
Report on Results of Expert Panel Deliberations concerning
the Proposed Increase in the Working Window of
Elapsed Time from 16 Hours to 18 Hours for Inclusion in the
Proposed Canadian Commercial Vehicle Drivers
Hours of Service Regulations

Submitted to the

**Standing Committee on Compliance and Regulatory Affairs
of the
Canadian Council of Motor Transport Administrators**

November 2004

Report on Results of Expert Panel Deliberations concerning
the Proposed Increase in the Working Window of
Elapsed Time from 16 Hours to 18 Hours for Inclusion in the
Proposed Canadian Commercial Vehicle Drivers
Hours of Service Regulations

Expert Panel

Members

Ronald J. Heslegrave, PhD
Chair Research Ethics Board, University Health Network, University of Toronto

Claire Labèrge-Nadeau, MD, MAH, MSc, Public Health Specialist
Researcher, Department of Social and Preventive Medicine
Laboratory on Transportation Safety, Université de Montréal

Harvey Moldofsky, MD, Dip.Psych., FRCPC
Professor Emeritus, Faculty of Medicine, University of Toronto
Director of Sleep Disorders Clinic, Centre for Sleep and Chronobiology, Toronto

Adam Moscovitch, MD, FRCPC, DABPN, DABFM, DABSM
Medical Director, Canadian Sleep Institute
Associate Clinical Professor, Faculty of Medicine, University of Calgary

Alison Smiley, PhD, CCPE
President, Human Factors North

Chair

Sesto Vespa, P.Eng., MSc
A/Chief, Technology Applications, Transportation Development Centre, Transport Canada

Reporter

Wayne Rhodes, PhD, CPE
President, Rhodes and Associates

November 2004

This report reflects the views of the expert panel and not necessarily the official views or policies of Transport Canada.

EXECUTIVE SUMMARY

INTRODUCTION

Results are presented of a review conducted by an expert panel convened by the Transportation Development Centre (TDC) of Transport Canada to provide an expert scientific assessment of an elapsed time window duration of 18 hours when compared with the 16 hours currently contained in the proposed revisions to the Canadian hours of service (HOS), and to provide a recommendation on the preferred option to implement.

The mandate accorded to TDC was provided by the Standing Committee on Compliance and Regulatory Affairs (CRA) of the Canadian Council of Motor Transport Administrators (CCMTA). It resulted from a directive of the Council of Ministers to CCMTA “to conduct an objective evaluation of the impacts of the 18-hour window in consultation with all stakeholders, including drivers, and report back to the Council of Deputy Ministers in 60 days.” In response to this directive, the CCMTA Board directed CRA to undertake the task. CRA also provided TDC with a list of proposed members for the expert panel that it considered would encompass a balanced set of professional skills, knowledge and perspective (document titled *Hours of Service 18-Hour Window Impact Analysis Review – Terms of Reference*, dated 4 October 2004).

Because of the short time frame involved for CRA decision making, the Expert Panel was requested to report back to CRA with a written summary of its assessment, conclusions and recommendations by November 19th, followed by submission of the complete final report by November 26, 2004. The Expert Panel has already submitted its *Summary Statement on Results of Expert Panel Deliberations Concerning Options for Elapsed Time Window Duration in Proposed Canadian Hours of Service Regulations*, dated November 19, 2004. The present document is the final report of the Expert Panel.

HOURS OF SERVICE PROPOSAL CONSIDERED

The proposed Commercial Vehicle Drivers Hours of Service Regulations (Canada Gazette Part I, 15 February 2003) include a provision for a 16-hour working window of elapsed time since reporting for work after the last principal period of rest (which must be a minimum of 8 consecutive hours). The establishment of a working window prevents a driver from driving 13 consecutive hours at the end of one day immediately followed by 13 consecutive hours of driving at the beginning of the next day. Within this window, a driver may be on duty for 14 hours, of which 13 hours may be driving, and must take any additional off-duty hours required to meet the daily 10-hour off-duty provision. The Canadian motor carrier industry, through the Canadian Trucking Alliance (CTA), has requested that consideration be given to extending the currently proposed 16-hour working window by 2 hours, thus lengthening it to 18 hours. As a result, two options for the elapsed time working window are under consideration - 16 and 18 hours.

