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Introduction

Commercial and public transportation has become an integral part of western societies ensuring that the flow of goods to consumers is uninterrupted. In Germany commercial trucking has drastically increased since 1993 when freight tariffs were deregulated causing an even greater shift from rail transportation to trucking with a forecast of the increase in trucking transportation from 1997 to 2015 by 60%[1]. Despite a reduction in overall weight of goods transported by trucking 2001 in Germany the ratio of distance per weight is steadily increasing[2]. Commercial and public transportation heavily relies on human operators.
A committee formed at the 1986 meeting of the Association of Professional Sleep Societies found that numerous performance failures leading to catastrophic events occur most often at times of day coincident with the temporal patterns of brain processes associated with sleep[3]. In addition, an investigation in the Netherlands showed that the highest accident rate in public transit accidents occurred in bus drivers who began an early work shift[4]. An assessment of the impact of sleep loss in commercial and public transportation is therefore needed.

To better understand the impact of sleep loss in transportation, we will examine the current evidence in the interaction between safety and sleep loss in road, rail, air, and marine which, in Europe, also includes inland navigation.

Factors responsible for accidents attributed to sleep loss

Investigations have shown that sleep loss has a significant impact on vehicular accidents. In this context the temporal distribution of single vehicle accidents within the 24-hour cycle plays an important role[5,6,7,8], meaning that vehicle operators are most susceptible to fatigue induced crashes in the early morning hours. Recent data published by the Federal Motor Carrier Safety Administration shows that 32% of all fatal large truck accidents occurred at night with 16.4% between 12am and 6 am and that 17% of all fatal large truck crashes constituted single-vehicle accidents[9]. Thus, it is not surprising that data from the largest over-the-road study involving commercial motor vehicle drivers in the US concluded that the strongest factor influencing driver fatigue and alertness was the time-of-day. Video observation of the drivers' (n=80) face indicated that drowsiness was markedly greater during nighttime. It was also shown that the drivers with less time asleep during their last sleep period were more likely to fall asleep during the middle of the night than the middle of the day[10].
The importance of hours-at-work was demonstrated by Hamelin who found that accident risk doubles when hours-of-work exceed the 11 hour limit[11] thus contributing to sleep loss.

Evidence for sleep loss in commercial and public transportation

A) Surface: Road commercial transportation
Based on the 1993 analysis of the Fatal Accident Report System (FARS) it was suggested that truck driver fatigue is a contributing factor in about 30 percent of heavy truck accidents. In 1990 the National Transportation Safety Board (NTSB) completed a study of 182 fatal-to-the-driver truck accidents to investigate the probable cause of the accidents. While the study was designed under the assumption that most fatal heavy truck crashes may be related to alcohol and other drugs, it was found that the most frequently cited probable cause was fatigue[12].

The NTSB then initiated a study of 113 single vehicle heavy truck accidents in which the driver survived. Information about the 96-hour-period prior to the crash were collected from 107 drivers. The analysis concluded that 58 percent of the accidents were fatigue-related. Eighteen percent of the drivers admitted having fallen asleep while driving[13]. This data was not based on anecdotal driver reports but on a multivariate analysis of a predefined set of factors, including measures of the drivers' duty, sleep times, rest times, road conditions, and weather conditions. The most critical factors in predicting fatigue-related accidents were the duration of the sleep period prior to the accident, the amount of sleep in the past 24-hour cycle, and the presence of split sleep patterns, i.e. daily sleep period split in two or more sections. Drivers participating in this study had an average of 2.5 hours shorter sleep period prior to the accident than drivers involved in nonfatigue-related accidents (5.5 vs. 8.0 hrs.). Overall, they also had 2.4 hours less sleep in the 24 hour period prior to the accident than drivers with nonfatigue-related accidents (6.9 vs. 9.3 hrs.). Interestingly, the data also suggest that there may be a relationship between driver compensation and fatigue-related truck accidents. Truck drivers in the US are paid by the mile driven while this payment modality is illegal in Europe. The results of experimental studies point in the same direction. A laboratory investigation of commercial driver sleep schedules (Balkin et al. 2000) was recently conducted in 66 drivers. They were monitored under varying bed times: 3, 5, 7 or 9 hours. The results showed that even a short reduction in the amount of average sleep lead to a measurable drop in performance measured as reaction time. The group with the lowest time in bed for 7 nights did not fully recover even after 3 consecutive nights of recovery sleep[14].

