervals over the approximately 31 days that each was studied. Participants worked when they would normally work and were off duty when they would normally be off duty. Drivers were studied for a continuous sequence of days. The study was designed to correlate work, sleep, and performance with respect to work start time and duration, and sleep duration and placement, all in relation to the normal 24-hour circadian work/rest cycle.

The operational day was defined as midnight to 11:59 p.m., and TST per day was the sum of all sleep (main sleep and naps) in each successive 24 hours. Similarly, total on-duty time per duty day was the sum of all duty periods during a 24-hour period from midnight to 11:59 p.m. Drivers recorded their duty start time, duty end time, and the duration of any breaks taken throughout the day. Duty duration was calculated by summing all work time for a 24-hour period minus their total break time for the same period.

2.2 PARTICIPANT RECRUITMENT AND SCREENING

The study was approved by the Washington State University Institutional Review Board and all volunteers gave written informed consent. The sample of motorcoach drivers was a sample of convenience. Participants were drawn from motorcoach companies across the United States whose operations are governed by the FMCSA HOS regulations. Drivers were recruited through presentations at motorcoach conferences, training events, union meetings, advertisements in *Bus Ride* Magazine, as well as direct mailings and phone calls to companies and unions. A substantial number of the participants were recruited by word of mouth. A participant was fit for the study if he or she was employed as a motorcoach driver and fit to drive as judged by his or her company's standards. Participants who reported working fewer than 2 days per week on average were not included. Participants were trained on study procedures over the telephone and materials were shipped to them prior to the training session. Drivers were compensated $450 for completing the study. Data collection occurred August 2010 through August 2011.

2.3 MEASURES

2.3.1 Duty Start Time and Duty Duration

Participants used a duty/sleep diary to record duty start and end times, as well as the beginning and end of mid-duty breaks. Drivers were asked to provide a brief description of their route. Duty start time was taken directly from the driver's duty/sleep diary as the first on-duty period after midnight. Duty time for a duty day was calculated by summing all work time for 24 hours minus their within-work break time for the same period. The 24-hour intervals were from midnight to 11:59 p.m. every day during the driver's participation in the study.

2.3.2 Sleep

TST per 24 hours was measured using a wrist-worn actigraph (Figure 1). An actigraph is a device containing an accelerometer, central processing unit, and memory that continuously records the number of arm movements per minute and stores the number of movements at one-minute intervals. Each participant's entire record was scored by actigraph sleep-scoring software to yield a minute-by-minute sleep/wake state which, extended over time, yields a sleep/wake history. The autonomous machine scoring was cross-referenced and reconciled with the actigraph event marker button presses indicating beginning and end of the sleep period coupled with data from the driver's duty/sleep diary. With respect to on-duty days, sleep could occur before, after, both before and after, or during duty time. With respect to accurately measuring TST, the actigraph is functionally equivalent to standard PSG sleep recording (Ancoli-Israel et al., 2003).

Figure 1. Photograph. The Actigraph

2.3.3 Performance

Vigilance performance was measured using a 5-minute PVT. The PVT is a simple reaction time test with a high-stimulus density (Dinges & Powell, 1985). At random 2–10 second intervals, a bull's-eye stimulus appears on the screen. The driver must press the designated button on the smart phone to indicate he/she saw the stimulus. The time from the appearance of the bull's-eye to the participant's pushing the button in response is scored as the participant's reaction time on that trial. Depending on how quickly the participant responds, there may be up to 50 responses with accompanying reaction time on the 5-minute PVT. The PVT is a standard assay of vigilance performance used to assess fatigue (Dorrian, Rogers, & Dinges, 2005). Performance on the PVT was expressed as the inverse of the speed measure (reaction time—1/RT x 1,000), with lower values indicating poorer performance (Belenky et al., 2003). For the present study, the PVT was implemented on a smart phone (Thorne et al., 2005; see Figure 2).

Figure 2. Photograph. The PVT Ported to a Smartphone

2.3.4 Subjective State

Subjective fatigue was measured by the Samn-Perelli Fatigue Scale (Samn & Perelli, 1982). The Samn-Perelli rating (from 1—*fully alert* to 7—*completely exhausted, unable to function effectively*) was recorded in the duty/sleep diary going on and off duty, and at the beginning and end of any mid-duty period breaks.

Subjective sleepiness was measured by the Karolinska Sleepiness Scale (KSS; Akerstedt & Gilborg, 1990). The KSS rating (from 1—*extremely alert* to 9—*extremely sleepy, fighting sleep*) was recorded in the work/sleep diary going on and off duty, and at the beginning and end of any mid-duty breaks.

Arguably, giving both the Samn-Perelli Fatigue and the KSS is unnecessary. However, both are widely used in operational studies of sleep and performance and fatigue risk management in operational settings. They appear to represent different constructs (Shen et al., 2006), and both have face validity to the operational community. The lack of norms for both the Samn-Perelli Fatigue Scale and KSS and the lack of baseline testing on the study's participants make these scales most appropriate for relative comparisons (i.e., going on duty and going off duty) (e.g., Baulk et al., 2009).

2.4 DATA ANALYSIS

For the naturalistic data collected in this study a combination of data visualization, descriptive statistics of central tendency, and model-based, mixed-effects analysis of variance (ANOVA) were completed. For the purposes of data visualization, data as a function of day and data as a function of driver are presented (Table 1). In a data-as-a-function-of-day plot, for example, all recorded duty start times are plotted directly. In a data-as-a-function-of-driver plot, the recorded duty times for each driver are averaged, and the averages are then plotted. Thus, in the data-as-a-function-of-day graphic, all 1,710 duty start times are plotted, and in the data-as-a-function-of-driver graphic, only the 84 individual driver average duty start times are plotted. The data as a function of day reflects the general public's overall exposure to fatigue risk from fatigued motorcoach drivers. Descriptive statistics, in the form of mean and standard deviation, were computed for both data-as-a-function-of-day and data-as-a-function-of-driver plots. Further, where appropriate, the data were analyzed using mixed-effects ANOVA models with Statistical Analysis Software (SAS) v9.2 Mixed Procedure (MP). Mixed-effects models allow for both fixed and random effects to be controlled; mixed models were used to integrate the data while controlling for individual driver. The model was fitted to the data by the restricted maximum likelihood (REML) method, a method appropriate for unbalanced groups. In the results section, this statistical analysis is abbreviated SAS MP/REML.

Table 1. Number of Drivers, On-Duty Days, and Off-Duty Days by Type of Operation

	Drivers	Total On-Duty Days	Total Off-Duty Days	Total Days
All	84	1,710	893	2,603
Charter	19	354	244	598
Tour	15	327	152	479
Regular Route	25	500	258	758
Commuter Express	25	529	239	768

3. RESULTS

3.1 DESCRIPTION OF MOTORCOACH DRIVERS PARTICIPATING IN THE STUDY

The participants were commercial motorcoach drivers and employed as such. The characteristics of the participant driver population are given in Table 2.

As is evident from the table, the motorcoach drivers in this study were, on average, middle-aged, overweight or obese, and were predominantly male. There were no significant differences in distribution of gender, age, or body mass index (BMI) by one-way ANOVA across the four types of motorcoach operations. BMI is measured by dividing the driver's weight in pounds by height in inches squared and multiplying by a conversion factor of 703. According to the Centers for Disease Control and Prevention, a BMI value below 18.5 is underweight; 18.5 to 24.9 is normal; 25.0 to 29.9 is overweight; and 30.0 and higher is obese.

The sample of driver-participants was a sample of convenience. It is not known how representative this sample of drivers is of the motorcoach industry as a whole.

Table 2. Driver Characteristics

Participants	Men	Women	Total
All	64	20	84
Charter	15	4	19
Tour	12	3	15
Regular Route	21	4	25
Commuter Express	16	9	25
Mean Age ± SD*	**Men**	**Women**	**Total**
All	49.7 ± 10.5	51.4 ± 9.9	50.1 ± 10.3
Charter	52.7 ± 11.1	52.7 ± 10.9	52.7 ± 10.8
Tour	49.7 ± 10.8	56.7 ± 10.0	51.3 ± 10.6
Regular Route	49.2 ± 9.9	56.3 ± 5.0	50.4 ± 9.5
Commuter Express	47.6 ± 11.1	46.3 ± 10.2	47.1 ± 10.5
Mean BMI ± SD**	**Men**	**Women**	**Total**
All	32.5 ± 6.0	31.7 ± 6.7	31.9 ± 6.5
Charter	28.1 ± 5.0	37.6 ± 4.7	30.2 ± 6.3
Tour	34.8 ± 6.2	34.7 ± 7.8	34.8 ± 6.2
Regular Route	32.9 ± 7.4	30.7 ± 5.8	32.5 ± 7.1
Commuter Express	31.4 ± 6.5	30.1 ± 5.0	31.0 ± 6.0

*77 responded with their age.

**76 responded with their BMI.

3.2 DISTRIBUTION OF DAYS OF PARTICIPATION BY DRIVER

Figure 3 represents the distribution of days of participation by driver summed across all four types of operations—Charter, Tour, Regular Route, and Commuter Express. A number of drivers dropped out of the study on or before day 7 and were excluded from the graph below and from the data analysis. Those who participated for at least 7 days generally completed the study with their participation lasting for an average of 31 continuous days (range 20–48 days).

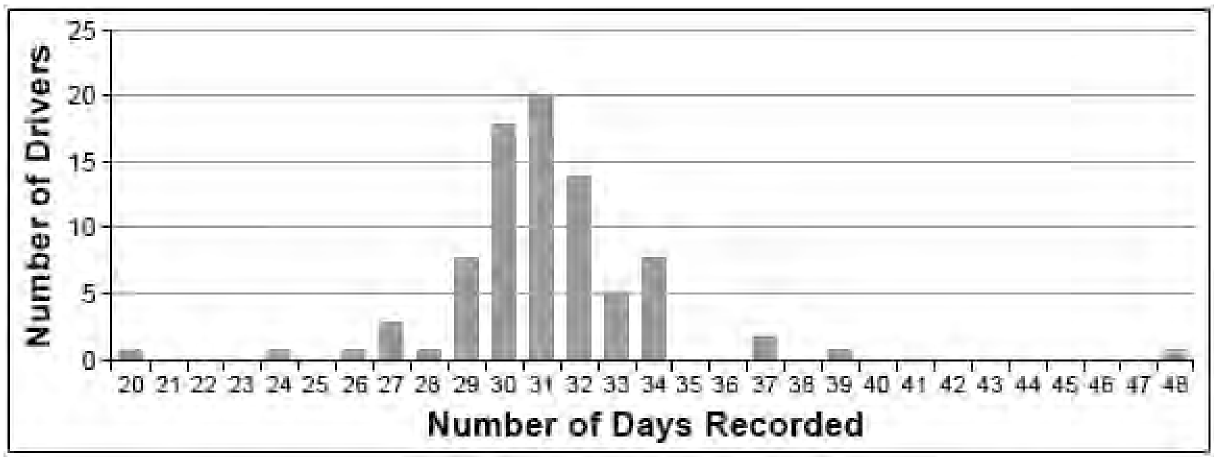

Figure 3. Bar Graph. Number of Drivers by Number of Days Recorded in the Study

3.3 DISTRIBUTION OF EXPOSURE TO DUTY DURATION

The distributions of total duty time for all recorded duty days and for all recorded duty days by type of operation (Figure 4 and Figure 5) provides an estimate of exposure to varying shift durations in the motorcoach industry and could serve as a factor in accident risk calculations evaluating accident risk as function of increasing time on duty. Only one reported accident occurred in the sample population during the study, so the exposure data are not used in the following data analysis. These percentile cumulative frequency plots are another way of visualizing the data as are presented in the histograms depicting total duty time. For example, on 67 percent of the duty days, drivers were on duty at least 8 hours. On 11 percent of duty days, drivers were on duty at least 13 hours.

