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RESEARCH REPORTS AND STUDIES SHOWING THE ADVERSE HEALTH AND SAFETY EFFECTS OF LONGER WORKING HOURS AND INADEQUATE REST TIME

Jovanis, P., Wu, K., Chen, C.; *Hours of Service and Driver Fatigue: Driver Characteristics Research*, FMCSA, May 2011:

◊ Examined the patterns of driving and work in the week before a crash.
◊ "There is a consistent increase in crash odd as driving time increases."
◊ "LTL drivers experienced increased crash odds after the 6th hour of driving."
◊ "Breaks from driving reduced crash odds."
◊ "There was an increase in crash odds associated with the return to work after a recovery period of 34 hours or more."
◊ TL drivers who drive during the day have increased odds of a crash with long driving hours.
◊ LTL drivers:

- Driving time substantially associated with crash odds.
- Highest odds in the 11th hour.
- Consistent increase in odds after the 5th through the 11th hours.

◊ Decrease in odds of a crash were significant for two breaks (sleeper or off duty).
◊ Using all of the data the crash exposure ratio gradually increases, especially after the 6th hour of driving.

Blanco, M., Hanowski, R., Olson, R., Morgan, J., Soccolich, S., Wu, S., Guo, F.; *The Impact of Driving, Non-Driving Work, and Rest Breaks on Driving Performance in Commercial motor Vehicle Operations*, FMCSA, May 2011:

◊ Studies 100 drivers, 4 companies, naturalistic data collection over 4 weeks for each driver.
◊ Analyses on driving hours and safety-critical event (SCE risk) found a time-on-task effect across hours.
◊ Analysis on work hours found an increase risk of SCE as work hours increased.
◊ SCE risk increased with driving late into the 14-hour workday.
◊ Breaks from driving were effective to counteract the negative effects of time on task.
◊ SCE rate in the 11th hour was statistically significantly higher than in hours 8, 9, or 10.
◊ No statistically significant difference between SCE rate in 11th and 10th.
◊ As work hour increases from beginning to end, there is a statistically significant increase in SCE rate.
◊ Rest breaks of at least 30 minutes were shown to decrease the SCE rate in the hour after the break compared to the hour before.
◊ Off duty break provided the greatest benefit.
◊ *Analysis of all of the data indicated increase in SCE risk with increasing driving time.*

Sando, T., Mtoi, E., Moses, R.; *Potential Causes of Driver Fatigue: A Study on Transit Bus Operators in Florida*, Transportation Research Board 2011 Annual Meeting, Nov. 2010:
◊ Studied data from transit agencies in Florida.
◊ "Scientifically and average person needs eight hours sleep every 24-hours cycle."
◊ "Most of the accidents (56.69%) occur when the operators are exposed to red fatigue conditions" ("red fatigue" is a highly fatigued state identified by the software utilized in the study, the Fatigue Audit Interdynamics (FAID) program).
◊ "The survey also revealed that the minimum off duty period of eight hours might not be adequate. It is likely that this could be another cause of fatigue among operators because it leads to inadequate rest and sleep."
◊ A fatiguing work schedule includes: split schedules, less sleep, long driving hours and early starting – late ending schedule patterns.
◊ Fatigue is cumulative, "after the accumulation of fatigue, the operator needs enough off duty period to recover from critical fatigue condition. To start with a green fatigue condition (full recovery) in a weekly schedule the operator needs at least two days off duty."
◊ "there is a statistically strong association between fatigue condition and crash occurrence."

Sando, T., Angel, M., Mtoi, E., Moses, R.; *Analysis of the Relationship Between Operator Cumulative Driving Hours and Involvement in Preventable Collisions*, Transportation Research Board 2011 Annual Meeting, Nov. 2010:
◊ Studies four transit agencies from the state of Florida.
◊ "The results show a discernable pattern of an increased propensity of collision involvement with an increase in driving hours. . . According to the findings of this study, it is clear that the present regulation that limits driver's on-duty time to a maximum of seventy hours per week should be revisited."
◊ Bus driver with straight schedules in preventable collisions drove an average of 49.8 hours in the week before the collision (95% confidence interval).
◊ Bus driver with split schedules in preventable collisions drove an average of 53.7 hours in the week before the collision (95% confidence interval).
◊ On average, drivers who were involved in preventable collisions drove over six hours more per week than that of the general population of drivers.
◊ Preventable collisions are more prevalent as the length of the driving period increases.

Park, S., P.P., Jovanis., *Hours of Service and Truck Crash Risk: Findings from 3 national U.S. Carriers during 2004.* Presented at 89th Annual Meeting of the Transportation Research Board, Washington, D.C., 2010.
◊ "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 200% in the 10th and 11th hour."

F. Saccomano, M. Yu, and J. Shortread, Effect of Driver Fatigue On Truck Accident Rates, *Urban Transport and the Environment For the Twenty-First Century* (ed. L.J. Sucharov), Computational Mechanics Publications, Southhampton, U.K., 1995, 439-446; and,
F. Saccomano and J. Shortread, ATruck Safety: Perceptions and Reality, *The Institute for Risk Research*, Ontario, 1996, 157-174.
◊ Found a significant increase in crash rates for truck driving shifts of more than 9 hours.
◊ The strong relationship between single-vehicle truck crashes and length of continuous driving time held regardless of the time of day.
◊ Findings confirmed earlier Federal Highway Administration research.

T. Lin, P. Jovanis, and C. Yang, Modeling the Effect of Driver Service Hours On Motor Carrier Accident Risk Using Time Dependent Logistic Regression, 72nd Annual Meeting of the Transportation Research Board, Washington, DC, 1993; and,
T. Lin, P. Jovanis, and C. Yang, Time of Day Models of Motor Carrier Accident Risk, *Transportation Research Record* 1467: 1-8, Transportation Research Board, National Academy of Sciences, 1994.
◊ Found a consistent elevation of crash risk from about the 8th to the 9th hour of driving.
◊ Found a dramatically increased risk if driving exceeded 9 continuous hours.
◊ Confirmed earlier Federal Highway Administration research.

T. Kaneko and P. Jovanis, *Multiday Driving Patterns and Motor Carrier Accident Risk: A Disaggregate Analysis*, U. of CA at Davis, Research Report UCD-TRG-90-9, April 1990.
◊ Driving patterns over the previous 7 days significantly affected crash risk on the 8th day.
◊ Consecutive driving hours have a consistent crash risk relationship.

T. Kaneko and P. Jovanis, Multiday Driving Patterns and Motor Carrier Accident Risk: A Disaggregate Analysis, *Accident Analysis and Prevention*, 25:5, 1992, 437-456.
◊ Consecutive hours of driving were the most significant predictor of accident risk.