Surface: Road public transportation

It is logical that some or all contributing factors arising from driver fatigue in commercial trucking may also be applicable to the sector of public transportation. Although there is less data available on the impact of sleep loss and driver fatigue in public transportation, several reports suggest that fatigue may also play a considerable role.

For 2001 the FMSCA reported a total of 331 fatalities involving buses in the US. Several motorcoach accidents have prompted the NTSB in the past to conduct a thorough investigation into accidents where fatigue may have played a role.

In 1997 the NTSB investigated the crash of a 47-passenger motorcoach in Burnt Cabines, Pennsylvania which travelled off the road and crashed into the back of a parked tractor-semitrailer killing the busdriver and 6 passengers. The accident occurred at 4:05 am. It was concluded that contributing factors to the accident were an irregular 4 day work-rest cycle with sleep during the daytime aggravated by a known complaint of insomnia by the driver[15]. Two additional bus accidents prompted an investigation of selective motorcoach issues[16] involving driver fatigue as a significant contributor to the fatal accidents . It was concluded that inverted duty-sleep periods (1997 Rite-Way accident in Stony Creek) caused the bus driver to fall asleep and run off the road. Inverted duty-sleep schedules were defined as driving schedules calling for a period of rest on one day while scheduling a driving period during the same time on the following day.

B) Surface: Railroad

In 1990 the most common cause of railroad accidents for the first time was attributed to human factors. The NTSB reviewed data from the Federal Railroad Administration (FRA) for the period 1990 to 1999 and concluded that in “only” 18 cases causal or contributing factor to the incident was the operator falling asleep. This is thought to be an underestimation of the true contribution of fatigue to railroad accidents[17]. In a 1985 NTSB report it was concluded that railroad crews are subjected to the most unpredictable work/rest cycles in the transportation industry with a high level of duty start time variability[18]. This is also true for work/rest cycles of railroad crews in Europe. An investigation in the US found, that more human factors contributed to railroad accidents between 2 am and 6 am than in any other 4 hour segment of the 24 hour cycle[19]. A study in 198 locomotive engineers has revealed that one third of them work in duty/rest cycles shorter than 24 hours. This is associated with a report of less overall sleep and reduced sleep quality[20].

As for the other modes of transportation there are numerous investigative reports where falling asleep while on duty has caused railroad accidents. These include the 1997 collision of two Union Pacific Railroad trains in Delia, Kansas on July 2, 1997 and the collision of two Union Pacific Railroad trains near Navasota, Texas on October 29, 1997 where additionally alcohol intake may have contributed to the accident. A more recent accident killing 2 engineers of an oncoming train occurred in an area near Clarkston, Michigan on November 15, 2001. The engineer and train conductor of the train which caused the collision had previously diagnosed but untreated obstructive sleep apnea syndrome and fell asleep around 6 am. Their medical condition was not listed in their company’s medical record. While the primary feature of obstructive sleep apnea syndrome on sleep structure is sleep fragmentation and not necessarily sleep loss, this incident highlights the fact that medical conditions leading to alteration of normal sleep can be the cause for performance decrements on duty.

C) Aviation: Air Traffic Controllers (ATCs)

Fatigue in commercial an public air transportation can have catastrophic consequences as a result of ATC, pilot, and potentially aircraft maintenance engineer failure.

Research indicates that for ATC the potential dangers from shiftwork should receive most of the attention because it can cause a significant sleep debt, reduced alertness, and performance. This problem is particularly important during night shifts[21,22] where ATCs have reported increased sleepiness compared to the day shift and at the beginning of early morning shifts[23,24,25]. Similarly to sleep periods of pilots on duty (later in this chapter) studies have shown that unintentional sleep episodes can also occur in ATCs[26]. This was demonstrated using actigraph recordings in 9 USAF ATCs indicating significantly more sleep on the night-shift compared to day-shift. This should not mean that there are no problems associated with the day-shift as ATCs do not necessarily try to recuperate lost sleep by going to bed earlier when prior working on an early morning shift instead of having had off-duty days. Data from a study released 1996 showed that 5 consecutive daytime sleeps imbedded in shift work schedules result to a total loss of 10 hours of sleep. A comparison of day and evening sleep showed that more sleep was lost during evening sleep than during day sleep[27], possibly a result of the clock-dependent alerting function.