EXPERT PANEL REVIEW PROCESS

The expert panel held a number of teleconferences and had a one-day meeting to review and discuss the matter at hand and a package of related documentation and scientific/technical literature provided to them by the chair. A CCMTA Briefing Note (document titled *Briefing Note: National Safety Code Hours of Service, Council of Ministers and Deputy Ministers*, dated 10 September 2004) was also provided as background to the review and as a brief overview of two views on the issue. Further, the expert panel was provided with feedback on the two options from CCMTA Associate Members (document titled *CCMTA Driver Operating Window Impact Analysis, Summary of Feedback from Associate members*, by SHERCON Associates Inc., dated 17 November 2004) and from driver focus groups held across Canada (document titled *Hours of Service Focus Group Research, Report on Findings*, by ENVIRONICS Research Group, dated 15 November 2004). Additional documentation and scientific/technical material were developed and identified by the various expert panel members during the course of the teleconferences and the meeting. During the first teleconference, CRA representatives gave a presentation to the expert panel on proposed changes to the HOS regulations and answered questions on a variety of related matters. Particulars of the expert panel and the meeting are as follows:

Expert Panel

Members: Ronald J. Heslegrave, PhD
Chair, Research Ethics Board, University Health Network, University of Toronto
Claire Laberge-Nadeau, MD, MAH, MSc, Public Health Specialist
Researcher, Department of Social and Preventive Medicine
Laboratory on Transportation Safety, Université de Montréal
Harvey Moldofsky, MD, Dip.Psych., FRCPC
Professor Emeritus, Faculty of Medicine, University of Toronto
Director of Sleep Disorders Clinic, Centre for Sleep and Chronobiology, Toronto
Adam Moscovitch, MD, FRCPC, DABPN, DABFM, DABSM
Medical Director, Canadian Sleep Institute
Associate Clinical Professor, Faculty of Medicine, University of Calgary
Alison Smiley, PhD, CCPE
President, Human Factors North

Chair: Sesto Vespa, P.Eng, M.Sc.
A/Chief Technology Applications
Transportation Development Centre, Transport Canada

Reporter: Wayne Rhodes, PhD, CPE
President, Rhodes & Associates Inc.

Meeting

Date: November 19, 2004

Location: Transportation Development Centre (TDC)
Policy Group, Transport Canada
800 René Lévesque Blvd. West, Suite 600, Montréal, Quebec H3B 1X9

SUSTAINED WAKEFULNESS AND PERFORMANCE: A PERSPECTIVE FROM THE SCIENTIFIC LITERATURE

It has been reported for decades that sustained wakefulness leads to deterioration in human performance. One way of understanding the impact of fatigue on driver performance is to compare its effects with those of alcohol, about which we know a great deal. Three studies have examined the effect of sustained hours of wakefulness on performance and compared it to the effects of alcohol (Dawson and Reid, 1997; Lamond and Dawson, 1999; Arnedt, Wilde, Munt and MacLean, 2001; Williamson et al., 2001). This is a useful comparison given our extensive knowledge of crash risk in association with blood alcohol content (BAC) level. All three studies examined the same situation, in which participants had a good night's sleep and started performance testing in the morning. Eighteen to nineteen hours later, at 2:30 – 3:00 a.m., performance was equivalent to that found at 0.05% BAC; twenty to twenty-five hours later, performance was equivalent to that found at 0.10% BAC.

While it can be argued that these studies confound time of day and hours of wakefulness and that the maximum hours are reached at the beginning of the most unfavorable time period (the circadian low point of 2 – 6 a.m.), this situation is similar to that of drivers who start in the morning, commute to work, and work a 16-18 hour split shift. Therefore, drivers who follow this schedule would be expected to have performance deficits at the end of such a split shift.

Drivers who start in the evening will experience two negative impacts, the first from driving during the entire circadian low point, and the second from trying to sleep during the day. Scientific evidence demonstrates that the circadian effect is stronger than time-on-task effect (i.e., sustained wakefulness). Although drivers starting in the evening will not be awake as long when they reach the circadian low point as the subjects in the above studies, they will, however, be taking their sleep during the unfavorable circadian periods, resulting in a greater sleep debt than would be the case for the morning start drivers. Then, on the subsequent night, they will be driving during the circadian low point in a sleep-deprived state, which a National Transportation Safety Board study (1995) has indicated is an important risk factor for single-vehicle nighttime crashes.

For the former U.S. HOS regulations with a 10-hour driving time and a 15-hour duty time, surveys of 511 to 1,249 long distance drivers found 19-28% of drivers reporting falling asleep in the last month (Braver et al., 1992; Abrams, Shultz and Wylie, 1997). The current proposal would result in longer sustained hours of driving and longer elapsed times than governed drivers participating in these surveys. As another example, it should be noted that U.S. and Canadian drivers participating in a study in which they operated under the former U.S. HOS and the Canadian HOS, respectively, were tired (Wylie et al., 1996). These drivers had available, on average, approximately 8.6 to 10.7 hours of continuous off-duty time (excluding time required for study protocol related demands). These drivers were judged drowsy during about 4.9% of the total time period. About two-thirds of the drivers were judged drowsy during at least one time period, with about 82% of these drowsy time periods occurring between 19:00 and 06:59, and 11 drivers (14%) accounted for more than half (54%) of all observed drowsy periods.