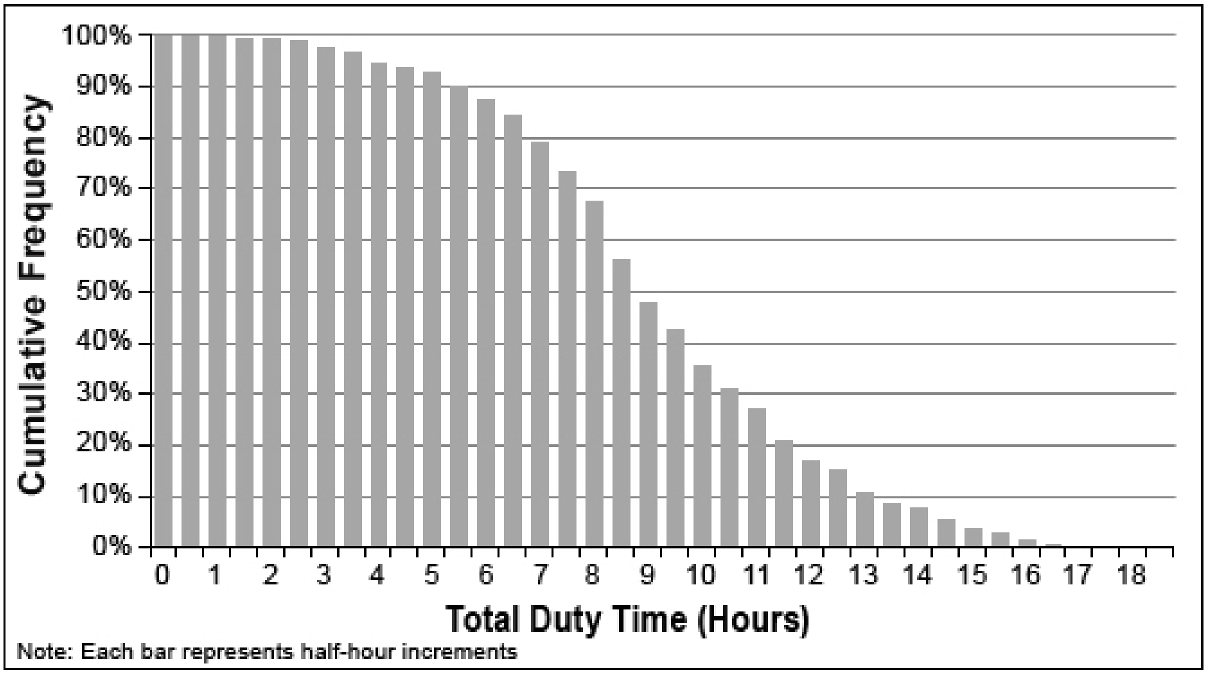

Figure 4. Bar Graph. Exposure to Total Duty Time per 24 Hours for All Duty Days

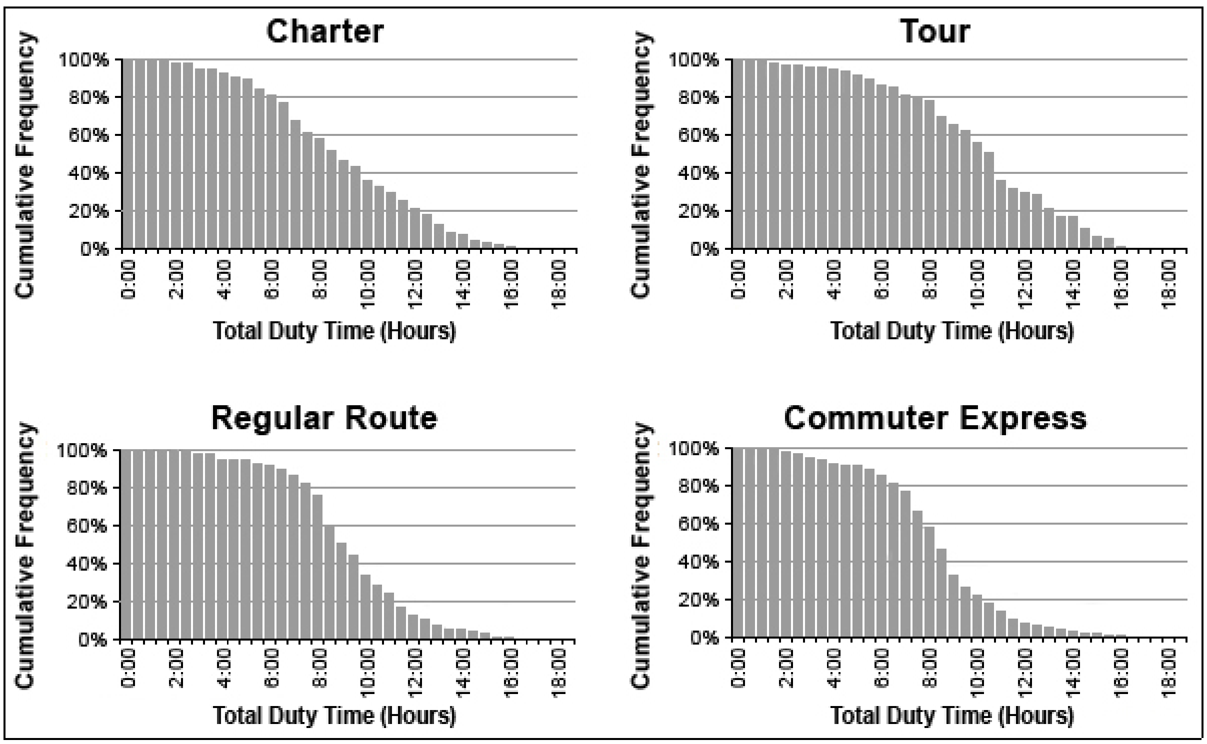

Figure 5. Bar Graph. Exposure to Total Duty Time per 24 Hours by Type of Operation

With respect to on- and off-duty days, all drivers had more on-duty days than off-duty days and the proportion of study days worked did not differ between Charter, Tour, Regular Route, and Commuter Express operations as indicated by mixed-effects modeling (Table 3).

Table 3. Days on Duty as a Proportion of Days in the Study for all Duty Days and for Duty Days by Type of Operation

	Proportion ± SD	SAS MP/REML*
All	0.65 ± 0.180	–
Charter	0.58 ± 0.041	A
Tour	0.68 ± 0.046	A
Regular Route	0.66 ± 0.036	A
Commuter Express	0.68 ± 0.036	A

*The groups sharing the designator A did not differ one from another in proportion of days worked by mixed-effects ANOVA.

3.4 MEAN DUTY HOURS PER WEEK BY DRIVER

In Figure 6 and Figure 7, the average duty hours per day were calculated then multiplied by seven to compute approximate hours worked per week for all drivers and for drivers by Charter, Tour, Regular Route, or Commuter Express operations.

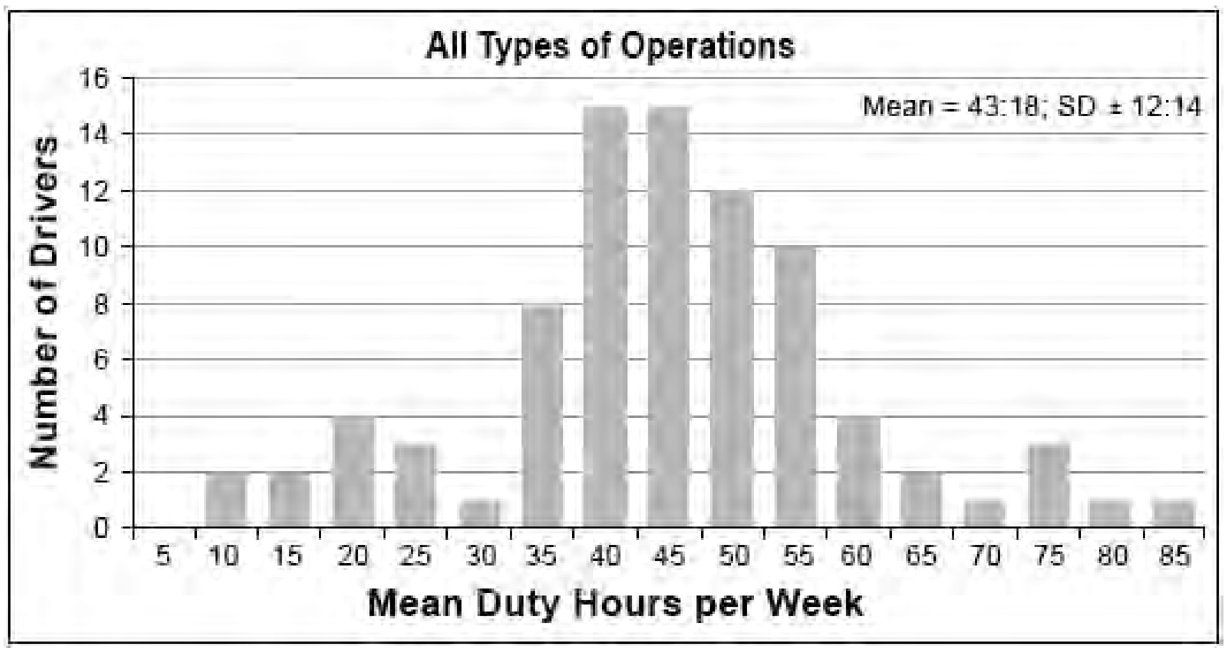

Figure 6. Bar Graph. Number of Drivers by Mean Duty Hours per Week

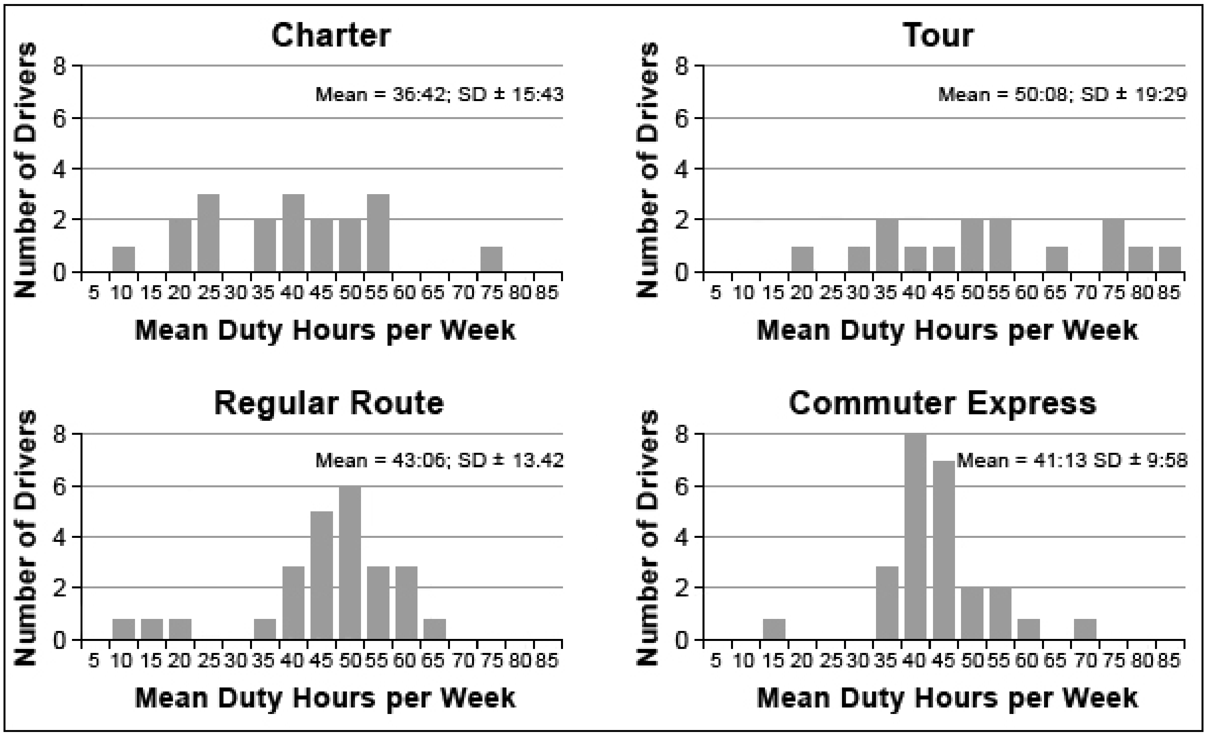

Figure 7. Bar Graph. Number of Drivers by Mean Duty Hours per Week by Type of Operation

The data are derived from each driver's duty/sleep diary. Descriptive statistics for Figure 6 and Figure 7 are in Table 4.

No analysis beyond the mean and standard deviation as a measure of central tendency was done because drivers did not necessarily have a consistent weekly schedule, making the choice of 7 days as the unit of analysis arbitrary. The figures and Table 4 are meant simply to give a rough estimate of workweek, the conventional measure of workload. Drivers appeared to work 43 hours per week on average. Note that the standard deviations are given in the same units (hours:minutes) as the means.

Table 4. Mean Duty Hours per Week for All Drivers and for Drivers by Type of Operation (Hours:Minutes)

	N	Mean ± SD
All	84	43:18 ± 13:14
Charter	19	36:42 ± 15:43
Tour	15	50:08 ± 19:29
Regular Route	25	43:06 ± 13:42
Commuter Express	25	41:13 ± 09:58

3.5 DUTY START TIME

Performance depends upon homeostatic sleep drive (a function of time awake) and circadian rhythm (a function of time of day). Time on task is also a factor. If duty start times cluster late in the day, either by duty day or by driver, this suggests that work is occurring in the context of increasing time awake and adverse circadian phase for work. If duty start times cluster very early in the day by duty day or by driver, this suggests that work is occurring in the context of truncated sleep and again adverse circadian phase for work. If there is no clear clustering of duty start time either by duty day or by driver, this suggests irregular scheduling and/or a less than 24-hour cycle of work and rest. If, however, duty start times cluster in the morning, this suggests a normal diurnal schedule with normal diurnal circadian phase synchronization. For a review of these issues see Drake and Wright (2011).

3.5.1 Duty Start Time by Duty Day

Figure 8, Figure 9, and Table 5 are plots and a table of means and standard deviations of duty start times as a function of duty day for all operations and for Charter, Tour, Regular Route, and Commuter Express operations.