Aviation: Aircraft Maintenance Engineers (AMEs)
For Aircraft Maintenance Engineers (AMEs) the situation is even worse. In January of 2002 Rhodes and Associates published an assessment of Aircraft Maintenance Engineers (AMEs) hours-of-work for the Transportation Development Centre Transport of Canada. It concluded that AMEs are working an average of 50 hours per week, many extending 12-hour shifts, or working additional 12-hours shifts on days off[28]. The study was based on questionnaires in 1209 AMEs, and interviews of 12 AMEs. Study results showed that long working periods with very few days off for recovery are customary. AMEs from the airlines working extended night-shifts (longer than 12 hours) indicated significantly more fatigue during these shifts. 25 to 38 percent of airline AMEs reported having nodded off at the wheel, and 9 to 12percent actually fallen asleep at the wheel. AME napping is forbidden at major airlines, although unplanned naps are not uncommon at major airlines and general aviation facilities.

Aviation: Flight Crew
The problem of sleep loss in flight crews namely pilots is twofold. Firstly, sleep loss can by induced by individual hours of service and secondly through the impact of jet lag, which in its effect can be compared to the impact of shift work. With respect to flight operations, sleep loss, often referred to as fatigue, can have catastrophic consequences. This fundamental problem may be as old as the history of flying itself. During his transatlantic flight, Charles Lindbergh used his thumb to pry open eyelids heavy with sleepiness. He later reported about "ghostly presences" of others in the cockpit. The occurrence of hallucinations in severe sleepiness is common and was reported by many long-haul truck drivers who participated in a field study conducted in Utah in 1994[29]. As recently demonstrated, that inverted duty-sleep periods are of specific concern to public transportation this has been addressed in a study involving flight personnel[30].

Much of today's understanding about the underlying factors and consequences of fatigue in the field of aviation comes from research that has been conducted by the NASA Ames Research Center over the past 20 years. Early field studies were undertaken to document the existence of fatigue in flight operations. The results obtained from lab and field studies demonstrate that fatigue plays a major role in flight operations. This applies to short-haul operations where crewmembers have less sleep on trips, an increased difficulty falling asleep with the subjective sensation of lighter and less restful sleep[31]. Sleep loss and circadian rhythm disturbance from long-haul flights have been identified as major cause of fatigue in public and commercial flight operations. Although short-haul operations do not have to cope with the consequences of travelling across multiple timezones, they are characterized by long duty periods, multiple flight segments, and relatively long periods on the ground. Since it has been demonstrated that the most vulnerable flight phases are take-off and landing[32], multiple flights during one duty period may pose an increased risk for reduced performance and increased fatigue[33]. It has also been shown that overall sleep time is decreased on short-haul trip nights compared to pre-trip nights. This was also partially due to the fact that short-haul operators had to report earlier for duty. This loss in overall sleep time may cumulate during the trip and lead to sleepiness and performance impairment on duty[34]. Early trip onset has recently been documented to have detrimental effect on performance and wakefulness in automobile drivers[35]. It is not surprising that crew members consumed 1.5 times more caffeine during the trip than on pre-trip days. Consumption of this stimulant together with reduced sleeptime, and difficulties falling asleep on pre-trip days, may explain the increased amount of alcohol ingestion during trips, used as help to wind down. Together, sleep loss and late afternoon alcohol intake will have additive effects on daytime sleepiness[36] the following day.