I. Jones and H. Stein, *Effect of Driver Hours of Service on Tractor-Trailer Crash Involvement*, Insurance Institute for Highway Safety, Arlington, VA, 1987; and,
I. Jones and H. Stein, Defective Equipment and Tractor-Trailer Crash Involvement, *Accident Analysis and Prevention*, 21: 469-481.
◊ Study used case-control design (3 matching controls for each case), controlled for time of day.
◊ Widely regarded as one of the most rigorous in-depth studies of fatigue ever conducted (*e.g.*, Haworth, Triggs, and Grey (1988)).
◊ Found a substantial increase in crash risk if drivers exceeded 8 continuous hours of driving.
◊ Crash risk for drivers whose reported driving time exceeded 8 hours was almost twice that for drivers who had driven fewer hours.
◊ Crash risk estimates conservative because number of driving hours based on driver self-reporting.

W. Frith, A Case-Control Study of Heavy Vehicle Drivers Working Time and Safety, *Proceedings of the 17th Australian Road Research Board Conference*, 1994, 17(5): 17-30.
◊ Case-control methodology, matched-pairs.
◊ Crash risk substantially increased for drivers with greater than 8 hours of driving but less than 9 hours.
◊ Crash risk rose even higher if driving exceeded 9 hours.
◊ Emphasized that his findings confirmed the 1987 research of Jones and Stein, and the 1993 research of Lin, Jovanis, and Yang.

S. Folkard, Time On Shift Effects In Safety: A Mini-Review, Abstract in the *Shiftwork International Newsletter*, May 1995, 12:1, Timothy Monk, ed., presentations from the 12th International Symposium On Night- and Shiftwork, Ledyard, CN, June 13-18, 1995.
◊ Major meta-analysis of relative risk of performance lapses over the course of various shift durations.
◊ Increase in relative risk of crashes over time was exponential.
◊ Risk was approximately doubled after 12 hours of work and trebled after 14 hours of work.
◊ Found that safest work duration is 6 to 9 hour long shifts.

P. Krauth, et al., ASystematic Selection of Shift Plans for Continuous Production With the Aid of Work-Physiological Criteria, *Applied Ergonomics*, 1979, 10:1, 9-15.
◊ Working times of more than 8 hours must be avoided because of long-term deleterious effects on worker health.
◊ Longer shift times found to reduce effective daily recuperation, produce adverse impacts on sleep length and quality [*e.g.*, see Smiley and Heslegrave (1997], and reduce desirable leisure activities.
◊ Showed that research literature consistently demonstrates that only in exceptional cases have 12 hours shifts, in particular, proved successful without measurable deterioration in safety, sleep quality, and worker health.
◊ Cites corroborative research findings, such as Rutenfranz (1973); Knauth and Rutenfranz (1972); Rutenfranz et al. (1974).

C. Abrams, T. Shultz, and C. Wylie, *Commercial Motor Vehicle Driver Fatigue, Alertness, and Countermeasures Survey*, Report FHWA-MC-99-067, Federal Highway Administration, U.S. Department of Transportation, August 1997.
◊ Survey of 511 commercial motor vehicle drivers undertaken concurrently with the 1997 Driver Fatigue and Alertness Study.
◊ Twenty-eight (28) percent of surveyed drivers admitted falling asleep at the wheel during the previous month.
◊ One-third of these fall-asleep drivers admitted falling asleep at the wheel from 3 to 6 times in the prior month.
◊ The majority of drivers who fell asleep at the wheel reported that they sometimes or always are aware of the danger of falling asleep, but nevertheless continue to drive.
◊ Nearly 47 percent of surveyed drivers stated that they sometimes cut their sleep short to make delivery schedules.
◊ Drivers often begin trips already fatigued, *e.g.*, more than 38 percent have already been awake

for 6 to 12 hours before beginning to drive.
◊ More than a third of drivers surveyed said that loading/unloading contributed to their fatigue and lowered their alertness.
◊ Ninety-one (91) percent of surveyed drivers slept in tractor sleeper berths, 6.7 percent in motels.
◊ About one-quarter of sleeper berth drivers split their sleeping time and overall slept fewer hours than drivers who rested in one period.
◊ Most drivers use breaks for other than napping purposes, *e.g.*, eating, fueling, restroom use, *etc.*
◊ Authors conclude that fatigue, drowsiness, difficulty of preventing falling asleep at the wheel may be more prevalent in the driver community than previously thought.

J. Rutenfranz and P. Knauth, Hours of Work and Shiftwork, *Ergonomics*, 19:3, 1976, 331-340.
◊ Found that the primary protection afforded workers against undue health risks were achieved by limitation of working hours as a direct means of curtailing risk exposure.
◊ A daily working time limit of 8 hours is shown to be optimal.

Simon Folkard, Black Times: Temporal Determinants of Transport Safety, *Accident Analysis and Prevention*, 29:4, 1997, 417-430.
◊ Showed that circadian rhythms are insufficient to account for the variation in crash risk over the 24-hour day.
◊ Deleterious effects of time on task overarch those derived from circadian effects (time of day).
◊ Safest continuous task duration, except for very short duty periods of about 2.5 hours, is about 8 to 10 hours of maximum shift length.

E. Grandjean, *Fitting the Task to the Man: An Ergonomic Approach*, London 1982.
◊ Shows that many studies have demonstrated that shortening the work day actually raises worker efficiency.
◊ Making the working day longer causes worker hourly efficiency to decline.
◊ Shows that many studies of actual workplace productivity demonstrate that increasing daily working hours beyond 10 hours actually results in a decline in productivity as a natural product of increasing fatigue which more than offsets the increased working hours.
◊ Found that working time of 8 hours per day cannot be increased to 9 hours or more without ill effects.

D. Linklater, Fatigue and Long Distance Truck Drivers, *Australian Road Research Board Proceedings*, 10:4, 193-201, 1980.
◊ Interviewed drivers of all types of vehicles at roadside restaurants and found that relative crash rates of truck drivers increased when weekly driving time exceeded 55 hours.
◊ Cites U.S. Bureau of Motor Carrier Safety finding in 1969 that 30 percent of single-vehicle truck crashes involved commercial drivers asleep at the wheel with 13 percent of those drivers verified to have exceeded maximum permitted hours of driving.
◊ New South Wales commercial drivers limited to a maximum of 72 hours driving per week, yet the crash risk of drivers has already begun to rise before this limit is reached.

Mark Rosekind, et al., From Laboratory to Flightdeck: Promoting Operational Alertness.
◊ All estimates of fatigue-related accidents in transportation are underestimated.
◊ Many shiftwork studies have found reductions in performance, lowered alertness, and increased proneness to error and injuries for 12 hour shifts.
◊ Cite many supporting research studies such as Rosa (1991); Rosa and Bonnet (1993); Rosa (1995).
◊ Authors point out that in Rosa (1995), analysis of a national occupational-injury database showed a constant accident/injury rate through 9 hours of work, but then a rapid and progressive increase to three times the rate at the end of 16 hours of work.

Raymond Fuller, *Prolonged Heavy Vehicle Driving Performance: Effects of Unpredictable Shift Onset and Duration, and Convoy vs. Independent Driving Conditions*, U.S. Army Research Institute for the Behavioral and Social Sciences, Tech. Report 585, Sept. 1983.
◊ Found that symptoms of fatigue were most typical near the end of the driving shift, becoming evident from about the 9th hour of driving.
◊ Asserts that his research shows that prudence dictates a driving regime of no more than 8 or 9 hours long.