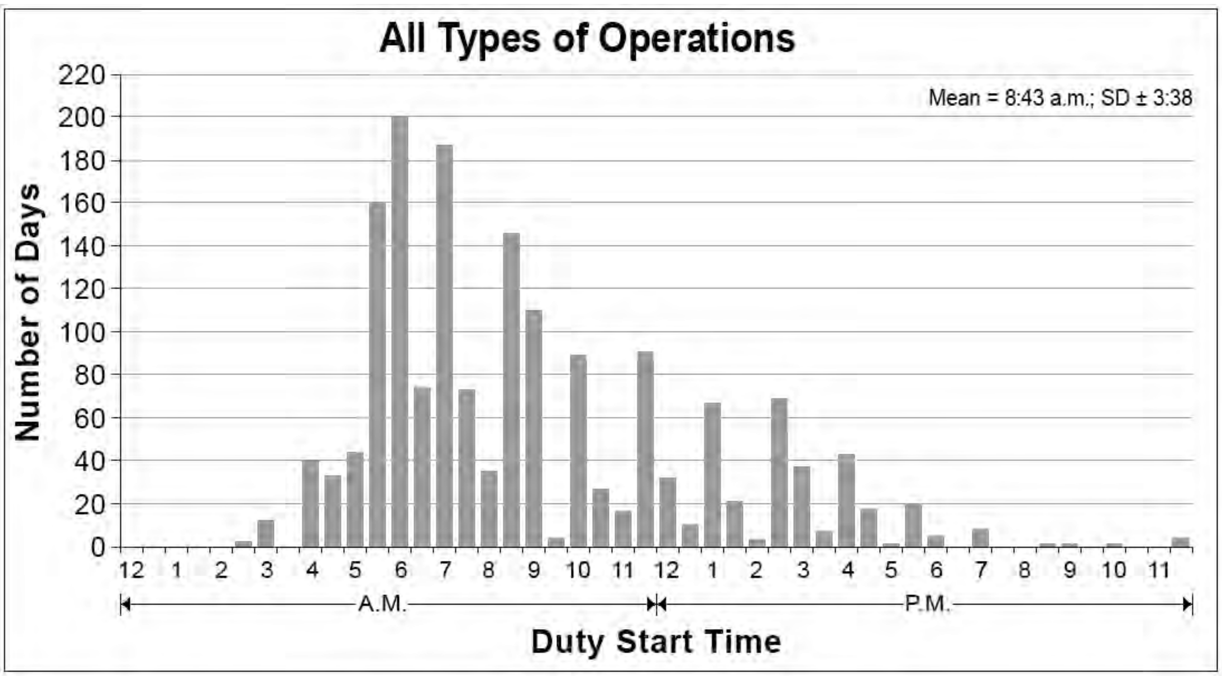

Figure 8. Bar Graph. Number of Days by Duty Start Time

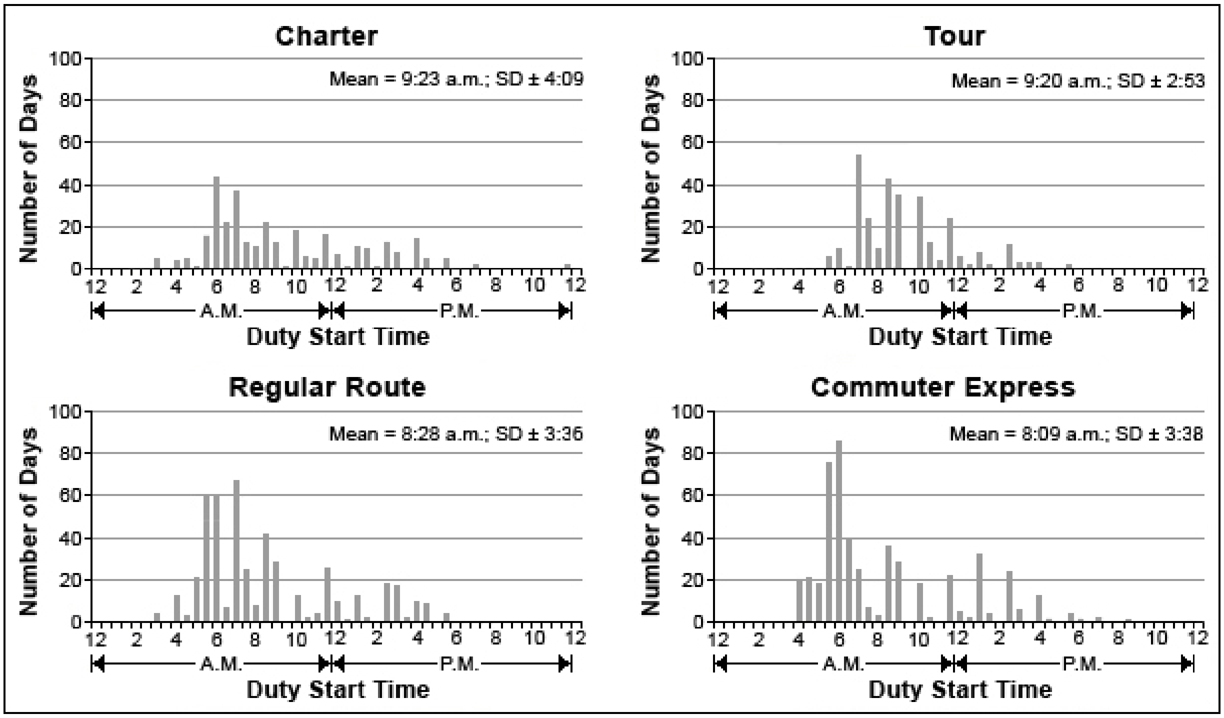

Figure 9. Bar Graph. Number of Days by Duty Start Time by Type of Operation

Duty start times cluster in the morning hours, and on average do not suggest a predominance of early starts.

Table 5. Mean Duty Start Time for All Days and for Days by Type of Operation

	Mean ± SD (Hours:Minutes)
All	8:43 a.m. ± 3:38
Charter	9:23 a.m. ± 4:09
Tour	9:20 a.m. ± 2:53
Regular Route	8:28 a.m. ± 3:36
Commuter Express	8:09 a.m. ± 3:38

3.5.2 Duty Start Time by Driver

Figure 10, Figure 11, and Table 6 show the means and standard deviations of duty start times as a function of driver for all drivers and for drivers involved with Charter, Tour, Regular Route, and Commuter Express operations.

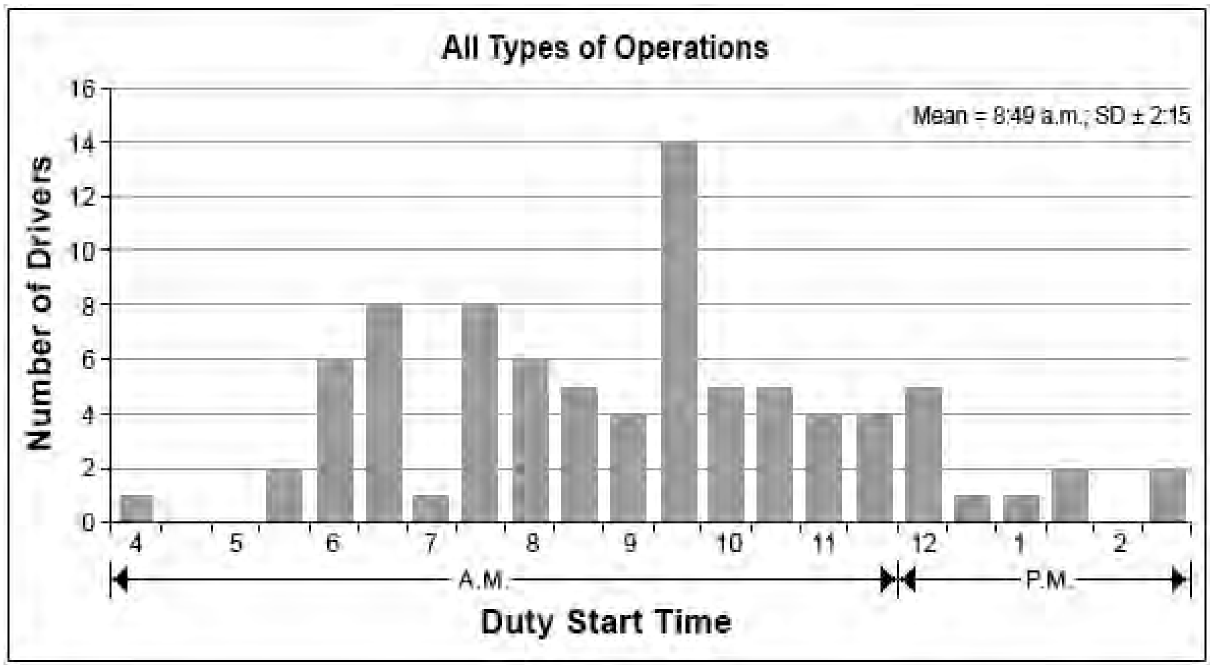

Figure 10. Bar Graph. Number of Drivers by Duty Start Time

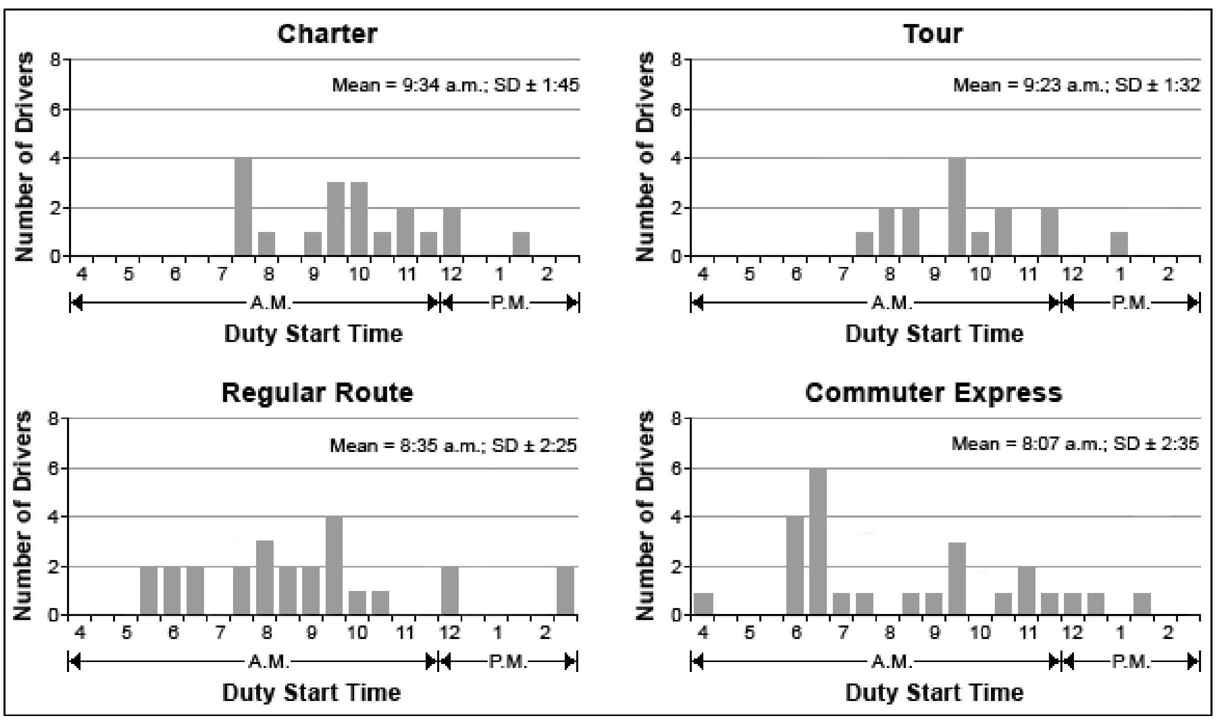

Figure 11. Bar Graph. Number of Drivers by Duty Start Time by Type of Operation

A mixed-effects model of duty start time indicated that there was no significant difference in start time between operation types.

An inspection of duty start times suggests that the lower PVT scores in regular route and commuter express drivers was a function of earlier start times (see Section 3.9—Performance, Figure 32, Figure 33, and Table 17). To determine if this was the case, a mixed effects analysis was done relating duty start time to PVT performance. There was no main effect of duty start time on PVT performance.

Table 6. Mean Duty Start Time for All Drivers and for Drivers by Type of Operation

	Mean ± SD (Hours:Minutes)	SAS MP/REML*
All	8:49 a.m. ± 2:15	–
Charter	9:34 a.m. ± 1:45	A
Tour	9:23 a.m. ± 1:32	A
Regular Route	8:35 a.m. ± 2:25	A
Commuter Express	8:07 a.m. ± 2:35	A

*The groups sharing the designator A did not differ one from another on duty start time by mixed-effects ANOVA.

3.6 TOTAL DUTY TIME

Performance depends upon homeostatic sleep drive (a function of time awake) and circadian rhythm (a function of time of day). Increased duty duration indicates extended work hours suggesting that work will occur in the context of increased time awake and adverse circadian phase for work.

3.6.1 Total Duty Time by Duty Day

The distribution of total duty time for the entire sample of 1,619 duty days for which duty duration was recorded is shown in Figure 12. Figure 13 shows the same distribution broken out by operation type.

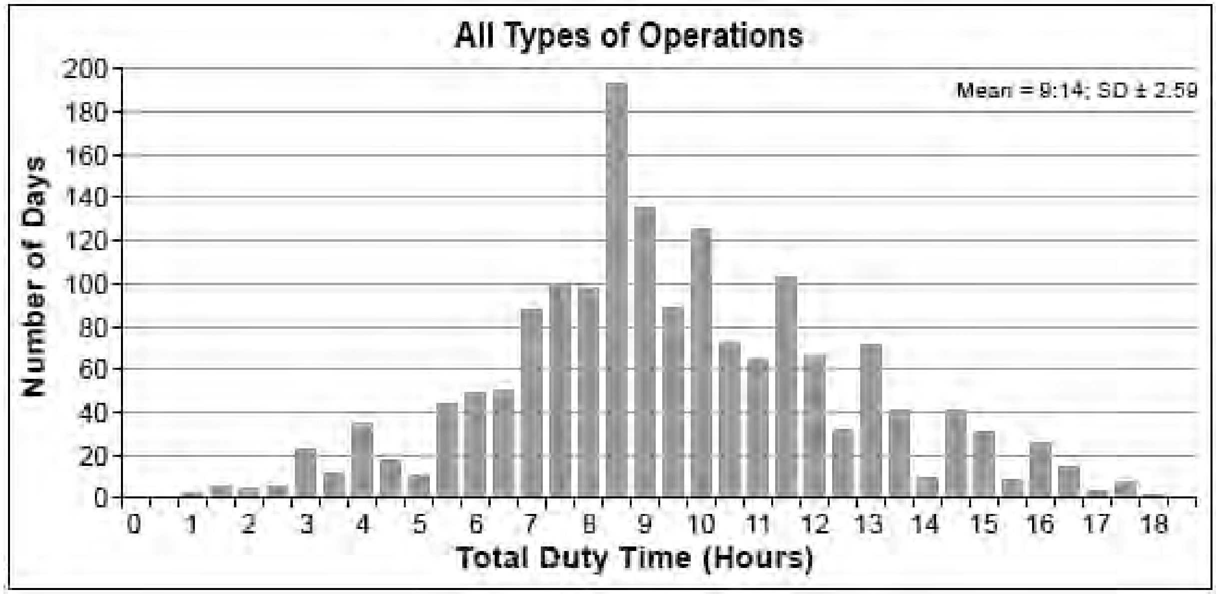

Figure 12. Bar Graph. Number of Days by Total Duty Time

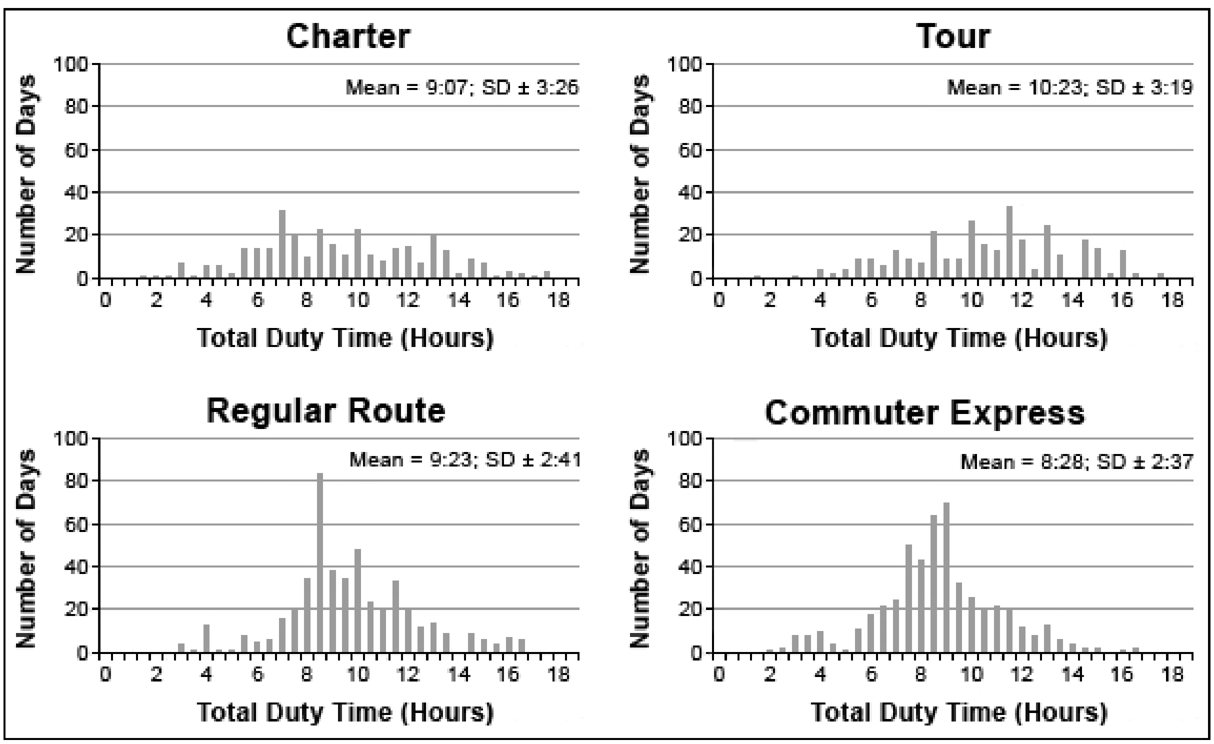

Figure 13. Bar Graph. Number of Days by Total Duty Time by Type of Operation

Mean duty time per day averaged slightly more than 9 hours for all drivers and the mean by operational type ranged from approximately 8.5 to 10.5 hours (Table 7).