Operational demands in long-haul operations across multiple timezones are different from those in short-haul operations. Duty cycles and layover periods are much longer. In addition multiple timezones are crossed desynchronising the 24-hour rhythm to which the circadian clock is synchronized. Sleep episodes on trips and total sleep within 24 hours are shorter than under pre-trip conditions[37]. Sleep patterns in long-haul crews show a split pattern with more than 1 episode of sleep within the 24-hour rhythm. During an 8-day long-haul trip to London 33% of crewmembers accumulated a cumulative sleep debt of 16 hours[37]. Although no safety-related incidents occurred during the observational studies, experimental studies have shown that a cumulative sleep debt this large is associated with reduced performance and shortened sleep onset time at MSLT[34,38]. Adverse effects on sleep and performance in long-haul flight crew crossing multiple timezones are more pronounced when the direction of the trip is eastward then westward[39]. Age may also play a role. Long-haul crew members are often older than crew members in the other operations. They tend to be morning type, an observation consistent with the effect of aging on morningness/eveningness and the notion that morning types have more difficulty adapting to changes in ciracadian timing[40]. Log books and observations in cockpits have shown that pilots are sometimes asleep in their cockpit seats[41]. Objective evidence of cockpit sleep also comes from objective in-flight monitoring of EEG showing that microsleep (longer than 5 sec.) can be feature of fatigue in long haul operations during landing[42].

As with other modes of transportation, evidence for fatigue-related accidents in aviation exist. In 1993 the NTSB concluded in its report regarding the loss of a Douglas DC-8 at Guantanamo Bay, Cuba, that the impaired judgement, decision-making, and flying abilities of the captain and flightcrew attributable to the effects of fatigue led to the accident[43].In a National Transportation Safety Board (NTSB) safety study of US major carrier accidents involving flight crew from 1978 to 1990, it was concluded that: "Half the captains for whom data were available had been awake for more than 12 hours prior to their accidents. Half the first officers had been awake for more than 11 hours. Crews comprising captains and first officers whose time since awake was above the median for their crew position, made more errors overall, and made significantly more procedural and tactical decision errors."[32]

D) Marine:

The nature of marine pilotage work is characterized by irregular work schedules where the entire 24-hour cycle is part of the schedule[44]. Thus, roughly 50% of marine pilot's workload falls into the night period. Rest periods are often far from home so that they need to be spent in hotels. Duty/rest periods are very variable and largely depend on the nature of the specific operation, the region in which those operations are carried out, and the company's system of assigning pilots to the task.
In 1996 a report was issued determining that 16 percent of critical vessel casualties and 33 percent of personnel injury casualties in US coastal waters during the second half of 1995, had some fatigue contribution[45].

Investigations of marine accidents has revealed that there is rarely a single factor which will cause an accident. Instead the accident is caused by a chain of events or decisions which, in their combination lead to the accident[46]. Based on the analysis of duty/rest cycles sleep loss is an important contributor to fatigue in maritime personnel. A survey of health, stress, and fatigue of Australian seafarers determined that 31 percent of pilots had an average of less than 4 hours sleep per day, while 65 percent had between 4 to 6 hours per day. Subjective perception of sleep quality showed that more than 50 percent of pilots in that study rated their sleep as fair, poor or very poor. This finding was in sharp contrast to more than 75 % of pilots sleeping between 7 and 8 hours in off-duty periods with sleep quality ratings between good and very good[47].

The grounding of the tankship Exxon Valdez in March 1989 highlights the extent of the damage that can result from catastrophic events involving fatigue or a combination between fatigue and alcohol intoxication. In this accident a combination of alcohol intoxication (master) and fatigue (third mate)[48] caused the ship to run aground on Bligh Reef of Prince William Sound spilling 11.2 million gallons of crude oil. While the loss of the tankship and cargo was estimated at about $30 million, the cost for the cleanup and reimbursements amounted to over $2 billion.

B. Hours-of Service Regulations

Each of the different transportation modes in the United States has its given regulations specifying maximum on-duty times and rest periods. Some of the regulations have been unchanged while others have been continuously updated. Regulations for motorcarrier operations were enacted in 1937 and virtually no changes have been made since. The Railroad Hours of Service Act from 1907 was revised in 1969, 1976, and again in 1988.

Aviation limits were addressed in the Civil Aeronautics Act of 1938 and the Federal Aviation Act of 1958. In 1985, domestic flight limitations and some commuter limitations were updated.