Gunther Hildebrandt, A12 & 24 H Rhythms In Error Frequency of Locomotive Drivers and the Influence of Tiredness, *International Journal of Chronobiology*, Vol. 2, 175-180 (1974).
◊ Tiredness was shown to play an important role in error frequency by train engineers, especially in the afternoon.
◊ Found that the increase in error frequency was linearly related to the number of hours previously worked.

Federal Highway Administration Report to Congress On Commercial Driver Hours of Service, November 1990.
◊ Openly endorses research findings showing the adverse effects of longer continuous driving times and of cumulative fatigue resulting from several consecutive days of driving.
◊ Asserts at the outset that the risk of crashes increases with the number of hours driven.
◊ Supports the 10-hour maximum regulatory restriction on continuous driving time because it is consistent with research showing that the potential for crashes rises as the hours of driving increase due to increasing driver fatigue.
◊ Favorably cites the Jones and Stein (1987) study by the Insurance Institute for Highway Safety that driving in excess of 8 hours may be associated with a significantly increased risk of crash involvement.
◊ Asserts that this increase in relative risk with increasing time of driving also confirms the 1978 FHWA study of Mackie and Miller.
◊ States that research has shown a cumulative fatigue effect after several successive days of driving.
◊ States that research indicates that time spent on-duty may be a more important factor in driver loss of alertness.

◊ These statements repeat previous assertions to the same effect made in 1980 (45 FR 82284, 82286, 82288, 82290).
◊ FHWA in 1987 again endorsed the findings that both increased consecutive driving hours and consecutive days of driving directly contribute to driver errors and crashes (52 FR 45215).
◊ Assertions to the same effect were made by FHWA in its November 29-30, 1988, Proceedings of the Federal Highway Administration Symposium On Truck and Bus Driver Fatigue.

W. Harris and R. Mackie, *A Study of the Relationships Among Fatigue, Hours of Service, and Safety of Operations of Truck and Bus Drivers*, Bureau of Motor Carrier Safety, Federal Highway Administration, BMCS-RP0-71-Z, June 1971-November 1972; and,
R. Mackie and J. Miller, *Effects of Hours of Service Regularity of Schedules and Cargo Loading On Truck and Bus Driver Fatigue*, Federal Highway Administration, DOT-HS-803-799, May 1975-October 1978.
◊ Classic federal studies funded through the Federal Highway Administration whose findings have been sustained by numerous later studies.
◊ Found that drivers suffered increased risk of crashes whether they were on regular or irregular driving schedules.
◊ Even on regular daytime schedules, adverse safety effects were clearly seen after about 8.5 hours of driving.
◊ Significant increases in driver errors and significant decreases in driver level of alertness began to show as early as the 4th hour of driving time on irregular schedules in particular (at about 8 hours on regular schedules) and increased throughout the trip.
◊ Frequency of crashes increased disproportionately after 7 hours of driving and remained significantly higher than expected for all driving times longer than 7 hours.
◊ Amount of driver recovery declined with each successive rest break; drivers taking a third rest break, after about 9 hours, showed no recovery and an actual further decline in alertness [See Lisper, Laurell, and VanLoon (1986): taking breaks had no lasting effects on reducing sleepiness among drivers].
◊ About twice as many crashes per mile traveled occurred in the second half of the trip as in the first half.
◊ Significant increases in driver errors and decreases in alertness occurred within the current 10-hour consecutive driving limit.
◊ Cumulative effects of fatigue appeared after the first 4 consecutive days on duty.
◊ Later U.S. Department of Transportation study (J.P. Eicher (1982)) relies heavily on the findings of these two studies.
◊ These findings further evaluated and relied on by the Office of Technology Assessment of the United States Congress in its September 1988 report (OTA-SET-382).

Benjamin F. Jones, et al., *Fatigue and Hours of Service of Interstate Truck Drivers*, U.S. Public Health Service, Public Health Bulletin No. 265, Washington, DC, 1941.
◊ Tests conducted showed lowered functional efficiency with increasing hours of work per week.

EEC Council Regulation No. 3820/85 (December 1985); EEC Council Regulation No. 98/0319SYN Amending Reg. 3820/85 and Directive 93/104/EC.
◊ Regulations establishing the European Economic Community policy on worker hours as based on extensive research and consensus agreements among member states.
◊ Regulations curtail weekly driving time to an average of no more than 48 hours per week as averaged over 4 months, with some derogations permitted (48 hours a week averaged over 6 months, 39 hours a week over 9 months, and 35 hours averaged over 12 months).
◊ Another EEC publication of November 18, 1999, emphasizes that 18 percent of fatal crashes in the European Union involve trucks or motor coaches, with 45,000 people killed each year.

F. van Ouwerkerk, Sub-Topic 4: Quality of Life and Social Costs - c) Working Conditions, *Resources For Tomorrow's Transport: Introductory Reports and Summary of Discussions*, ECMT, Brussels, September 12-14, 1988.
◊ Found serious, adverse health and social impacts from truck driver hours of service demands.
◊ High percentages of drivers admit to falling asleep or almost falling asleep at the wheel.
◊ Sixty (60) percent of drivers report anxiety, chronic heart problems, and hypertension.
◊ Relies heavily on B. Jansen (1987) study which showed that shiftwork produces pervasive problems of fatigue, sleep deprivation, gastrointestinal complaints, low family contact time, no community life, personal isolation, inability to pursue education, inadequate access to commonly available public facilities and activities such as public transportation/schools/sports, etc.
◊ Drivers have little leisure time and are disengaged from common social activities.
◊ More than one-quarter of drivers are not home on one of two weekend days.
◊ Drivers cannot schedule reasonable social time because much of their weekends are spent recovering from fatigue and sleep deprivation accrued from previous week's driving.
◊ Drivers report adverse impacts on spouses and households where the net effect of international driving is a one-parent home.
◊ Nearly half of all drivers have high rates of domestic discord with spouses and children.
◊ Drivers have more problems and more severe problems than the general population.
◊ Relatively high percentage of drivers reporting crash involvement due to falling asleep at the wheel of a moving truck probably a considerably low estimate because many drivers fell asleep and died in the crashes.

Torbjorn Akerstedt, Readily Available Countermeasures Against Operator Fatigue, *Managing Fatigue In Transportation: International Conference Proceedings*, April 29-30, 1997, 105-117.
◊ Valuable review of research literature on shift work, sleep/fatigue, and related risk.
◊ Allowing the same minimum off-duty or layover time for driver recovery following successive nights of driving are not equivalent to the restorative effects of the same amount of time allowed for recovery from the fatigue of daytime driving.
◊ Stresses other major research findings on the effects of extended shiftwork hours (Kurumatani (1994): very high correlation between length of free time between shifts and proportional sleep duration; Hamelin (1987): fast rise in crashes beginning before the 11th hour of driving).
◊ Also emphasizes that all studies since 1971 show that rest breaks induce only very short-lived increases in alertness with a return to sleepiness and error proneness almost immediately after the end of a break.