Table 7. Total Duty Time by Day for All Days and for Days by Type of Operation (Hours:Minutes)

	Mean ± SD
All	9:14 ± 2:59
Charter	9:07 ± 3:26
Tour	10:23 ± 3:19
Regular Route	9:23 ± 2:41
Commuter Express	8:28 ± 2:37

3.6.2 Total Duty Time by Driver

The distribution of total duty time by driver for the entire sample of duty days for which duty duration was recorded is shown in Figure 14. Figure 15 shows the same distribution broken out by operation type.

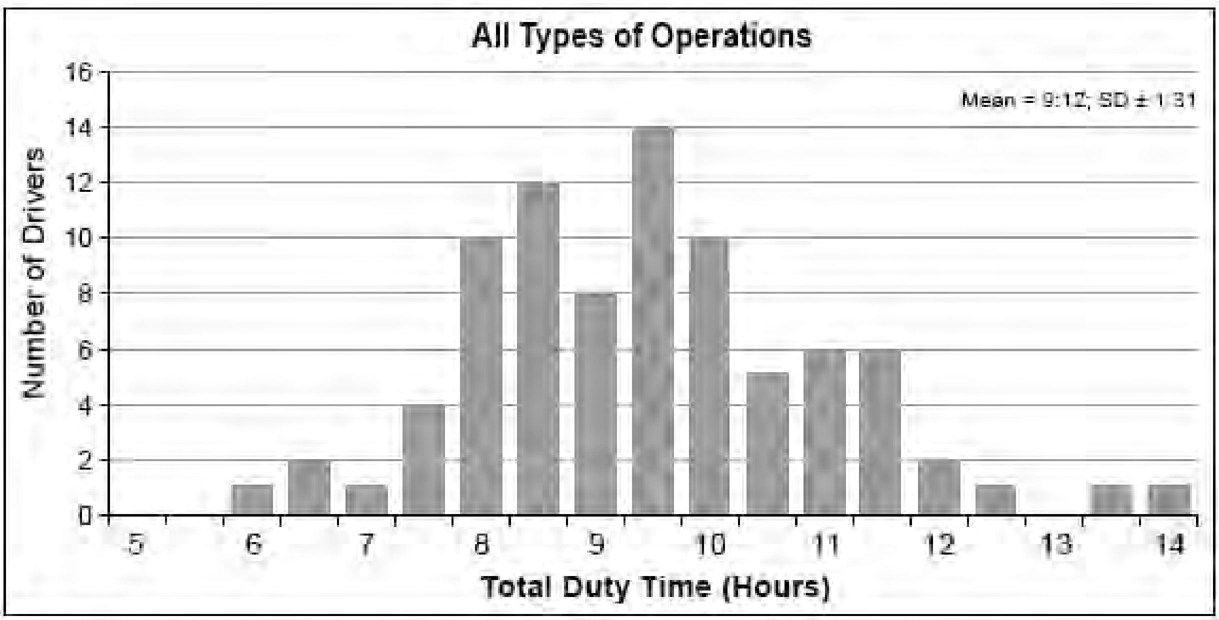

Figure 14. Bar Graph. Number of Drivers by Total Duty Time

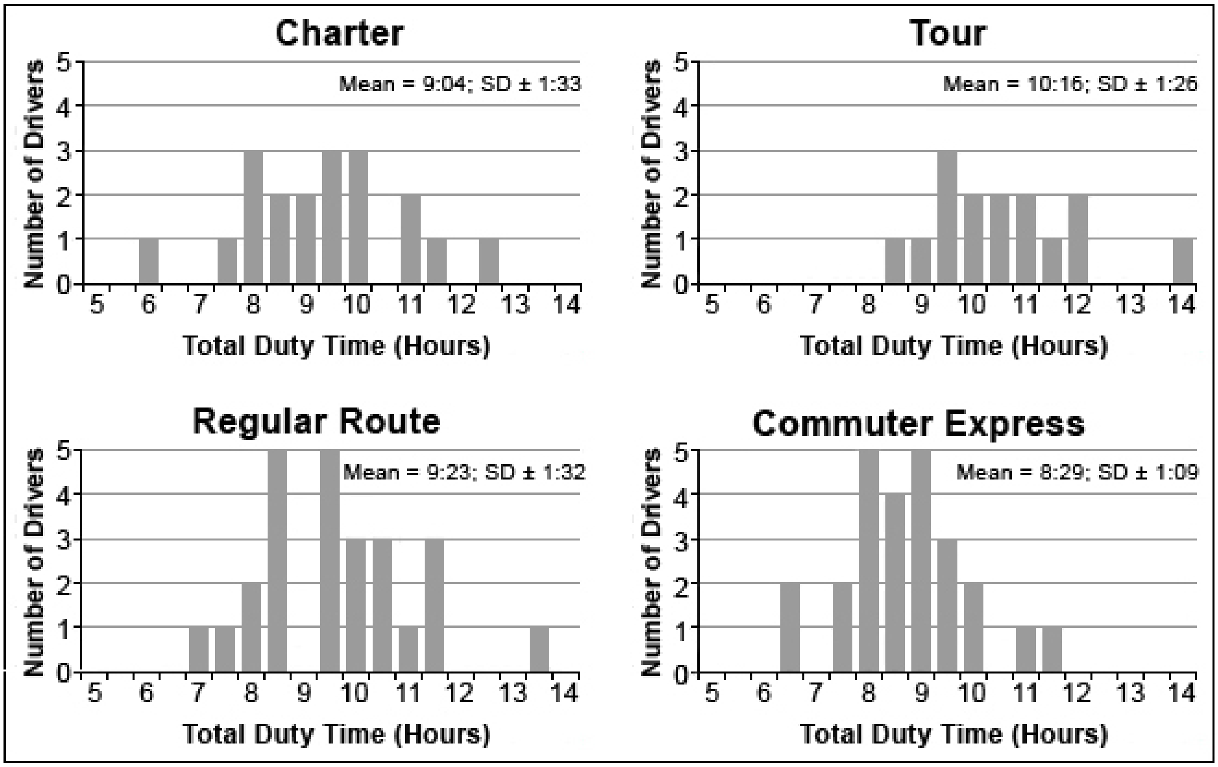

Figure 15. Bar Graph. Number of Drivers by Total Duty Time by Type of Operation

Mean total duty time was slightly more than 9 hours. A mixed-effects analysis of mean total duty time indicated that there was a main effect of operational type on total duty time with Tour drivers having more daily on-duty time than Commuter Express drivers (Table 8).

Table 8. Mean Total Duty Time for All Drivers and for Drivers by Type of Operation (Hours:Minutes)

	Mean ± SD	SAS MP/REML*
All	9:12 ± 1:31	–
Charter	9:04 ± 1:33	A B
Tour	10:16 ± 1:26	A
Regular Route	9:23 ± 1:32	A B
Commuter Express	8:29 ± 1:09	B

*The designator A or B indicates that groups sharing A did not differ one from another and that groups sharing B did not differ one from another on total daily duty time by mixed-effects ANOVA.

3.7 SLEEP

TST per 24 hours, including both main sleep and naps, sustains performance. Extended work hours, shift work (especially night shift work), irregular schedules, and early morning starts fragment or truncate sleep and degrade performance. Split and consolidated sleep appear to be equally sustaining of performance provided they sum to the same total sleep time in a given 24-hour period. There is reduced recuperative value with fragmented sleep defined as sleep interrupted more frequently than every 20 minutes. In the present study, TST was plotted both as a function of day (TST per recorded day; see Figure 16 and Figure 17) and as a function of driver (average TST for each driver; see Figure 20 and Figure 21). TST per 24 hours includes all actigraphically-scored sleep (main sleep periods and naps) with the 24-hour period running from midnight to 11:59 p.m.

3.7.1 Total Sleep Time per 24 Hours, by Day

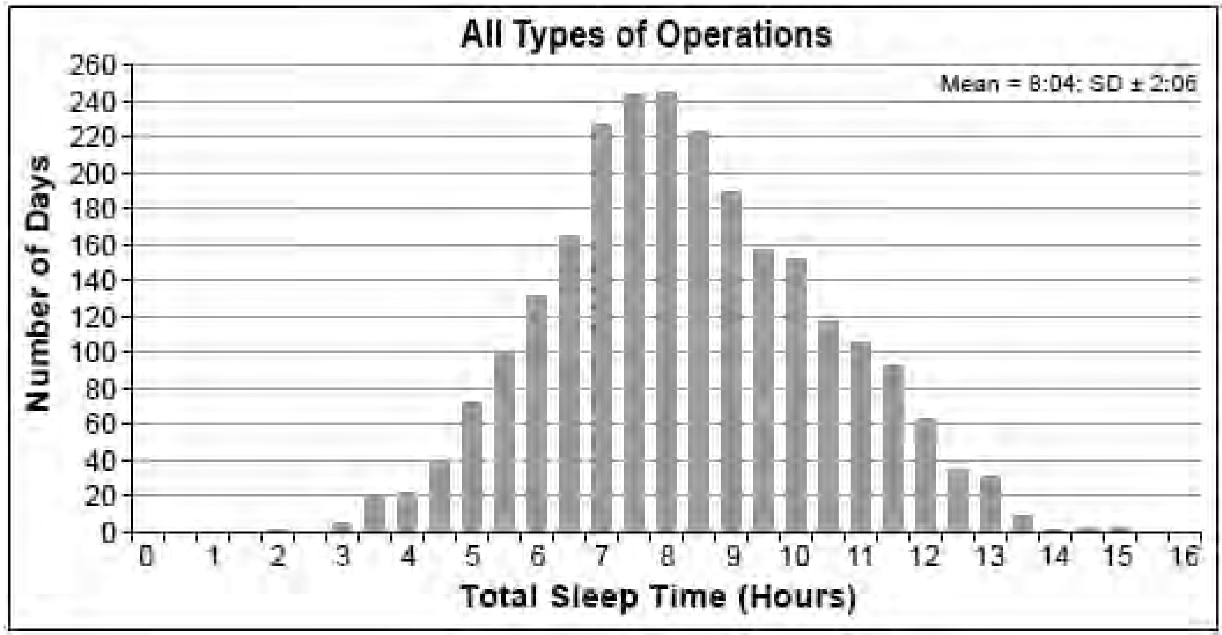

Figure 16. Bar Graph. Number of Days by Total Sleep Time

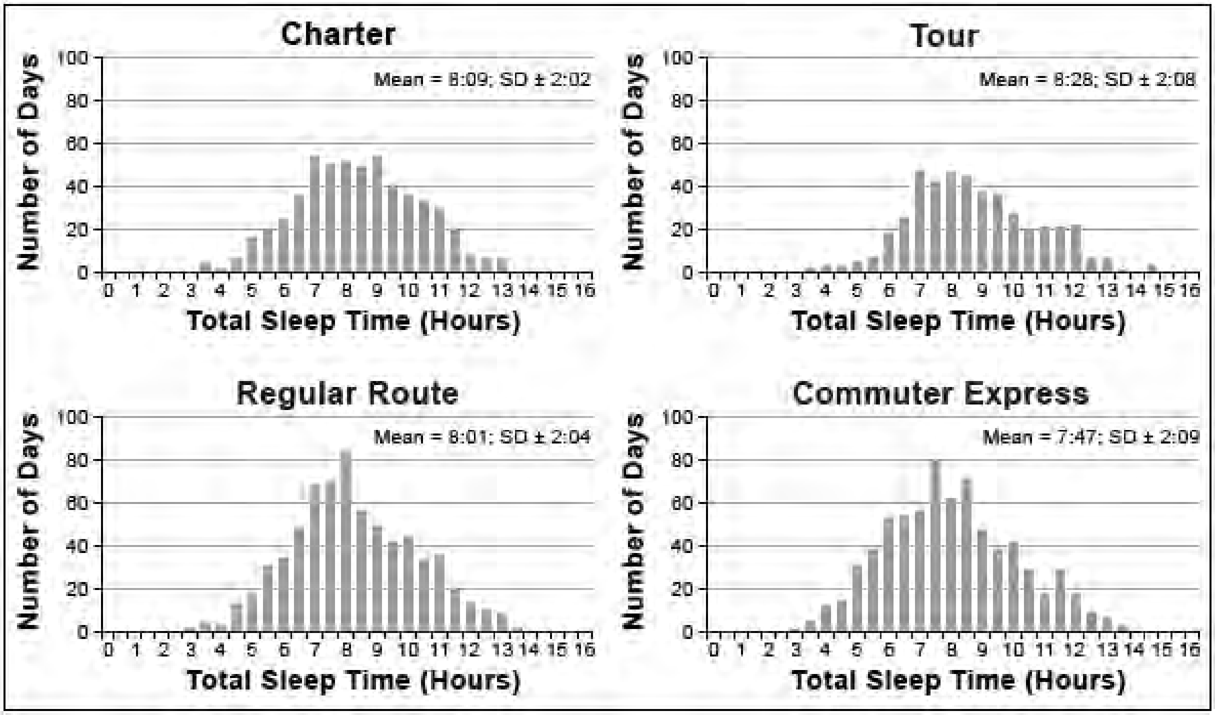

Figure 17. Bar Graph. Number of Days by Total Sleep Time by Type of Operation

Descriptive statistics (mean and standard deviation) indicate a normal total sleep time per 24 hours for the overall and for Charter, Tour, Regular Route, and Commuter Express operations (Table 9).