The work-hour regulations for marine are specified in Title 46 *United States Code* (U.S.C.) 8104 and date back to the early part of the 20th century. In 1997, work-hour regulations from the *Standards for Training, Certification, and Watchkeeping* of the International Maritime Organization became effective, requiring a minimum 10-hour rest period during any 24-hour period. The work and rest provisions for operators in the various modes are summarized in table 1–1. The regulations for aviation, highway, and some marine vessel types impose weekly work and rest limits. Only the aviation mode has monthly and annual limits as well. The maximum number of hours an employee of each mode is permitted to work in the course of a 30-day period is shown in figure 1–1. 4 A commercial pilot may fly up to 100 hours per month; a truckdriver may be on duty up to about 260 hours per month; licensed individuals on an oceangoing vessel or coastwise vessel of not more than 100 gross tons (GT) may operate up to 360 hours per month when at sea; and locomotive engineers may operate a train up to 432 hours per month.

Table 1. Hours of service regulations for the different transportation modes[49]

US - Motor Carrier (49 CFR Part 395)
• Drivers may drive for 10 hours or be on duty for 15 hours. • Drivers must have 8 consecutive hours off following a 10/15 hour on-duty period. • If drivers use a sleeper berth, they may split the 8-hour period into two periods as long as neither period is less than 2 hours. • Drivers may not exceed 70 hours in 8 days, if the carrier operates 7 days a week. • Drivers may not exceed 60 hours in 7 days if the carrier does not operate every day of the week.
US - Rail (49 U.S.C. 211; 49 CFR Part 228)
• Maximum duty limit of 12 hours. • Must be off-duty for 10 consecutive hours, after working 12 consecutive hours or off 8 consecutive hours if worked less than 12 consecutive hours. • Time spent in transportation (deadheading) to duty assignment counts toward on-duty time. • Time deadheading from duty assignment does not count toward on-duty or off-duty time.
US - Aviation (14 CFR Part 121; 14 CFR Part 135)
• Pilots flying domestic Part 121 operations may fly up to 30 hours per week, 100 hours per month, and 1,000 hours per year. • Pilots flying domestic Part 135 operations may fly up to 34 hours per week, 120 hours per month, and 1,200 hours per year. • If the scheduled flight time is less than 8 hours, the minimum rest period in the 24 hours preceding the scheduled completion of the flight segment is 9 hours. This time may be reduced to 8 hours if the following rest period, to begin no later than 24 hours after the commencement of the reduced rest period, is increased to 10 hours. • If the scheduled flight time is 8–9 hours, the minimum rest period in the 24 hours preceding the scheduled completion of the flight segment is 10 hours. This time may be reduced to 8 hours if the following rest period, to begin no later than 24 hours after the commencement of the reduced rest period, is increased to 11 hours.

• If the scheduled flight time is equal to or greater than 9 hours, the minimum rest period in the 24 hours preceding the scheduled completion of the flight segment is 11 hours. This time may be reduced to 9 hours if the following rest period, to begin no later than 24 hours after the commencement of the reduced rest period, is increased to 12 hours.

US - Marine (46 U.S.C. 8104; 46 CFR Parts 15.705, 15.710, and 15.1111)