C.D. Wylie et al., *Commercial Motor Vehicle Driver Fatigue and Alertness Study*, FHWA Report No. MC-97-001, U.S. Department of Transportation, 1997; and,
C.D. Wylie et al., *Commercial Motor Vehicle Driver Rest Periods and Recovery of Performance*, Transportation Research Centre, TP 12850E, Transport Canada, Montreal, Canada, 1997.

◊ Major study effort conducted over 5 years by the Trucking Research Institute of the American Trucking Associations in cooperation with Transport Canada.

◊ Prospective cohort study of commercial operators driving different schedules, truck equipment, time of year, and routes in U.S. and Canada.

◊ Severe methodological deficiencies, including threshold errors in sample size and subject selection, also unrecorded sleep and unmonitored naps.

◊ Many data gathering inadequacies, including acquisition of data from intermittent vigilance tests of drivers, *e.g.*, authors failed to acknowledge the well-known phenomenon resulting from use of secondary task techniques which provide extratask stimulus (alerting effect) offsetting effects of fatigue on alertness and capacity (see, *e.g.*, Brown (1978); Brown, Simmonds, and Tickner (1967); Brown, Tickner, and Simmonds (1966); Home and Wilkinson (1985); Haworth, Triggs, and Grey (1988); Dinges and Kribbs in Monk (ed.) (1991)).

◊ Study adversely criticized by peer review panels and in peer review journals for study design.

◊ *Post hoc* statement by researchers of hypothesis of interest, *viz.*, whether time of day of driving (circadian effect) overarches driving duration or time-on-task.

◊ Evidence of drowsiness in drivers not found in physiological testing but through visual interpretation of drivers' faces recorded on camera; drowsiness judgments uncorroborated in research community because face videos protected from disclosure.

◊ Primary reliance on judgments made from face videos confuses drowsiness indicators with fatigue -- drivers can be fatigued, *i.e.*, increasingly unable to perform a task well or safely, without appearing drowsy because of, *e.g.*, drooping eyelids.

◊ Due to lack of adequate data and multiple research design failures, study could not demonstrate a dominant circadian effect in comparison with performance and alertness deficits associated with duration of time-on-task.

◊ The follow-up study by Wylie et al. for Transport Canada studied 25 of the original 40 Canadian drivers participating in the DFAS, but statistical power of the follow-up is quite low (primarily from small sample size), especially as regards the study premise of whether adequate driver recovery from fatigue and sleep debt following 60 hours of driving within a seven-day period occurs after no (actually a nominal 12 hours), one (actually a nominal 36 hours), or two workdays (nominally 48 hours) of off-duty time.

◊ The follow-up study also relied on EEG, face video interpretation, vehicle lane tracking, and surrogate performance testing data as collected for the DFAS, all of which had various major deficiencies as described above.

◊ Use of these drivers during the layover days during the DFAS study further confounded the findings of both the DFAS and the follow-up study, and constitute a major research design failure.

◊ However, the initial study and its follow-up produced corollary information which is nevertheless highly suggestive:

(1) No objective evidence that drivers could sufficiently recover from consecutive days of driving with a 36-hour or even a 48-hour off-duty period [*e.g.*, see Smiley and Heslegrave (1997)];
(2) All driver cohorts, whether driving 10-hour or 13-hour shifts, suffered severe and chronic sleep deprivation throughout the length of the study.

A. Smiley and R. Heslegrave, *A 36-Hour Recovery Period for Truck Drivers: Synopsis of Current Scientific Knowledge*, Transportation Development Centre, Transport Canada, 1997.

◊ Excellent literature review of studies specifically relating to driver recovery time needs.
◊ Evaluation of known research (*e.g.*, Lille (1967)) indicates serious concerns over the sufficiency of a 36-hour driver clock reset provision after several consecutive days of driving – drivers still fatigued and carrying unresolved sleep debt, resulting in quickly deteriorating performance when resuming work.
◊ Thirty-six- (36) hour layover especially inadequate following night shift work.
◊ Several studies strongly indicate inadequacy of even 48 hours off for full performance recovery (*e.g.*, Hildebrandt, Rohmert, and Rutenfranz (1975); Mallette (1994)).
◊ Authors conclude that commercial drivers need minimum of 48 hours off after several consecutive days of driving, but this still does not secure full performance and alertness recovery -- 72 hours or more are needed.
◊ Research literature also consistently shows that long work shifts result in accumulation of sleep debts.
◊ Concludes that Wylie study strongly indicates that even four 13-hour consecutive driving shifts results in significant performance deterioration.
◊ Long work shifts and associated inadequate sleep/recovery results in family and social dysfunction, increased substance abuse and health problems.

Roger Rosa and Michael Colligan, Extended Workdays: Effects of 8-Hour and 12-Hour Rotating Shift Schedules On Performance, Subjective Alertness, Sleep Patterns, and Psychological Variables, *Work and Stress*, 1989, 3:1, 21-32.

◊ Demonstrated the lower performance and alertness produced by an extra 4 hours added to shifts which result in more sleep reduction, disruption of personal activities, and increased self-reported stress.
◊ Use of a 12-hour rather than an 8-hour shift caused an increasing accumulation of unresolved sleep debt, as shown by substantial diminishment of sleep latency.
◊ None of these adverse effects was found on an 8-hour shift.
◊ Shift workers make inroads on sleeping time to perform normal personal activities within less off-duty time.

Roger Rosa, Performance, Alertness, and Sleep After 3-5 Years of 12 H Shifts: A Follow-Up Study, *Work and Stress*, 1991, 5:2, 107-116.
◊ Confirmed findings of earlier study.
◊ Also showed the adverse health effects of 12-hour versus 8-hour work shifts.

Roger Rosa and Michael Bonnet, Performance and Alertness On 8 H and 12 H Rotating Shifts At a Natural Gas Utility, *Ergonomics*, 1993, 36:10, 1177-1193.
◊ A review of the data of the 1991 study confirming the lowered performance, decreased alertness, reduced quality of social life, and increased health complaints associated with 12-hour shifts.

Ivan Brown, Driver Fatigue, *Human Factors*, June 1994, 36:2, 298-314.
◊ Drivers may be fatigued, yet sustain performance effectiveness, but at an increasing cost of experienced fatigue until performance begins to collapse.
◊ Long work shifts produce reactive inhibition in which the human brain becomes disinclined to continue producing the same repeated response to the same environmental stimuli.
◊ Typical 8-hour shift has no adverse implications for drivers.
◊However, research has long established that extended work periods both impair task performance and increase sickness absence and injuries (*e.g.*, Vernon (1921)).
◊ Daily hours and weekly hours must be balanced to avoid fatigue and performance degradation (*e.g.*, Rosa et al. (1985) showed that a 12 hour/4-day week more detrimental to performance and produces more self-reports of drowsiness and fatigue than 8-hour/6-day week).
◊ The longer the duty period, more stressful the task, and more hazardous the working conditions, the more restitutive sleep a driver will be obliged to take.
◊ Performance deterioration more severe in performance of tasks which are long, familiar, monotonous, and complex such as driving.