Table 9. Total Sleep Time per 24 Hours for All Duty Days and for Duty Days by Type of Operation (Hours:Minutes)

	Mean ± SD
All	8:04 ± 2:06
Charter	8:09 ± 2:02
Tour	8:28 ± 2:08
Regular Route	8:01 ± 2:04
Commuter Express	7:47 ± 2:09

3.7.2 Total Sleep Time per 24 Hours, On and Off Duty by Day

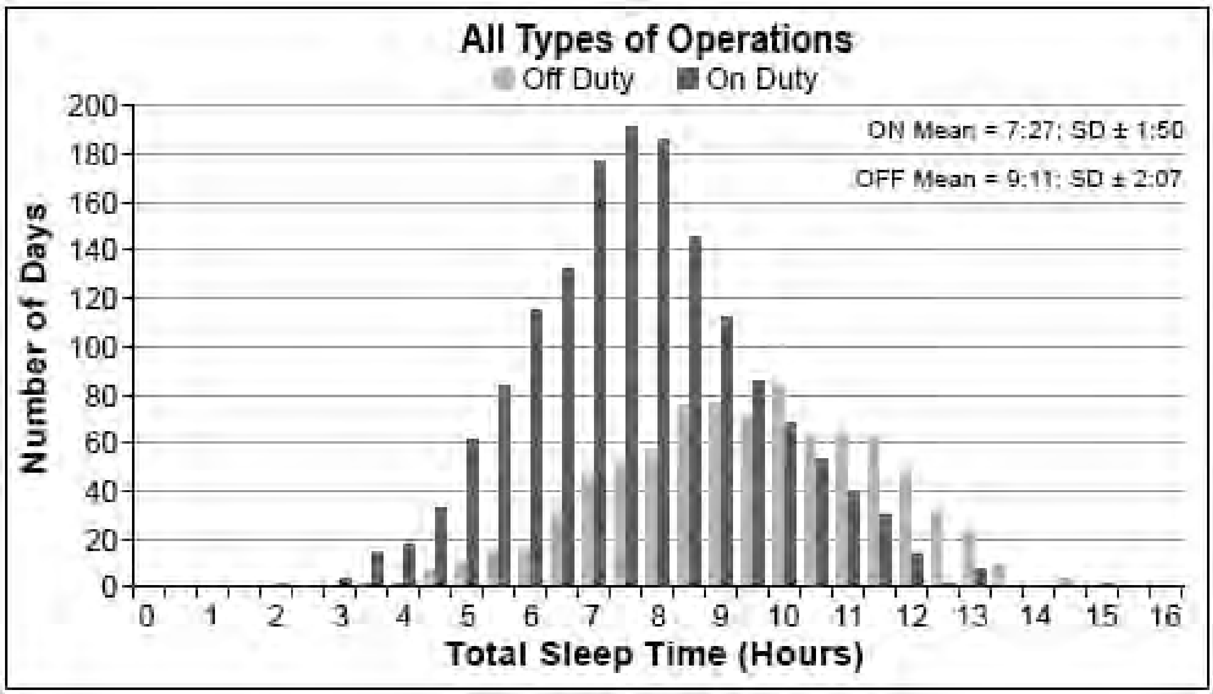

Figure 18. Bar Graph. Number of Days by Total Sleep Time by On Duty and Off Duty

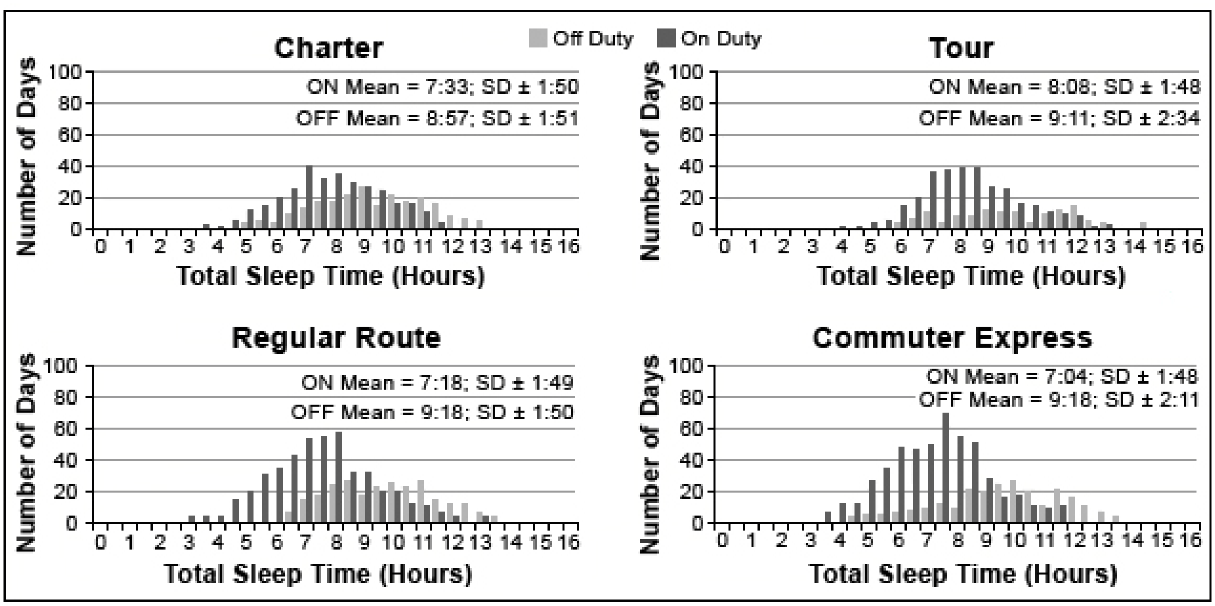

Figure 19. Bar Graph. Number of Days by Total Sleep Time by On Duty and Off Duty by Type of Operation

Sleep as a function of day descriptive statistics suggest longer sleep on off-duty days. This suggestion is confirmed (as shown in Table 10).

Table 10. Total Sleep Time per 24 Hours for All Duty Days and for Duty Days by Type of Operation (Hours: Minutes)

	On-Duty Mean ± SD	Off-Duty Mean ± SD
All	7:27 ± 1:50	9:11 ± 2:07
Charter	7:33 ± 1:50	8:57 ± 1:51
Tour	8:08 ± 1:48	9:11 ± 2:34
Regular Route	7:18 ± 1:49	9:18 ± 1:50
Commuter Express	7:04 ± 1:43	9:18 ± 2:11

3.7.3 Total Sleep Time per 24 Hours by Driver Combining On- and Off-Duty Days

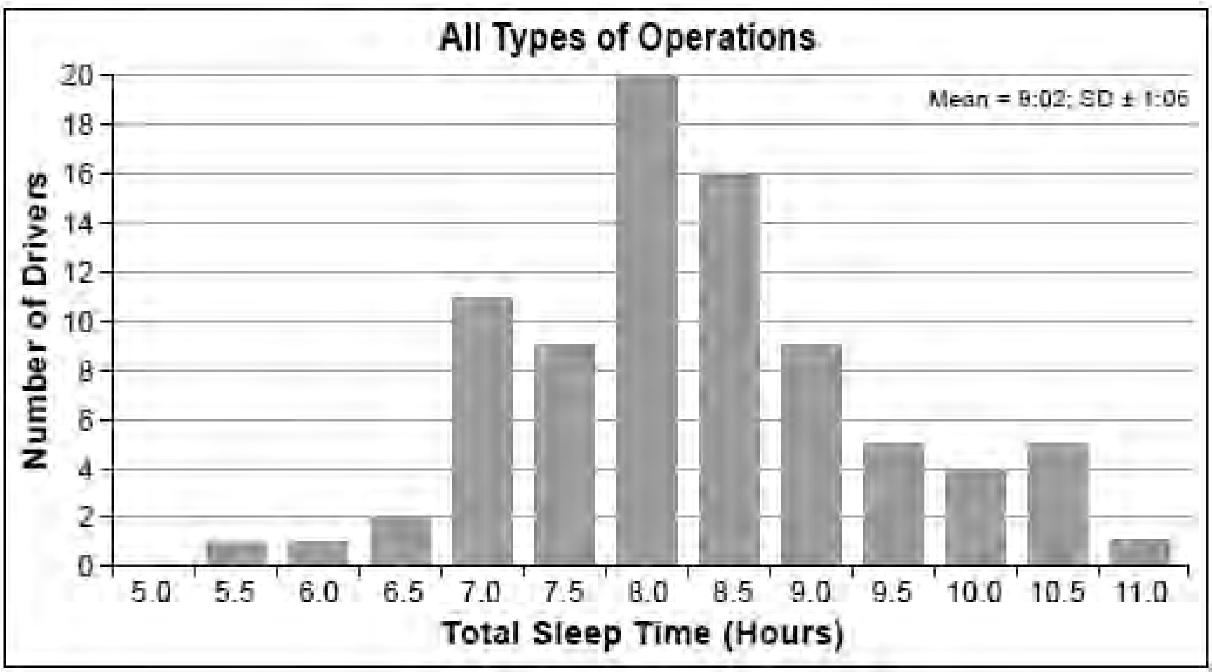

Figure 20. Bar Graph. Number of Drivers by Total Sleep Time

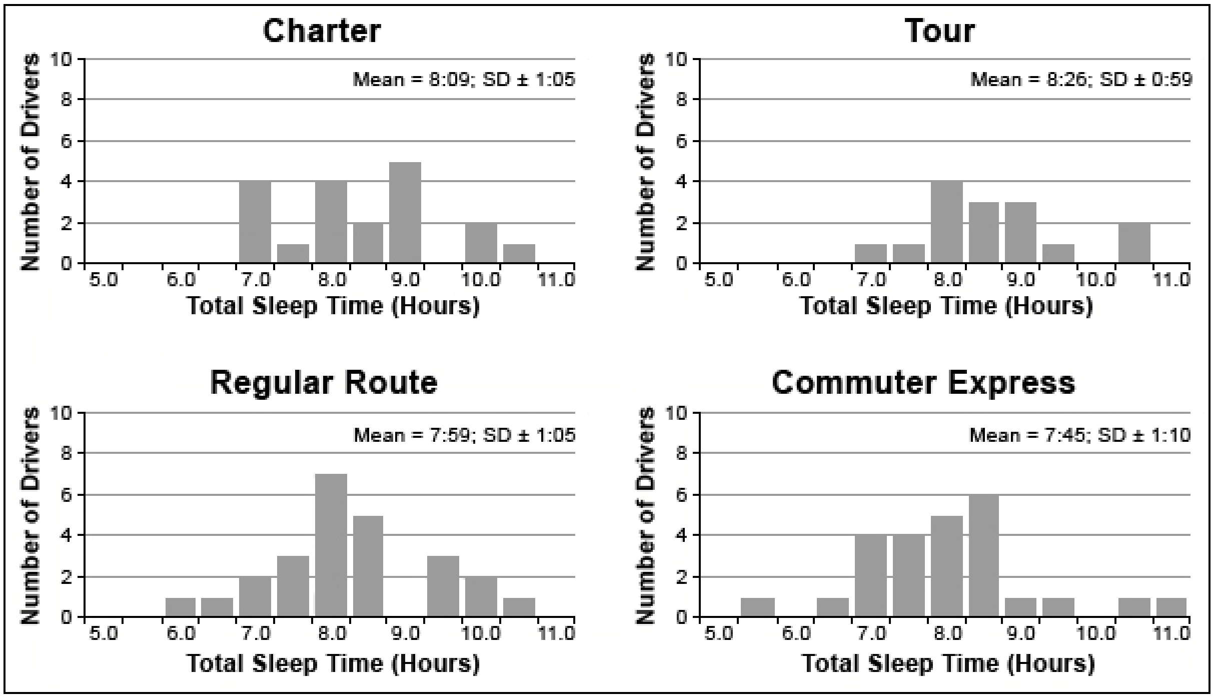

Figure 21. Bar Graph. Number of Drivers by Total Sleep Time by Type of Operation

Mixed effects analysis indicated no difference in TST between Charter, Tour, Regular Route, and Commuter Express operations combining on- and off-duty days (Table 11).

Table 11. Mean Total Sleep Time per 24 Hours for All Drivers and for Drivers by Type of Operation (Hours:Minutes)

	Mean ± SD	SAS MP/REML*
All	8:02 ± 1:06	–
Charter	8:09 ± 1:05	A
Tour	8:26 ± 0:59	A
Regular Route	7:59 ± 1:05	A
Commuter Express	7:45 ± 1:10	A

*The groups sharing the designator A did not differ one from another on TST per 24 hours by mixed effects ANOVA.