• Hours-of-service or watch requirements vary depending on type of vessel.
• An officer must be off duty for at least 6 hours within the 12 hours immediately before leaving port before taking charge of the deck watch on a vessel when leaving port.
• On an oceangoing or coastwise vessel of not more than 100 gross tons (GT), a licensed individual may not work more than 9 of 24 hours when in port or more than 12 of 24 hours at sea, except in an emergency.
• On a towing vessel operating on the Great Lakes, harbors of the Great Lakes, and connecting or tributary waters between Gary, Indiana; Duluth, Minnesota; Niagara Falls, New York; and Ogdensburg, New York, a licensed individual or seaman in the deck or engine department may not work more than 8 hours in one day, except in an emergency.
• On a merchant vessel of more than 100 GT, the licensed individual shall be divided into three watches and shall be kept on duty successively to perform ordinary work incident to the operation and management of the vessel.
• On a towing vessel, an offshore supply vessel, or a barge that is engaged on a voyage of less than 600 miles, the licensed individual and crewmembers may be divided, when at sea, into two watches.
• On a fish processing vessel, the licensed individuals and deck crew shall be divided into three watches. However, if the vessel entered into service before January 1, 1988, and is more than 1,600 GT or entered into service after December 31, 1987, and has more than 16 individuals on board primarily employed in the preparation of fish or fish products, then the licensed individuals and deck crew shall be divided into two watches.
• On a tanker, a licensed individual or seaman may not work more than 15 hours in any 24-hour period or more than 36 hours in any 72-hour period, except in an emergency or a drill.
• On a fish tender vessel of not more than 500 GT engaged in the Aleutian trade, the licensed individuals and crewmembers shall be divided into at least three watches. However, if the vessel operated in that trade before September 8, 1990, or was purchased to be used in that trade before September 8, 1990, and entered into that trade before June 1, 1992, the licensed individuals and crewmembers may be divided into two watches.
• On a vessel used only to respond to a discharge of oil or a hazardous substance, the licensed individuals and crewmembers may be divided into two watches when the vessel is engaged in operation less than 112 hours.
• On a towing vessel operating in the Great Lakes, harbors, or connecting or tributary waters or a merchant marine vessel of more than 100 GT, a seaman may not work alternately in the deck and engine compartments, or be required to work in the engine department if engaged for deck department duty or required to work in the deck department if engaged for engine department duty. A seaman cannot be required to do unnecessary work on Sundays, New Year's Day, July 4, Labor Day, Thanksgiving day, or Christmas day, when the vessel is in safe harbor. When a vessel is in safe harbor, 8 hours is a day's work.
• Offices in charge of a navigational or engineering watch on board any vessel that operates beyond the boundary line shall receive a minimum of 10 hours rest in any 24-hour period. The hours of rest may be divided into no more than two periods, of which one must be at least 6 hours in length. The hours of rest do not need to be maintained in an emergency. The hours of rest may be reduced to 6 hours if no reduction extends beyond 2 days and not less than 70 hours of rest are provided in each 7-day period.

EU- Surface: Road and Rail VO (EWG) Nr. 3820/85

• time on driving duty between 2 rest periods may not be longer than 9 hours and can be extended to 10 hours no more than 2 times per week
• after a maximum of 6 driving duty periods a rest period of 45 hours must follow
• total driving duty may not exceed 90 hours in two weeks
• after a driving duty of 4.5 hr a break of at least 45 minutes has to be taken unless the driver starts a rest period
• these breaks can be substituted by 15 minutes breaks if they are taken during the driving duty
• during these breaks the driver may not engage in other than driving work-related tasks
• these breaks may not be applied to rest periods
• within a 24-hour period the driver has to take a rest period of 11 contiguous hours which can be reduced to no less than 9 hours for a maximum of three times per week
• rest time lost in reduced rest periods must be substituted by the end of the next week
• rest periods may be taken in a vehicle with sleeper berth if the vehicle is not in motion
• to ensure the safety in commercial and public transportation paid compensation for drivers may not be based on mileage driven or of the amount of goods transported

EU - Marine 2000/34/EG

• generally maximum daily hour-of-work of 8 hours
• the maxim number of daily hour-of-work may not exceed 14 hours within a 24 hour period and 72 hours in one week (7 days)
• rest periods may not be shorter than 10 hours within one 24-hours cycle and 77 hours within one week (7days)
• rest periods may not be split into more than 2 periods
• one rest period must have at least a duration of 6 hours. If 2 periods are choosen they must occur in a time frame of no longer than 14 hours
• 24 hours of rest per week and rest during holidays
• paid vacationtime of at least 4 weeks per year

EU – Aviation Ammendment of (EEC) No 3922/91

• Pilots may fly up to 60 hours per week, 190 hours in any 28 consecutive days, and 900 cumulative block hours (time from take-off to engine halt) per year.
• The maximum basic daily flying duty period is 13 hours
• The maximum daily flying duty period can be extended by up to one hour;
• Extensions are not allowed for a basic flying duty period of 6 sectors or more
• When an FDP with extension starts in the period 22:00 to 04:59 hours the operator will limit the flying duty period to 11.45 hours
• The Window of Circardian Low (WOCL) is the period between 02:00 hours and 05:59 hours. Within a band of three time zones the WOCL refers to home base time. Beyond these three time zones the WOCL refers to home base time for the first 48 hours after departure from home base time zone, and to local time thereafter.
• The minimum rest which must be provided before undertaking a flight duty period starting at base shall be at least as long as the preceding flight duty period or 12 hours whichever is the greater.