T. Sanquist, et al., *Fatigue and Alertness In Merchant Marine Personnel: A Field Study of Work and Rest Sleep Patterns*, U.S. Coast Guard Report No. CG-D-06-97, June 1996.
◊ One hundred forty-one (141) mariners in commercial maritime industry studied for their work and sleep patterns on shipboard duty.
◊ Major fatigue/sleep deprivation problem in commercial maritime industry.
◊ Mariners averaged 6.6 hours of sleep in each 24 hours and quickly accumulated large sleep debts with pervasive symptoms of fatigue, including critically low alertness levels and extremely short sleep latencies.
◊ Response of Congress to sleep deprivation of watch mate prior to grounding of Exxon Valdez was enactment of legislation limiting tank vessel personnel to 15 hours duty time in each 24 hour period, 36 hours duty in 72 hour period.
◊ This statutory regime promotes sleep deprivation and accumulated sleep debt coupled with deteriorating performance over consecutive days.
◊ Minimum off-duty period of 9 hours provides insufficient opportunity for enough sleep by mariners.
◊ Once diurnal alertness is achieved, even with some accumulated sleep debt, mariners avoid afternoon naps in particular because of high sleep inertia following them.
◊ Conversely, mariners often report poor sleep following duty periods because of work inertia, resulting in insufficient sleep even with enough time available to secure needed sleep.

◊ Cites numerous research findings that fragmenting sleep into shorter, intermittent periods [*e.g.*, in truck sleeper berths] results quickly in sleep deprivation, reduced alertness, and lowered performance, a practice explicitly avoided for flight crew in commercial aviation because FAA regulations require 9 consecutive hours of rest following a flight of 8 hours or less.
◊ Cites research (*e.g.*, Kecklund and Akerstedt (1995)) showing that at least 16 hours between work shifts in necessary to consistently achieve sleep durations of 7-8 hours.

A. Fletcher and D. Dawson, Cabin Safety and Hours of Work: Developing a General Risk-Control Model for Fatigue, *Journal of Centre for Sleep Research*, 2: 9-26, 1997.
◊ Surveys research literature showing that the longer a work period, the more fatiguing it is likely to be.
◊ Fatigue impact of longer working hours is compounded by also abbreviating the available time for rest and restorative sleep.
◊ Confirms previous studies that laboratory-based studies such as those showing no differences in performance between shifts of varying lengths are unreliable for making generalizations applying to specific workplaces.
◊ Experimental studies typically oversimplify the complex psycho-social context in which shiftwork occurs and fail to model real-world shift schedules.
◊ Stresses that many organizations view financial and service imperatives as overriding determinants of shift schedules.
◊ Without reliable empirical tools to accurately quantify actual relationships between fatigue and organizational costs, there is little incentive to implement coherent hours of work schedules.
◊ In developing fatigue policies, organizations will ignore objective scientific information not suiting their economic goals.

Patrick Hamelin, Lorry Driver's Time Habits In Work and Their Involvement In Traffic Accidents, *Ergonomics*, 1987, 30:9, 1323-1333.
◊ Cites MacDonald (1984) and concludes that, based on a comparison with exposure to risk, both long hours of work and driving at night are associated with a much higher rate of accidents than shorter hours and daytime driving.
◊ The accident rate in the second half of driving trips is twice as high as in the first half.
◊ Risk rate linked to work span duration is probably underestimated.
◊ Points out that several authors (*e.g.*, Pokorny et al. (1981)) have show the existence of a slight excess-risk rate immediately after work resumption following a break.

James C. Miller, *Fundamentals of Shift Work Scheduling*, 2nd ed., c1992.
◊ Manual sets forth quantitatively-based recommendations for shift work scheduling, including shift rotations.
◊ Most current work schedules are not based on worker efficiency and health needs, but on productivity goals which have been abstracted from the workers' needs.
◊ Stresses that real-world policy investigations of shiftwork impacts have clearly shown that 12 hour shifts are not appropriate for continuous operations (citing P.M. Lewis, *Recommendations for NRC Policy On Shift Scheduling and Overtime At Nuclear Plants*, U.S. Nuclear Regulatory Commission, NUREG/CR-4248, PNL-5435, 1985).
◊ Also cites J.T. Mets, AAdverse Effects of Working 12-Hour Shifts, *Proceedings of the 2nd Annual Conference of the Ergonomics Society of Southern Africa,* Cape Town, April 14-15, 1986,

who showed the increased injury rates for workers in auto manufacturing plants when management changed plant policy from 9 to 12 hour shift lengths.
◊ Also cites Gardner and B.D. Dagnall, AThe Effect of 12-Hour Shift Working On Absence Attributed to Sickness, *British Journal of Industrial Medicine*, 1977, 34, 148-150, who showed the consistent increase in work absence rates for sicknesses among process workers in an oil refining/petrochemical plant as a direct consequence of switching from 8 hour to 12 hour shifts.

P.M. Lewis, *Shift Scheduling and Overtime: A Critical Review of the Literature*, Nuclear Regulatory Commission Contract DE-AC06-76-RLO, 1985; and,
P.M. Lewis, *Recommendations for NRC Policy On Shift Scheduling and Overtime At Nuclear Power Plants*, Division of Human Factors Safety, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC, 1985.
◊ Found that the number of hours worked in a 7-day period must be limited.
◊ Basis of recommendations was a comparison of findings from studies of work/risk relationships in other industries.
◊ Relied on federal regulations limiting airline pilots and flight crew to 30 hours aloft in 7-day period.
◊ Cites Nicholson's (1972) findings of total duty time of 55 hours in 7 days and Mohler's (1976) physiological index for pilots and crew indicating that 56 hours/7days is a high work load and that 84 hours in 7 days is far too much.

David Dinges and Nancy Kribbs, Performing While Sleepy: Effects of Experimentally-Induced Sleepiness, *Sleep, Sleepiness, and Performance*, Timothy H. Monk, ed., John Wiley and Sons, Ltd., c1991, 97-128.
◊ Inadequate sleep is endemic in industrialized societies that prize irregular hours and view sleep as a potential source of additional work time.
◊ More attention has been paid to the physiological, neurological, and psychopathological effects of sleep loss than to performance effects.
◊ The most powerful determinant of lapsing [on tasks] and decreased performance in a sleepy person is the required task duration -- the longer the task duration, the greater likelihood that performance will show evidence of impairment early on during sleep deprivation.
◊ Cites several studies to support this conclusion, including Williams, Kearney, and Goodnow (1959) who consistently found that reaction time was an increasing monotonic function of task duration.
◊ Even providing enough time for gaining off-duty sleep cannot by itself offset the increased risk from longer exposure to high-risk tasks such as driving a commercial motor vehicle because many drivers will still get inadequate sleep.
◊ Research literature consistently shows that increased exposure time will correspondingly produce more performance lapses (failures), especially if workers get inadequate sleep.