3.7.4 Total Sleep Time per 24 Hours, On and Off Duty by Driver

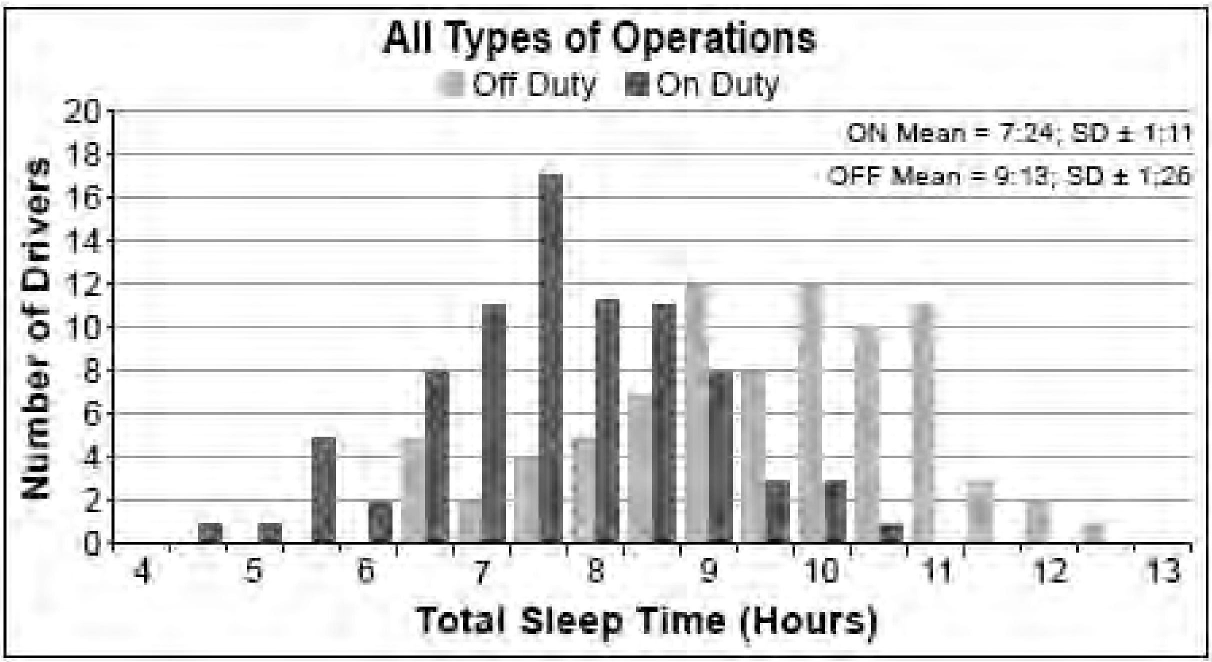

Figure 22. Bar Graph. Number of Drivers by Total Sleep Time by On Duty and Off Duty

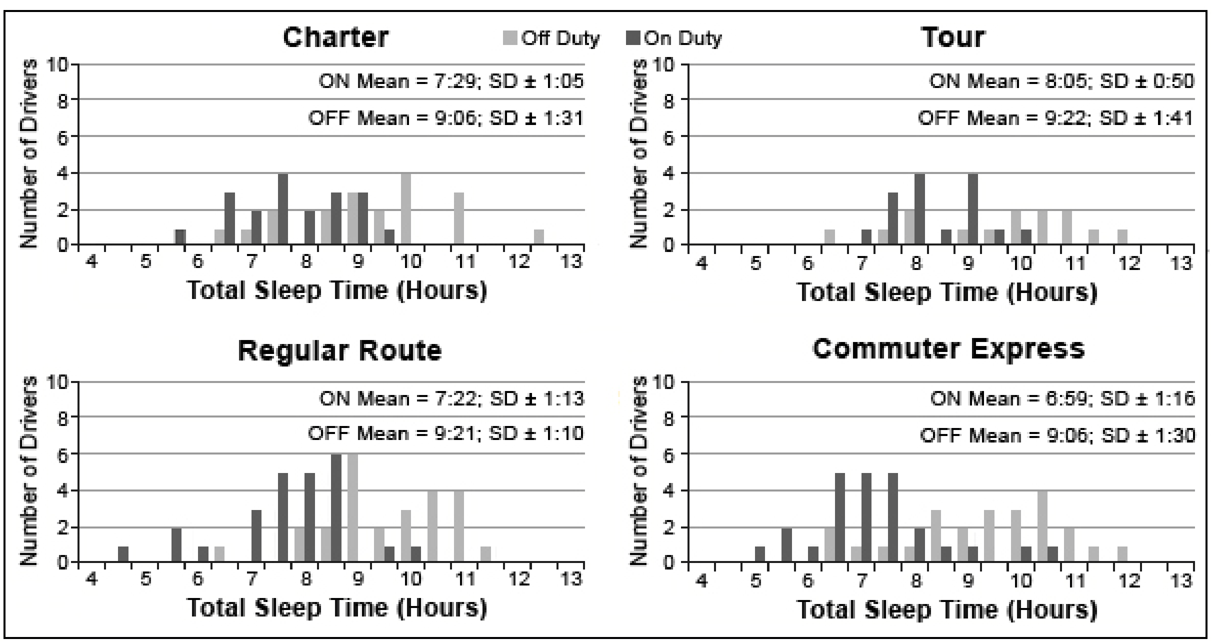

Figure 23. Bar Graph. Number of Drivers by Total Sleep Time by On Duty and Off Duty by Type of Operation

Mixed-effects analysis showed a main effect of on or off duty and a significant interaction of on or off duty and operation type. Drivers slept longer on off-duty days. With respect to the interaction, it appears that there was a larger difference between on- and off-duty sleep in the

Regular Route and Commuter Express operations. Overall and for Charter, Tour, Regular Route, and Commuter Express operations, TST was in the normal range (Table 12).

Table 12. Mean Total Sleep Time per 24 Hours, On- and Off-Duty for all Drivers and for Drivers by Type of Operation (Hours:Minutes)

	On-Duty Mean ± SD	Off-Duty Mean ± SD
All	7:24 ± 1:11	9:13 ± 1:26
Charter	7:29 ± 1:05	9:06 ± 1:31
Tour	8:05 ± 0:50	9:22 ± 1:41
Regular Route	7:22 ± 1:13	9:21 ± 1:10
Commuter Express	6:59 ± 1:16	9:06 ± 1:30

3.8 DUTY START TIME, TOTAL DUTY TIME, AND TOTAL SLEEP TIME

3.8.1 Duty Start Time and Total Sleep Time per 24 Hours by Day

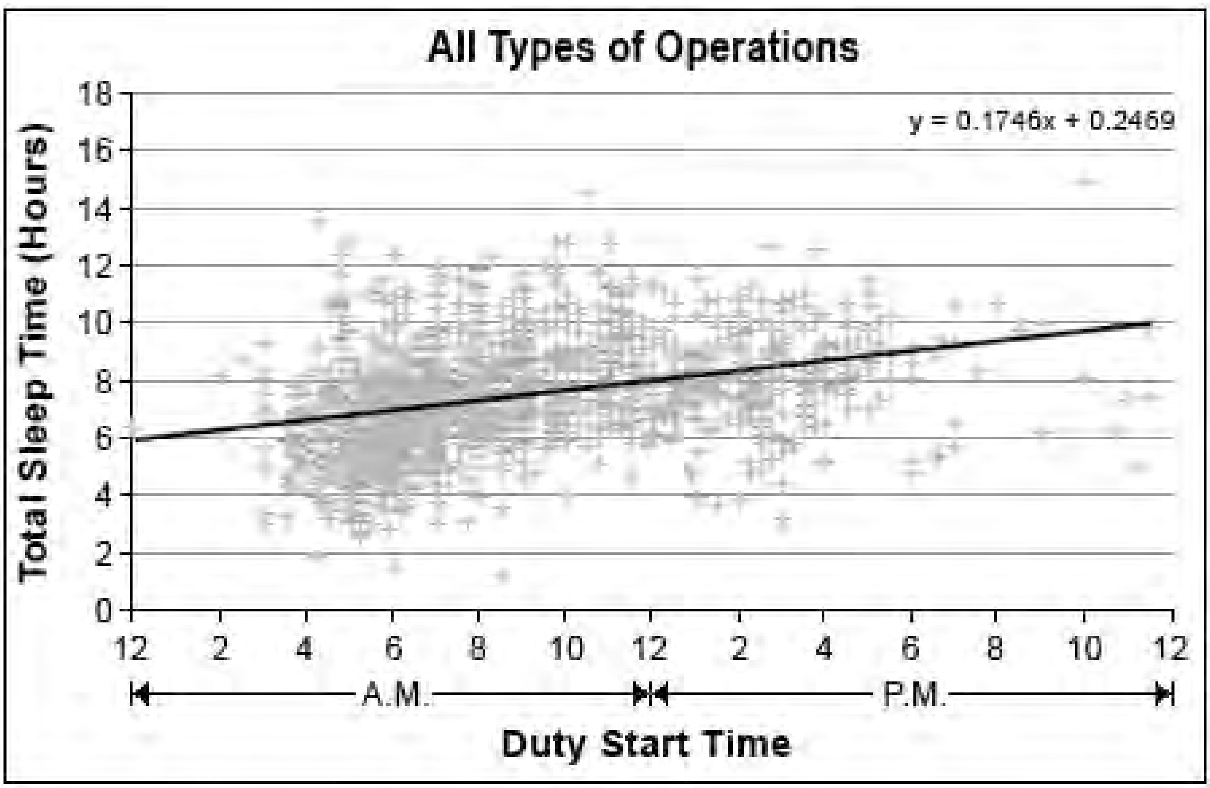

Figure 24. Scatter Plot. Total Sleep Time by Duty Start Time by Day

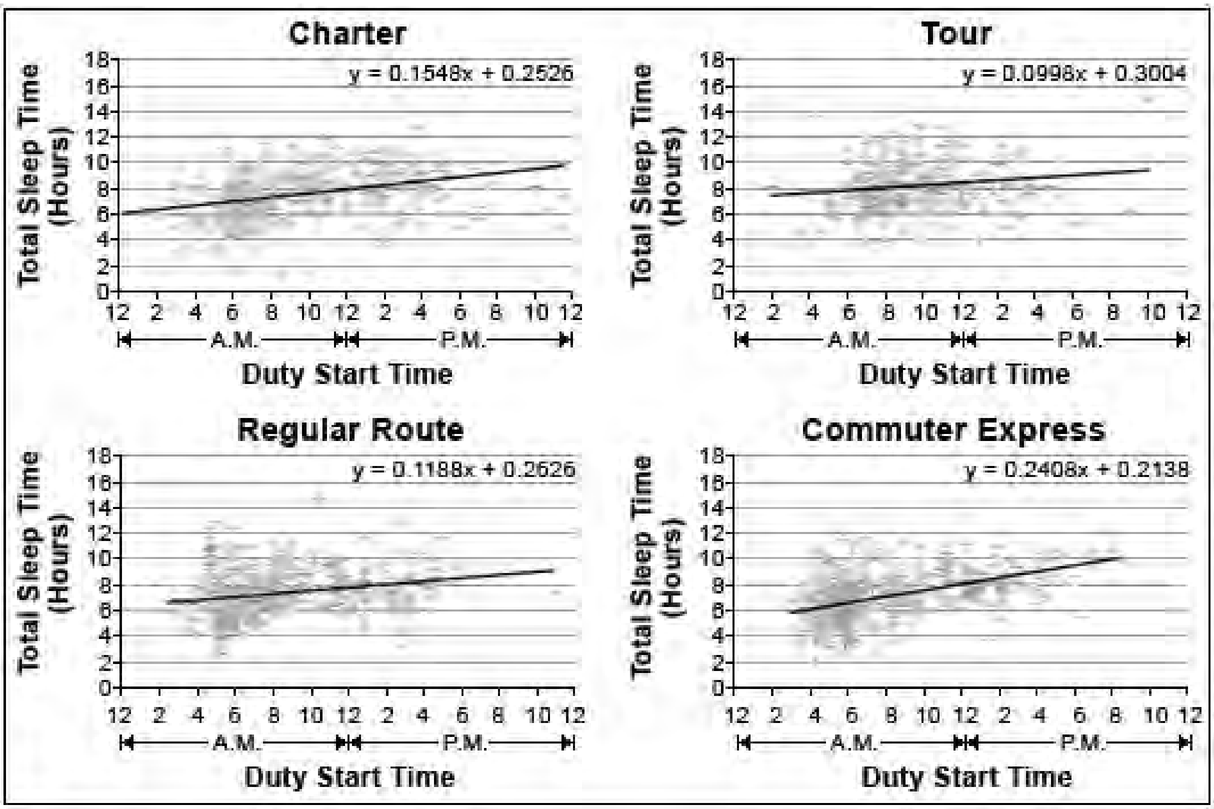

Figure 25. Scatter Plot. Total Sleep Time by Duty Start Time by Day by Type of Operation

From the linear regression, it is clear that in this as a function-of-day analysis, the later the start time the greater the TST both overall and for Charter, Tour, Regular Route, and Commuter Express operations.

Table 13. Linear Regression Results of Total Sleep Time as a Function of Duty Start Time for All Duty Days and for Duty Days by Type of Operation

	Regression Equation*	R	*P*
All	y = 0.1746x + 0.2469	0.345	<0.01
Charter	y = 0.1548x + 0.2526	0.355	<0.01
Tour	y = 0.0998x + 0.3004	0.158	<0.01
Regular Route	y = 0.1188x + 0.2626	0.228	<0.01
Commuter Express	y = 0.2408x + 0.2138	0.498	<0.01