Synopsis

24-hour operations in the field of public and commercial transportation will automatically place operators at risk for sleep loss. This sleep loss mainly stems from a disruption of circadian biological rhythms due to the nature of the service around the clock. While human operator failure cannot be avoided entirely precautions must be taken to minimise the risk of accidents due to fatigue.

Numerous accidents which have occurred under the influence of operator fatigue have been documented by institutions such as the National Transportation Safety Board in the US. Some of these accidents have been described earlier in this chapter. As a result of these incidences extensive research has been conducted to address the factors involved in human operator fatigue. This research was mainly commissioned by federal institutions in United States and Canada. In Europe, little or no work has been commissioned to investigate underlying factors for human operator fatigue. Consequently, for many years new laws have been implemented in the US and Canada to reduce the risk of fatigue-related catastrophes while outdated regulations are still in effect in Europe. Therefore, it is not surprising that the latest implementation of hours-of-service regulations for European pilots, A5-0263/2002[50], has been heavily opposed by the European Cockpit Association.

Based on extensive research in the field of performance and sleep loss the only effective countermeasure to fatigue is sleep. Hours-of-service regulations have to take this fact into account and be tailored around it. Adequate rest periods with sleep are far more efficient to combat fatigue than tasks examining the fitness for duty. About 25 years ago Peter and coworkers have demonstrated that trained professionals can adapt to a paced secondary task enforcing wakefulness while being drowsy. The concept of sleep as countermeasure against fatigue has been implemented in long-haul flights of US pilots. Rosekind et al. have demonstrated that napping during long-haul flights is a proven measure to reduce microsleep episodes during the most vulnerable in-flight task of landing[42].

In aviation much consideration has been given to the maximum duration of duty periods. In Europe the amendment A5-0263/2002, which has recently been passed by the European Parliament, determines a maximum duty period of 14 hours for pilots. Therefore, the European Cockpit Association has argued that this maximum allowable period together with the mandated rest times may constitute a recipe for cumulative sleep debt. This suspicion is supported by the work of Hamelin who found that accident risk doubles when duty periods exceed 11 hours. Thus, this new EU regulation is weaker in its potential to prevent pilot fatigue than the old UK regulation was.

Hours-of-service regulations differ for the various modes of transportations. While in the US commercial truck drivers may be on driving duty for 10 hours (9 hours in Europe) commercial pilots may be on flying duty for up to 14 hours in Europe. This disparity does not make sense and therefore it can be concluded that hours-of-service regulations for the different modes of transportation are not based on the same principles of factors leading to fatigue. Overall duty period length may also be influenced by operator compensation. In any field should it be allowed to compensate for distance travelled. Public and commercial operators should not be tempted or rewarded for sleep loss. In Europe this problem has been identified where compensation for distance travelled is illegal.

Furthermore, rest is poorly defined. As earlier stated, sleep is the only effective countermeasure to fatigue/sleepiness. Rest needs to be redefined explicitly as sleep although it may be difficult to enforce.

Accident data shows a strong influence of time-of-day factors. Thus, hours-of-service regulations cannot only be based on the overall length of the duty period. Instead, they must include a careful consideration of the positioning of the duty period within the 24-hour cycle. In addition inverted duty-sleep periods need to be avoided. If operators are to work during their usual period of sleep enough lead time must be given to minimize the risk of sleep loss.

Finally, sleep disorders per se can have the same outcome on operator performance as sleep loss or alcohol intoxication. It does not make sense that commercial truck drivers must be screened for arterial hypertension but not for obstructive sleep apnea syndrome. The need for general screening of commercial and public operators for obstructive sleep apnea syndrome is highlighted by the fatal train accident in Clarkston, Michigan on November 15, 2001.

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