Gregory Belenky, The Effects of Restricted Sleep On Performance and Subsequent Recovery: Implications for Managing Sleep to Sustain Performance, *Fourth International Conference On Fatigue In Transportation*, Freemantle, Australia, Mary 19-22, 2000.
◊ Reviews studies conducted by the U.S. Army and Walter Reed Hospital showing that anything less than eight to nine hours of sleep per night leads to degraded work performance over time.
◊ The longer a person suffers from restricted sleep, the longer it takes them to recover even when given optimal conditions for sleep.

T. Balkin *et al.*, *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance*, Walter Reed Army Institute of Research, Report No. DOT-MC-00-133, Federal Motor Carrier Administration, U.S. Department of Transportation, May 2000.
◊ Study comprised two separate research efforts, one a field study using wrist actigraphy to determine sleep duration and timing in long- and short-haul commercial drivers over 20 consecutive days, the other a sleep dose/response laboratory study on commercial drivers to determine the effects on performance of differing times spent in bed each night (3, 5, 7, 9 hours) over 7 consecutive days.
◊ Overall purpose of the study was the attempt to quantify the relationship between different amounts of sleep and subsequent performance during wakefulness.
◊ Field portion of the study showed that daily sleep duration was strongly correlated with the amount of off-duty time.
◊ In the field portion, long- and short-haul drivers averaged about 7.5 hours of sleep.
◊ Long-haul drivers obtained almost half of their daily sleep during work shift hours principally in sleeper berths which suggests that they spend a significant portion of the work shift in a state of partial sleep deprivation.
◊ Even for small reductions in average nighttime sleep duration to about 6.3 hours in the 7-hours of sleep group, there was measurable performance decrements on several tests, including the psychomotor vigilance test.
◊ The performance deterioration for even small amounts of sleep restriction was maintained over the entire 7 consecutive days of sleep restriction suggesting that there is no compensatory or adaptive response to even mild amounts of sleep loss.
◊ For more severe sleep restriction, it was found that recovery of performance is not complete even after three consecutive nights of attempted recovery sleep based on 8 consecutive hours of time in bed each night, showing that expunging substantial sleep debt takes extended periods of recovery sleep over several days.
◊ These findings also suggest that the extant level of daytime alertness and performance capability is a function not only of an individual's circadian rhythm, amount of time since his/her last sleep period, and the duration of that sleep period, but is also a product of that person's long-term sleep history extending back several days.
◊ Temporal concordance between electroencephalograph defined lapses in alertness and performance on simulated driving was low, indicating that sleepiness-induced performance reductions most often occur in the absence of visually observed electrophysiological evidence of impaired alertness.

N. Haworth, T. Triggs, and E. Grey, *Driver Fatigue: Concepts, Measurement and Crash Countermeasures*, Australia Transport and Communications, Federal Office of Road Safety, Report CR72, June 1988.

◊ Massive, detailed evaluation of prior research and speculation on nature, origin, effects, and measurement of fatigue.

◊ Precise estimation of contribution of fatigue to road crashes in Australia cannot be made, but there are strong indications that the effects are far greater than hitherto believed, with 5 - 10 percent in all crashes, 20 - 30 percent in casualty crashes, 25 - 35 percent in fatal crashes, and perhaps up to 50 percent in single-vehicle tractor-semi-trailer fatal crashes.

◊ Authors' review of prior research shows that drivers' relative risk of crashes increase with increasing work duration and is compounded by drivers taking more risks as fatigue increases.

◊ In-depth studies of fatigue effects, even as rigorous as the Jones and Stein (1987) study, may still underestimate the contribution of fatigue to crash causation.

◊ Probable that most fatigue-related crashes are unidentified because they do not result in serious injuries or deaths, therefore are unreported and/or disregarded for investigation (see, *e.g.*, Hampson, *Contributing Factors In Road Crashes*, Working Document No. WD78, Federal Office of Road Safety, Australia).

◊ Cites studies showing the poor relationship between breaks or naps and recovery of alertness, *e.g.*, Lisper, Laurell, and van Loon (1986) (drivers fell asleep again soon after a five-minute walk break); Lisper and Eriksson (1980) (no difference in recovery of alertness after one, two, or five rest pauses as compared with control who had no pause); Lisper et al. (1979) (no difference between breaks of 15 and of 60 minutes for restoration of alertness).

◊ Discusses repeated findings that commercial drivers, including U.S. truck drivers, widely use amphetamines to increase alertness and performance to offset the fatiguing effects of long driving hours, which use, however, also measurably increases risktaking behavior (*e.g.*, Guinn (1983); Baumler (1975) in Seppala et al. (1979)) and increases crash rates (*e.g.*, Smart, Schmidt, and Bateman (1969)).

◊ Prolonged hours of service, including both driving and non-driving duty time, is an important cause of fatigued commercial drivers and reduction of excessive driving hours is an effective countermeasure.

J. Stutts, J. Wilkins, and B. Vaughn, *Why Do People Have Drowsy Driving Crashes?: Input From Drivers Who Just Did*, AAA Foundation for Traffic Safety, Wash., DC, Nov. 1999.

◊ Case-control study of drowsy driving crashes, with a very large sample size of over 1,400 cases and controls.

◊ Cases were drivers involved in police-reported crashes in North Carolina whose condition following the crash was explicitly characterized as asleep or fatigued, two control cohorts of non-sleepy crash-involved drivers and non-crash-involved drivers.

◊ Both cases and controls interviewed by telephone (interviewers blinded to case or control status of each interviewed driver) with survey results analyzed descriptively and through multiple logistic regression models.

◊ Very high percentages of both cases and controls interviewed regard drowsiness in driving to be a major cause of motor vehicle crashes, second in importance only to alcohol consumption.

◊ Study importantly recognizes distinction between sleepiness and fatigue: the former is the

inclination to sleep, the latter a disinclination or inability to continue performing a task.
◊ Drivers in sleep- and fatigue-related crashes were behind the wheel significantly longer prior to the crash, were awake for longer the day of their crashes, and had slept fewer hours the night before (both asleep and fatigued crash-involved drivers averaged about 6.5 hours of sleep per day).
◊ Twenty-seven (27) percent of the asleep crash-involved drivers and 20.6 percent of the fatigued crash-involved drivers work more than 60 hours each week; 43.4 percent asleep drivers and 37.3 percent fatigued drivers 50 or more hours per week; and 88 percent asleep drivers and 83.3 percent fatigued drivers 40 or more hours per week.
◊ Working more than 60 hours a week increased the odds of having a crash by 40 percent.
◊ More than half of all asleep crash-involved drivers and almost half of all fatigued crash-involved drivers have regular daytime work schedules.
◊ Half of the fatigued and asleep drivers reported feeling only slightly drowsy or not at all drowsy prior to their crashes.
◊ There was evidence that fatigue-related crashes are underreported, as well as drivers unable or unwilling to recognize the influence of drowsiness or fatigue in their crashes.