* x is duty start time and y is total sleep time

3.8.2 Duty Start Time and Total Sleep Time per 24 Hours by Driver

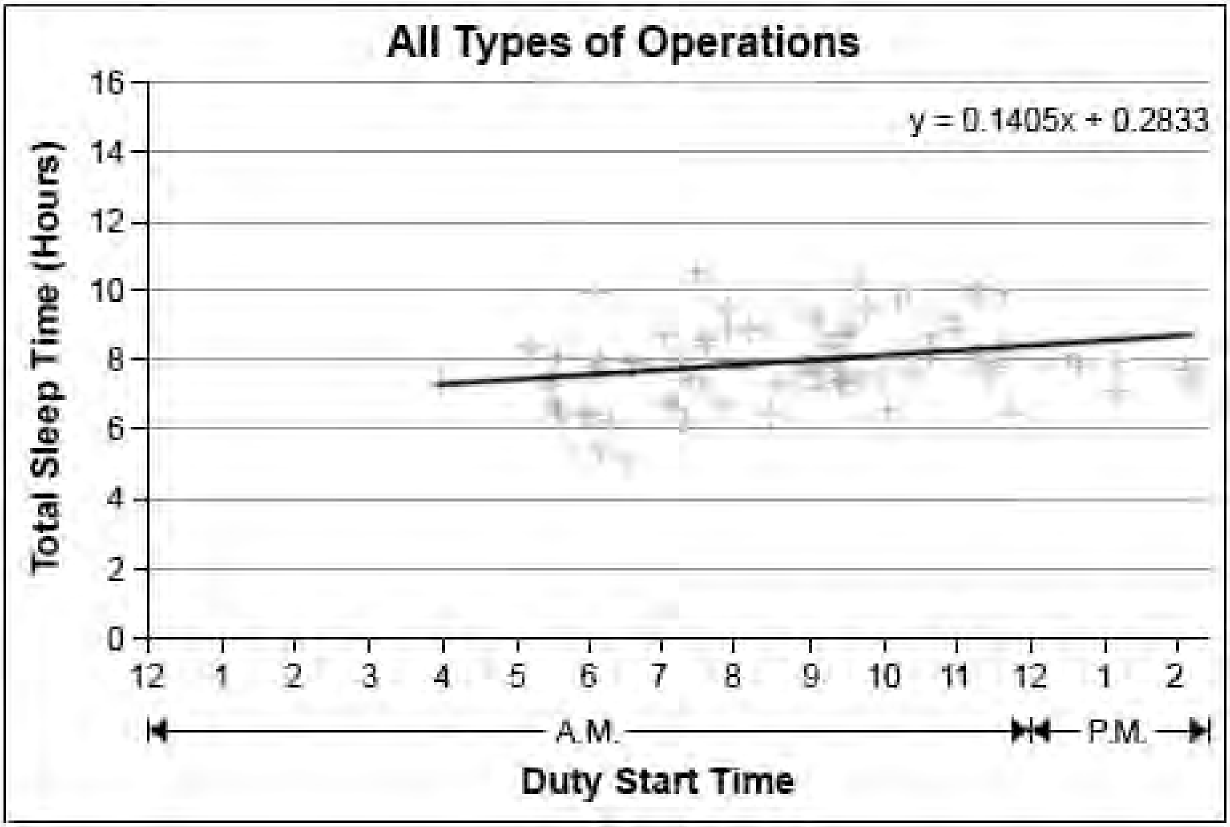

Figure 26. Scatter Plot. Total Sleep Time by Duty Start Time by Driver

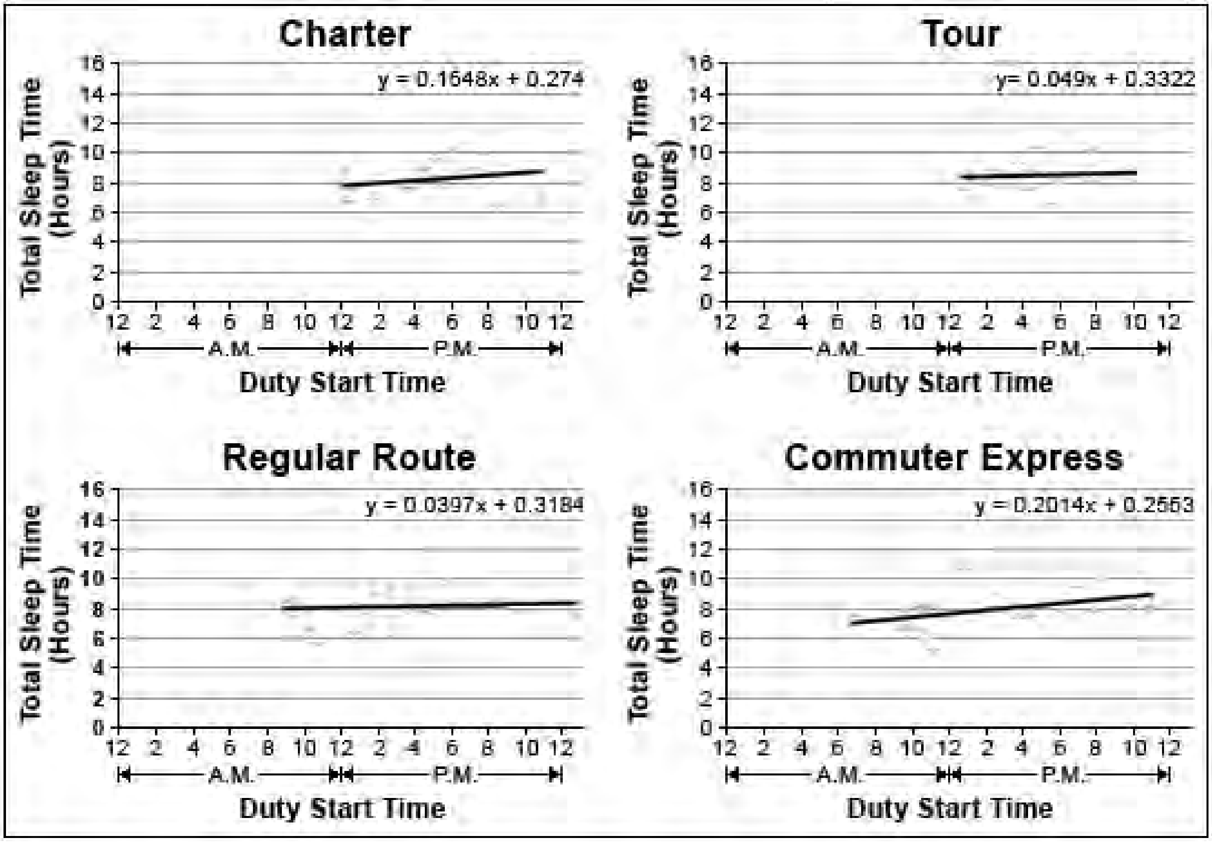

Figure 27. Scatter Plot. Total Sleep Time by Duty Start Time by Driver by Type of Operation

Table 14. Linear Regression Results of Total Sleep Time as a Function of Duty Start Time for All Drivers and for Drivers by Type of Operation

	Regression Equation*	R	*P*
All	y = 0.1405x + 0.2833	0.286	0.008
Charter	y = 0.1648x + 0.2740	0.265	0.273
Tour	y = 0.0490x + 0.3322	0.077	0.789
Regular Route	y = 0.0397x + 0.3184	0.089	0.676
Commuter Express	y = 0.2014x + 0.2553	0.446	0.025

* x is duty start time and y is total sleep time

Overall and for Charter, Tour, Regular Route, and Commuter Express operations there was a significant positive correlation between duty start time and sleep. The later the duty start time, the longer the sleep.

A mixed-effects analysis was used to model the relationship between duty start time and sleep duration by type of operation. There was a main effect of duty start time on sleep duration, with later start times associated with more sleep. There was a main effect of operational type with Tour operations yielding the most sleep and Commuter Express the least sleep for on-duty days. Further, there was an interaction between start time and operation with Regular Route and Commuter Express operations having earlier start times than Charter and Tour.

3.8.3 Total Duty Time and Total Sleep Time per 24 Hours by Duty Day

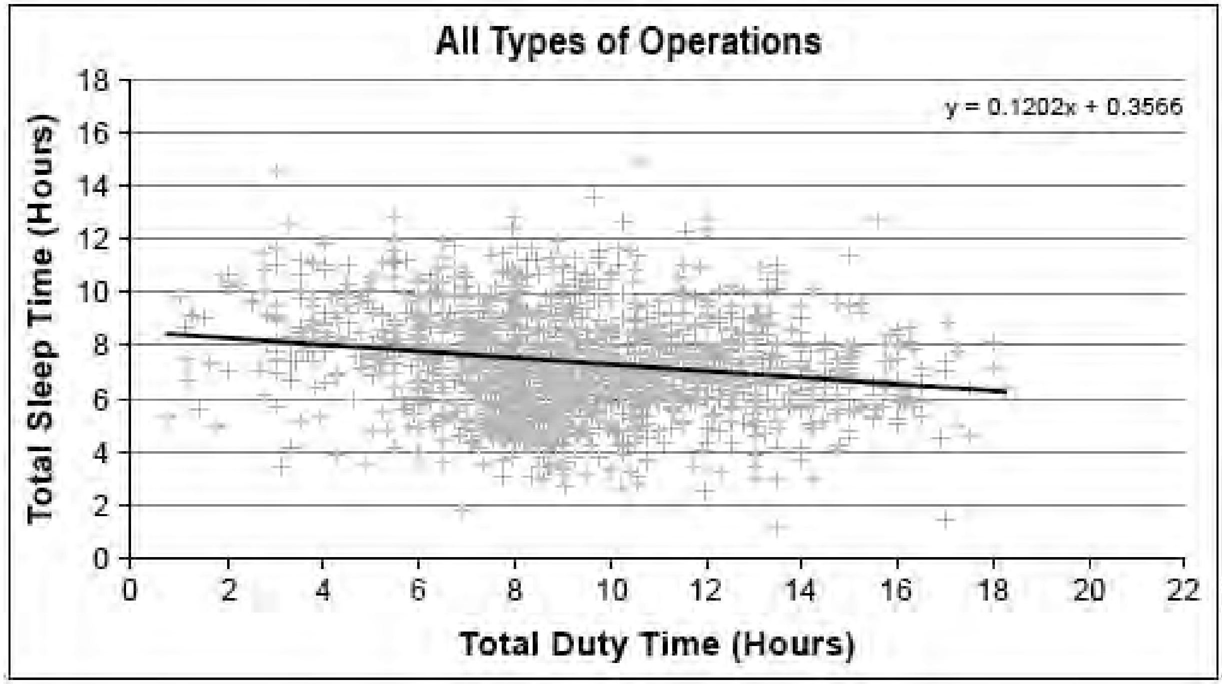

Figure 28. Scatter Plot. Total Sleep Time by Total Duty Time by Duty Day

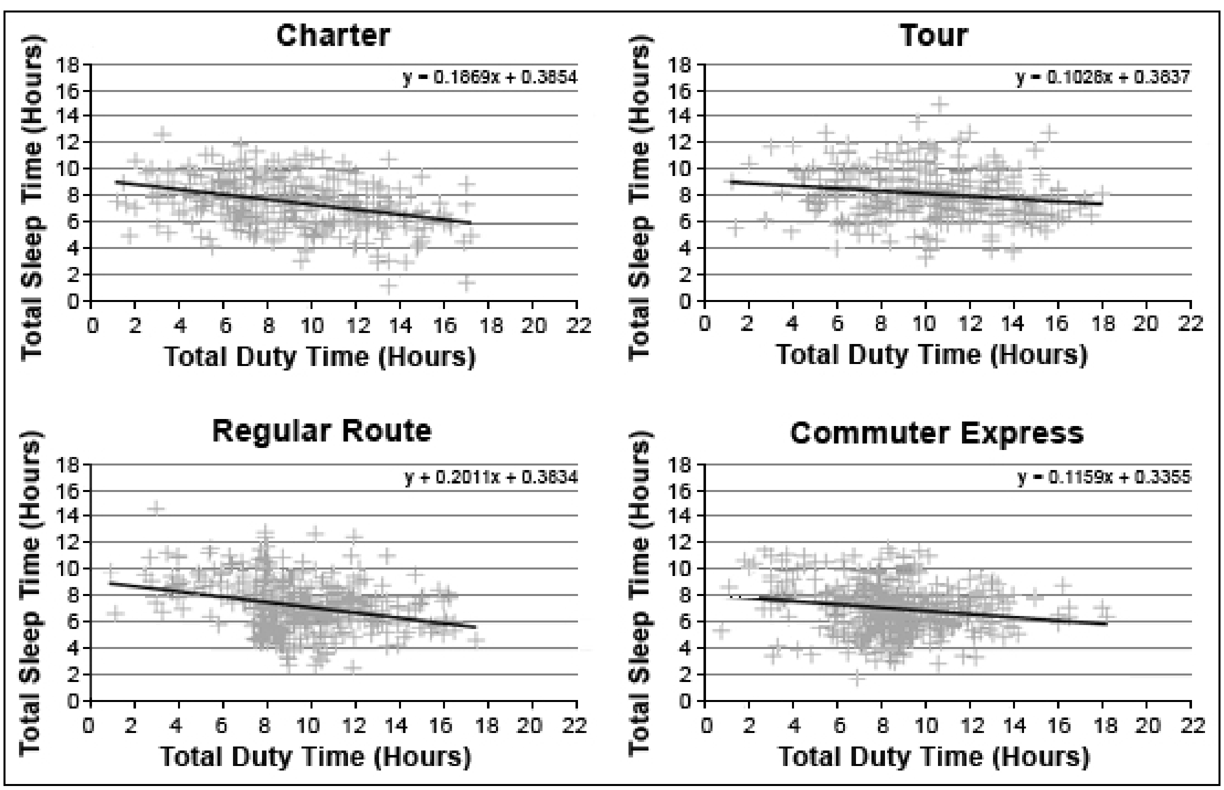

Figure 29. Scatter Plot. Total Sleep Time by Total Duty Time by Duty Day by Type of Operation

As can be seen from the linear regression, in this function-of-day analysis, there is a negative correlation overall and by operational type between total duty time and TST. The longer the total duty time, the less total sleep.

Table 15. Linear Regression Results of Total Sleep Time as a Function of Total Duty Time by Day by Type of Operation

	Regression Equation*	R	*P*
All	y = -0.1202x + 0.3566	0.197	<0.01
Charter	y = -0.1869x + 0.3854	0.354	<0.01
Tour	y = -0.1028x + 0.3837	0.184	<0.01
Regular Route	y = -0.2011x + 0.3834	0.300	<0.01
Commuter Express	y = -0.1159x + 0.3355	0.173	<0.01