The National Highway Traffic Safety Administration and National Center On Sleep Disorders Research Program to Combat Drowsy Driving: Report to the House and Senate Appropriations Committees Describing Collaboration Between the National Highway Traffic Safety Administration and the National Center on Sleep Disorders Research, National Heart, Lung and Blood Institute, National Institutes of Health, March 15, 1999; and,
***Drowsy Driving and Automobile Crashes*, NCDSR/NHTSA Expert Panel Report on Driver Fatigue and Sleepiness, DOT HS 808 707, April 1998.**
◊ Report jointly authored by NHTSA and NCSDR to comply with the mandates of the Fiscal Year 1996 and Fiscal Year 1997 Senate Appropriations Committee Conference Reports which stated that police statistics on fatigue-related crashes represent underreporting of the prevalence of these crashes, as well as a failure to identify driver inattention problems leading to crashes.
◊ The FY96 Report asserted that NHTSA has not devoted sufficient resources to understanding and addressing driver fatigue, sleep disorders, and driver inattention.
◊ The FY97 conference agreement supplied $1,000,000.00 to NHTSA to analyze the role of driver fatigue, sleep disorders, and inattention in cooperation with NCSDR.
◊ One of the risk factors identified by the Expert Panel was shift workers accruing long daily working hours, including drivers driving long hours each day.
◊ The Panel emphasized that periods of work longer than 8 hours have been shown to impair performance and increase crashes (*e.g.*, performance is worse on 12 hours per day work schedules than 8 hours per day (Ivan Brown (1994)).
◊ The Panel explicitly distinguished sleepiness from fatigue, recognizing that fatigue is a disinclination to continue performing a task at hand whereas sleepiness is a neurobiological drive or need to sleep.
◊ The Panel found that sleepiness can contribute to fatigue- and inattention-related crashes, but that fatigue-related crashes do not necessarily involve sleepiness [See Stutts, Wilkins, and Vaughn (1999)].

T. Dingus, *et al.*, *Impact of Sleeper Berth Usage on Driver Fatigue: Final Project Report*, Virginia Tech Transportation Institute, Federal Motor Carrier Safety Administration Contract DTFH61-96-C-00068, USDOT, July 2002.
◊ Prospective study of 56 commercial drivers in 13 team cabs and 30 solo drivers working for 4 for-hire, over-the-road trucking firms, using Class 8 tractors with semi-trailers.
◊ Multiple data acquisition systems including PERCLOS (videoed driver face drowsiness interpretation as percentage of eye closure), steering movements, lane maintenance and departures, braking, automated piezo-electric sleep-monitoring system, subjective driver sleep self-ratings, Karolinska Sleepiness Scale (trained observer interpretative use), sleeper berth data noise/vibration/temperature.
◊ Study preceded by 10 focus group interview sessions in 1997-1998 comprising 74 drivers.
◊ Several drivers in focus groups admitted to illegal conduct related to their commercial driving.
◊ The focus group driver admissions of violations were confirmed later in the study participants: there were a significant number of cases where study drivers, even though they knew they were being observed, violated hours of service regulations by driving in excess of 10 consecutive hours without taking the required minimum 8 hours off-duty rest period.
◊ Excessive (illegal) consecutive hours of driving ranged from 11 hours to 15 hours, and most violations were committed by solo drivers.
◊ However, the 5 percent of the shifts that illegally exceeded 10 consecutive hours of driving had very few recorded critical incidents, and although there were 22 cases where a drive drove over 14 hours in a single shift, there were no occurrences of a critical incident or driver error in any of these cases, according to the authors.
◊ Study authors could only verify whether violations of driving hours were committed because logbooks and truck data collection systems cannot verify on-duty not-driving time.
◊ Drivers in the focus groups are required to stay awake while waiting in line for long periods of time to load/unload and would like to sleep, but don’t for fear of losing their place in the loading/unloading queue.
◊ Drivers in the focus groups mentioned that they often cannot load/unload within schedules, and if schedules are not adhered to, they would like to be able to sleep.
◊ Drivers in every focus group claimed that carrier dispatchers coerce them to continue driving even when the drivers feel they need to rest.
◊ Drivers in the focus groups complained that trucking companies do not give them enough anticipation of a driving tour of duty to enable the drivers to get sufficient sleep before going on the road.
◊ Drivers in the focus groups emphasized that they were paid by the mile, were not paid for any time when their trucks were immobile (*e.g.*, during waiting to load/unload), and that this practice impelled them to violate hours of service requirements and to speed.
◊ Authors suggest that this industry practice leads drivers to falsify their logbook entries to conceal violations.
◊ Low study participant (driver) interaction with data collection systems, but drivers had to don Nightcap sleep monitoring system and attach piezoelectric film to one eyelid.
◊ One study participating driver subverted the data collection systems by placing opaque tape over the cab-mounted video camera.
◊ Critical incident recordation protocol (video and computer storage) governing indications of

fatigue, performance lapses, safety-related events, potentially hazardous driving behavior.
◊ Solo drivers were found to be greatly affected by drowsiness which compromises their ability to safely operate large trucks.
◊ Solo drivers were greatly affected by their level of drowsiness which translated into dangerous driving behavior.
◊ Solo drivers had many more critical incidents at all levels of severity as compared with team drivers and the differences were large at all trigger severity levels.
◊ The ratio of critical incidents to timed triggers in the extremely drowsy category for solo drivers was far greater than expected and hypothesized.
◊ Solo drivers were found to be extremely drowsy in almost 2.5 times as many incidents as hypothesized.
◊ Solo drivers were involved in 4 times the instances of very/extremely drowsy observer ratings than were team drivers (20 occurrences solo drivers, 3 occurrences team drivers).
◊ Six (6) of the extreme fatigue occurrences took place when drivers had <5 hours sleep in previous 24 hours.
◊ Authors note that only 9 of the extreme drowsiness drivers had more than 7 hours of sleep in the previous 24 hours.
◊ However, only 3 of the extremely drowsy drivers had rated themselves subjectively for prior quality of sleep as worse than Level 4 (slept fairly well) [Note GAD: a finding that accords with several studies over the years showing that drivers cannot accurately judge or predict how drowsy they are or will be while driving].
◊ Solo drivers were more alert in the morning and gradually became fatigued as the day progressed.
◊ Solo drivers experienced high rate of extreme drowsiness after the second or third bout (authors use the term shift) of driving after the first day of several days of consecutive driving.
◊ The authors believe that this high rate of extreme drowsiness is the combination of long consecutive driving hours and multiple days of consecutive driving, and several measures indicate that this extreme drowsiness is the product of cumulative fatigue.
◊ The impact of drowsiness on single drivers increased as the days of a duty tour accumulated.
◊ Solo drivers in the extremely drowsy category were involved in over 20 times as many abrupt steering incidents than hypothesized, a result that was much larger than expected by the authors.
◊ The authors believe the combination of long driving shifts over multiple days creates a high potential for significant drowsiness for commercial drivers, especially in the final days of several consecutive days of driving.
◊ Quality and depth of sleep during a tour of duty were worse than home sleep, especially for team drivers who had difficulty especially in sleeping in sleeper berths while trucks were on the road.
◊ Team drivers got more sleep during the study than solo drivers, but the sleep was overall of poorer quality.
◊ Both solo and team drivers reported having a harder time falling asleep in sleeper berths than at home.
◊ Both solo and team drivers slept more deeply during a tour of duty as the days of consecutive driving elapsed due perhaps to the presence of a growing, cumulative sleep debt.