* x is total duty time and y is total sleep time

3.8.4 Total Duty Time and Total Sleep Time per 24 Hours by Driver

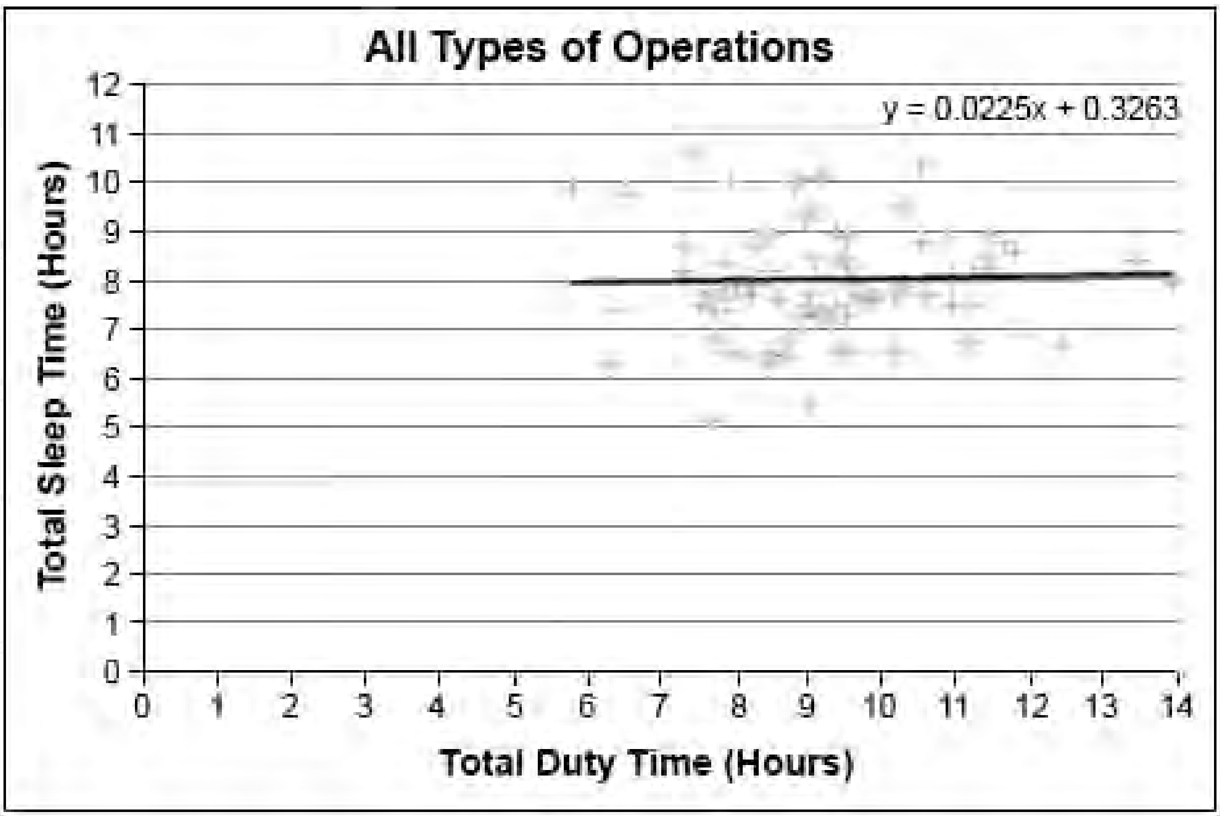

Figure 30. Scatter Plot. Total Sleep Time by Total Duty Time by Driver

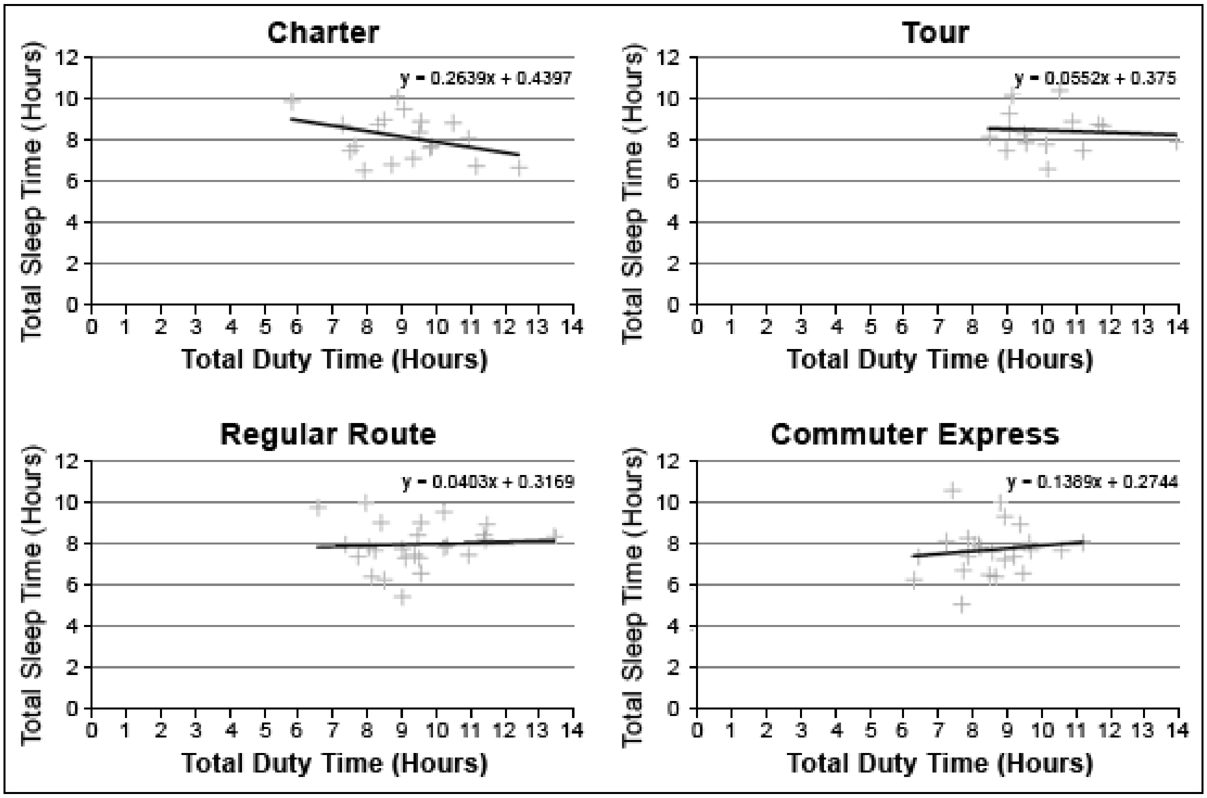

Figure 31. Scatter Plot. Total Sleep Time by Total Duty Time by Driver by Type of Operation

Linear regression as a function of driver showed that mean total duty duration per 24 hours did not predict mean total sleep duration per 24 hours (Table 16).

Mixed-effects analysis shows that there is a main effect of total duty time on TST, a main effect of type of operation on TST, and an interaction between duty time and type of operation on sleep, with Tour drivers sleeping more than Commuter Express.

Table 16. Linear Regression Results of Total Sleep Time as a Function of Total Duty Time by Driver by Type of Operation

	Regression Equation*	R	*P*
All	y = 0.0225x + 0.3263	0.032	0.780
Charter	y = -0.2639x + 0.4397	0.374	0.114
Tour	y = -0.0552x + 0.3750	0.077	0.777
Regular Route	y = 0.0403x + 0.3169	0.055	0.786
Commuter Express	y = 0.1389x + 0.2744	0.138	0.513

* x is total duty time and y is total sleep time

3.9 PERFORMANCE

Participants were asked to take a 5-minute PVT at the start of each duty day, at the start and end of any break greater than 90 minutes, and at the end of each duty day. Of the 84 participants, PVT data were available for 78 at the start and end of the duty day. For these 78, three were eliminated from the analysis. One participant's reaction time (RT) averaged 3.9 seconds, above the average reaction time for the other participants in the study and well above the normal reaction time for a healthy adult (Belenky et al., 2003). Another participant pressed the wrong key with every response and averaged a reaction time of 538 milliseconds (again, above the normal reaction time for a healthy adult). One participant's PVT times could not be linked with his/her duty/sleep diary data. Thus, PVT data were available for analysis for 75 participants. Though participants were instructed to take the PVT four times per on-duty day, the analyses focused on only the beginning and end of shift PVT test because a number of drivers who likely had a break greater than 90 minutes in duration did not take the PVT at the start and end of their breaks.

Speed on the PVT declined from the beginning to the end of duty indicating increasing fatigue. A mixed effects analysis controlling for duty duration showed a main effect of operation type on PVT speed and also a main effect of beginning and end of duty on PVT speed, but found no interaction between the two. Note that the observed PVT speed was slower than those found in controlled laboratory studies (e.g., Belenky et al., 2003). We expect that this is due to distractions in the testing environment (e.g., testing in the motorcoach or motorcoach terminal). While perhaps not appropriate for absolute comparisons in this study, the PVT speed metric can be used for relative comparisons (i.e., across shifts and between groups). Note also that there is no true rested baseline data on any of the drivers. Only Commuter Express showed a significant decrease in PVT speed from the beginning to the end of shift (Table 17).

Table 17. PVT Mean Performance at the Start and at the End of Duty by Driver by Type of Operation (Seconds)

	Start of Duty ± SD (PVT Speed x 1,000)	End of Duty ± SD (PVT Speed x 1,000)	SAS MP/REML*
All	3.502 ± 0.661	3.413 ± 0.684	–
Charter	3.682 ± 0.151	3.607 ± 0.152	A
Tour	3.920 ± 0.173	3.897 ± 0.173	A
Regular Route	3.370 ± 0.130	3.328 ± 0.130	A
Commuter Express	3.213 ± 0.133	3.120 ± 0.133	A

*The groups sharing the designator A did not differ one from another (there was no main effect of type of operation) by mixed effects ANOVA.

3.10 SUBJECTIVE MEASURES

Participants were asked to take the Samn-Perelli Fatigue Scale and the KSS at the start of each duty day, at the start of any break greater than 90 minutes, at the end of any break greater than 90 minutes, and at the end of each duty day. Data was available for 80 participants. Though the participants were asked to rate fatigue and sleepiness four times per duty day, many participants failed to make ratings at the start and end of breaks greater than 90 minutes. Therefore, only the Samn-Perelli Fatigue Scale and the KSS ratings made at the start and end of each duty period were compared.

3.10.1 Fatigue as Measured by the Samn-Perelli Fatigue Scale

For the Samn-Perelli Fatigue Scale, there was a main effect of start and end of duty with fatigue being higher at the end of the duty day. There was no main effect with type of operation but there was an interaction between start and end of duty and type of operation. The drivers reported increasing levels of fatigue across the duty day in each operational group. This effect was least pronounced for Commuter Express (Table 18).

Table 18. Mean for the Samn-Perelli Fatigue Rating at the Start and End of Duty for All Drivers and for Drivers by Type of Operation

	Start of Duty Mean ± SD	End of Duty Mean ± SD	SAS MP/REML*
All	2.22 ± 0.79	3.86 ± 0.99	–
Charter	1.90 ± 0.62	3.86 ± 1.10	A
Tour	2.07 ± 0.62	3.76 ± 0.86	A
Regular Route	2.20 ± 0.86	4.02 ± 1.01	A
Commuter Express	2.56 ± 0.82	3.76 ± 1.01	A

*The groups sharing the designator A did not differ one from another (there was no main effect of type of operation) by mixed-effects ANOVA.

3.10.2 Sleepiness as Measured by the KSS

For the KSS, there was a main effect of start and end of duty with sleepiness being higher at the end of the duty day. There was no main effect with type of operation but there was an interaction between start and end of duty and type of operation. The drivers reported increasing levels of sleepiness across the duty day in each operational group. This effect was least pronounced for Commuter Express (Table 19).

Table 19. Mean for the KSS at the Start and End of Duty for All Drivers and for Drivers by Type of Operation

	Start of Duty Mean ± SD	End of Duty Mean ± SD	SAS MP/REML*
All	2.65 ± 1.05	4.58 ± 1.38	–
Charter	2.41 ± 1.10	4.84 ± 1.66	A
Tour	2.26 ± 0.74	4.45 ± 1.19	A
Regular Route	2.53 ± 1.05	4.57 ± 1.43	A
Commuter Express	3.16 ± 1.02	4.50 ± 1.24	A

*The groups sharing the designator A did not differ (there was no main effect of type of operation) one from another by mixed effects ANOVA.

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4. SUMMARY OF FINDINGS

The 84 participants in this study were on average middle-aged (average age 50.1 ± 10.3 years) and on the border between overweight and obese (average BMI 31.9 ± 6.5). Of these, 24 percent were women.

Participants included in the analyses completed an average of 31 days in the study (range 20–48).

Distributions of duty start times were examined for the following:

- The entire sample.
- Differences between the Charter, Tour, Regular Route, and Commuter Express operations.

It was hypothesized that if drivers were pushing the limits of the regulations and working 18–23-hour work/rest cycles then duty start times would be more or less evenly distributed across the 24-hour day. This was not found to be the case. Duty start times for the entire sample were clearly clustered in the morning or early morning hours (average duty start time was 8:43 a.m. ± 3:38 SD hours:minutes), with the most frequent duty start times centered around 6 a.m. Duty start times were not significantly different among Charter, Tour, Regular Route, and Commuter Express operations. Overall, the later the duty start time, the longer the TST. Given the distribution of duty start times, it would appear that in this study sample, drivers do not push the hours of service regulatory limits with respect to the work/rest cycle.

Total time on duty per duty day for the entire sample was examined. Average total duty time per day was 9:14 ± 02:59 SD (hours:minutes). By inspecting the duty time histogram, the most frequent on-duty time per duty day was 8 hours and 30 minutes. Very few on-duty times per duty day exceeded the regulatory limit of 15 hours. No individual driver averaged more than 15 hours duty per duty day. The average duty duration was longest for Tour drivers (10:16 ± 01:26 SD hours:minutes) and shortest for Commuter Express drivers (8:29 ± 01:09 SD hours:minutes).

Estimates of workload (on-duty days as a percent of total days) were calculated. For the entire sample, 65 ± 18 percent of total days were on-duty days (days with some on-duty time logged).

Average hours on duty over 7 days (as an estimate of workweek) was calculated by taking on-duty days as a percent of total days and multiplying these values by the values for mean total duty time per duty day. It appears that, on average, motorcoach operators in our sample worked 43:18 ± 13:14 SD hours:minutes a week.

Sleep/wake history was measured using the wrist-worn actigraph. Sleep/wake history was obtained for a mean of 31 days on 84 participants. Mean daily sleep time by actigraphy was 8:04 ± 02:06 SD hours:minutes in the middle of the recommended range of 7–9 hours of sleep per 24 hours. Tour drivers slept the most and Commuter Express drivers slept the least. For each of the four types of operation, mean daily TST was within the recommended range of 7–9 hours per 24 hours. Drivers slept more on off-duty days (9:11 ± 02:07 SD hours:minutes) than on on-duty days (7:27 ± 01:50 SD hours:minutes) but on average were within the normal range for sleep during both on- and off-duty days. Overall, the longer the on-duty time, the shorter the sleep time.

Vigilance and subjective fatigue and sleepiness were assessed during duty days. Vigilance performance was measured using the PVT going on and off duty. Few participants recorded mid-duty breaks, took mid-duty break PVTs, or filled out mid-duty break fatigue and sleepiness scales. Thus, we compared results from going on duty with those from going off duty. PVT speed was slower at the end of the duty period than at the beginning. With respect to subjective measures (e.g., the Samn-Perelli Fatigue Scale and the KSS), both fatigue and sleepiness increased from the beginning to the end duty period. The smallest increase in fatigue and sleepiness was with Commuter Express drivers.

5. CONCLUSIONS

Our sample of 84 motorcoach drivers was middle-aged, overweight or obese, and predominantly male. They were studied for an average of 31 consecutive days with actigraphy. They self-identified as Charter, Tour, Regular Route or Commuter Express drivers. They went on duty in the early to mid-morning, were on duty an average of more than 9 hours. There was no indication of drivers out of sync with the 24-hour circadian rhythm. In particular, there was no evidence of backwardly rotating 18–23-hour rest/duty cycles. These would have manifested in duty start times being distributed across the 24-hour day. Few drivers exceeded the regulatory limit of 15 hours on duty.

Days with on-duty time constituted 65 percent of total days in the study. A rough calculation of hours on duty per week indicated that drivers worked a little more than 40 hours a week. As indicated by wrist-worn actigraph, mean daily TST was around 8 hours, well within the recommended range of 7–9 hours. Drivers slept more on off-duty days than on on-duty days.

Overall, the earlier the start time and the longer the on-duty time, the less the sleep. For all four operation types (Charter, Tour, Regular Route, and Commuter Express) daily TST, both on and off duty, averaged between 7 to 9 hours, again within the recommended range. Subjective ratings of fatigue and sleepiness appeared to increase from the beginning to the end of the on-duty period.

In short, motorcoach operations in the present sample involved slightly more than a 40-hour week, start times in the morning or early morning, a typical duty day of approximately 9 hours, and on average a normal 8 hours of TST per 24 hours.

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