◊ Solo drivers, unlike team drivers, continued to push their driving when very tired and judged to be extremely drowsy.
◊ Solo drivers on average reported one hour less sleep per day than team drivers during a tour of duty.

B. Wright and E. Fogel, *On-Board Recorders: Literature and Technology Review*, Cambridge Systematics, Inc., FMCSA Contract No. DTFH61-99-Z-00083, July 2002.
◊ Literature review of 4 studies:

▫ Deborah Freund, *Agency Working Paper: On-Board Automated Recording for Commercial Vehicle Driver's Hours-of-service Compliance: The European Experience.*
▫ Federal Highway Administration Global Positioning System Pilot Program 1998 (unpublished materials reviewed by authors), derived from GPS Technology Notice of Interpretation with Request for Participation in Pilot Demonstration Program, 65 FR 16697 (April 6, 1998).
▫ K. Campbell and S. Lang, *Electronic Recorder Study: Final Report*, University of Michigan Transportation Research Institute, Federal Highway Administration, June 1998.
▫ *Field-Testing of On-Board Recorder, Smart Card, and Digital Signature Technology: Phase I*, Public Works and Government Services Canada Western Quebec Region and TECSULT, September 2001.

◊ Technologies include digital tachographs, engine control modules (widely used and installed by engine manufacturers, GPS, and wireless communication system.
◊ Technologies need to record number of hours driver has rested, number of hours driver has been awake and the time s/he awoke, number of hours driver on duty but not driving.
◊ About 4.2 million commercial drivers subject to logbooks.
◊ Authors note early on concerns regarding sufficiency of relying exclusively on GPS data for determining RODS and hours-of-service compliance.
◊ Authors recommend that RODS and compliance need to be governed by effective combinations of technologies, not just one type.
◊ 49 CFR Pt. 395.15, adopted in 1988, cannot be fulfilled by GPS because reg specifically requires any non-logbook technology to be integrally synchronized with specific vehicle operations, therefore must record engine use, road speed, miles driven, date, and time of day.
◊ Special pilot program necessary in 1998 because GPS does not use engine data to create RODS reports.
◊ Clear from GPS pilot program that technologies chosen must protect the regulatory interests of the federal government.

◊ **Deborah Freund agency working paper review**: European Union has made advances in promoting use of on-board recordation technologies along with defining their requirements for monitoring compliance with hours-of-service requirements.
◊ EU specifies that buses carrying more than 9 passengers and trucks weighing more than 7,700 lbs. must have automatic recording devices for distance traveled, speed, driving times, non-driving work time, and rest time.
◊ EU reg. Annex 1 prescribes requirements for development, testing, installation, and periodic inspection of the recording devices (includes design specs even for cable types and insulation).
◊ Digital tachographs poised to replace tamper-prone mechanical tachographs in near future.
◊ Digital tach uses electronic recording on a smart card, and permits printouts of daily, weekly,

monthly info of date, time, names of drivers and inspectors, driving times, breaks, rest periods, standby times, start-finish times of all transportation-related activities.
◊ Authors concluded that few on-board technologies are available in the market designed specifically to capture Record of Duty Status (RODS) because they cannot record activity of driver while not in a driving mode, cannot distinguish between on-duty/not-driving and off-duty activities.
◊ Some European interest groups opposed to use (International Road Transport Union).

◊ **GPS pilot program** conducted 1995-1998, 2000 drivers, written logbooks used alongside GPS.
◊ System calculates driving time by determining time and distance between truck location updates not direct recordation of driving time.
◊ GPS operates on several algorithmic default assumptions B if vehicle idle >2 hours, system codes sleeper berth; if vehicle idle for <2 hours, driver status coded off-duty; no driving time recorded if truck and trailer travels <15 miles or tractor alone travels <25 miles; if driver fails to record how long on-duty not-driving, GPS automatically records default of 15 minutes for loading/unloading.
◊ Inspection and enforcement personnel can examine either display or printed hard copy of RODS.
◊ No FMCSA claims either supporting or opposing company claims about value or accuracy of RODS with GPS.
◊ However, Cambridge Systematics interviewed several FMCSA personnel about GPS pilot program.
◊ FMCSA personnel said that technology needed because commercial driver so not always accurately log on-duty times per regs and provide other economic/administrative benefits.
◊ FMCSA do not believe that there has been any documented improvements in compliance or safety due to GPS use in the pilot program.
◊ FMCSA personnel observed that 40% of HOS OOS citations were for no log or log not up to date, not falsified entries.
◊ FMCSA personnel cautioned that default assumptions governing GPS in pilot program could lead to an inaccurate picture of a driver's working time and total distance traveled.
◊ One FMCSA staffer questions accuracy of sleeper berth default judgment (two hours motionless vehicle).
◊ FMCSA personnel think GPS not enough, need use with other engine-related EOBRs.
◊Some GPS pilot program drivers found ways to tamper with data, compromise safety.
◊ FMCSA personnel admitted that some carriers don't want EOBRs because they regularly violated HOS limits, want to avoid enforcement.
◊ FMCSA personnel do not believe an EOBR mandate is imminent because, among other things, current Administration is pro-business.

◊ **UMTRI electronic recorder study** conducted 1998 on benefits/costs of EOBRs by interviewing major trucking organizations and independent owner-operators.
◊ Low response rate (1,200 responses of 10,000 distributed survey forms).
◊ Of respondents, only 175 use EOBRs.
◊ Multiple purposes of EOBR use, not just regulatory.
◊Larger firms = more common use.
◊ Private fleets use more than for-hire.

◊ 57 percent have HOS function for EOBRs.
◊ Only 37 fleets of 1,200 use EOBRs for HOS compliance and RODS tracking.
◊ But no for-hire and owner-operators used EOBRs for HOS compliance.
◊ EOBR buy/install $2,000 or less, <$200 annual operating costs.
◊ Fleets cite driver paperwork timesaving, better fleet management.
◊ Most carriers don't want them, won't get them.
◊ UMTRI authors concluded no economic benefits to EOBR use.

◊ **Transport Canada October 2001 Study EOBRs, Smart Cards, Digital Signatures** Phase 1 conducted with several national and provincial transportation agencies and one motor carrier.
◊ 16 companies providing EOBRs, smart cards, and digsigs evaluated.
◊ No company could prove that its technology could meet regulatory requirements.
◊ But part of problem is the lack of clear legal framework to tailor technical specs.
◊ Study (Phases 2-4) will proceed to other phases of actual in-service testing, specification of actual processes for recordation.