CONCLUSIONS AND RECOMMENDATIONS

The Expert Panel strongly supports the preservation of the 24-hour day, which was a core, scientifically supported recommendation of both the Canadian and U.S. expert panels of 1998. The Expert Panel recognizes that a limitation on the elapsed time window is required that is consistent with the 24-hour day. The Expert Panel does not find any evidence to support an 18-hour window as consistent with safeguarding the health and safety of the driver and the public. Although the 18-hour window is worse than the 16-hour window, it should also be noted that neither the 18-hour nor the 16-hour split shift durations are supportable from human health and performance perspectives. However, considerable evidence does exist to show that long shifts such as considered under both options herein have an adverse effect on health, performance and safety. Industry operational problems and concerns (such as scheduling, loading and unloading delays, and sufficient accessibility to rest/sleep areas) need to be dealt with by industry and government through proactive measures and not through the use of extended split shifts.

Regarding driver health and public safety, the following issues, among others, are a concern with respect to the 18-hour split shift (i.e., window) option:

- It is not consistent with the 24-hour day, which was a core, scientifically supported recommendation of both the Canadian and U.S. expert panels of 1998.
- It pushes drivers, under all operational schedules that include the window, into using the midnight to 6 a.m. nighttime period at the start, middle or end of a shift. There was strong consensus by both the Canadian and U.S. expert panels of 1998, and which is confirmed by this Expert Panel, that driving during this time period of circadian low (with lower alertness and performance) should be minimized.
- Without the use of a sleeper berth, the additional two hours off duty is unlikely to be used for recuperative sleep.
- As a result of the aging population, sleep-related health problems will increase and thus many more drivers will be expected to experience problems working with the 18-hour split shift.
- Focus group drivers suggested this may increase falsification of logs, since the 18-hour window will allow more opportunities for falsification. On-board recorders, which would make it more difficult to violate the HOS, have not been included for consideration, although this should be addressed.
- It reduces incentives for industry to become more efficient, such as by reducing delays due to loading/unloading, scheduling, etc.

The following concerns should also be noted with respect to both the 16-hour and 18-hour window options:

- The Expert Panel is not aware of any studies that have directly compared the 16-hour and 18-hour windows; however, there are ample studies that show the deleterious effects on performance of these long hours of sustained wakefulness

- Although the HOS and related documentation reviewed by the Expert Panel speaks about – and uses – words such as “rest” and “off-duty”, it is essential to understand that these are sometimes misinterpreted in the context of fatigue and sleepiness. With respect to safety, the key issue is the actual amount of sleep obtained. Without sleeper berth or other appropriate sleeping facilities, there is the practical issue of transferring opportunities for rest into sleep. Proactive measures to address operational problems should be proposed which safeguard the health and safety of drivers and the public, rather than long split shifts
- Medications are being used more broadly in the general population. Some of these have an adverse effect on sleep and cognitive performance, which may increase the likelihood for health and safety risks.

With respect to health and safety, it must further be considered that truck driving is a relatively hazardous profession, with among the highest work-related fatality rates (U.S. Department of Labor, 2003). In this regard, the Expert Panel provides the following for further consideration by government and industry:

- We need to learn more about the prevalence and nature of workplace accidents attributable to driver health, which may be affected by long hours, and that may help lead to the development of effective countermeasures.
- We need to learn more about what commercial vehicle drivers are doing from the scheduling perspective. This is a necessary prerequisite to optimizing hours of service regulations in terms of efficiency, performance and safety.
- We need more data on driver health-related matters. We do not know, for example, about the use of drugs with sedating side effects nor stimulants designed to keep people awake but that may impair judgment. Another expert panel on medical issues should be struck to develop a comprehensive approach to proper monitoring and assessment of drivers for health- and sleep-related matters, including use of medications.
- We need to develop and implement fatigue risk management programs to deal more effectively with the overall issue of fatigue instead of strict reliance on regulatory prescriptive approaches.

ETHICAL AND PROFESSIONAL NOTICE

For ethical and professional reasons, it should be noted that the expert panel, based on the evidence presented herein, does not sanction either one of the options for elapsed time window duration (i.e., 16 and 18 hours), since it considers that both have potentially significant negative health and safety implications for drivers and the public.

TABLE OF CONTENTS

1. Introduction	1
1.1 Mandate	1
1.2 Hours of Service Proposal Considered	1
1.3 Expert Panel Review Process	2
2. Schedule Considerations	3
2.1 Hours of Service Provisions	3
2.2 Work/Rest Cycles under 16- and 18-Hour Windows	3
2.3 Issues Associated with 18-Hour Working Window	4
3. Sustained Wakefulness and Performance	7
3.1 Phase Shifting the Work/Rest Cycle	7
3.2 Extending the Time Awake	8
3.3 Impact of Sleep Debt	9
3.4 Use of the Off-Duty Period	10
3.5 Working Environment Practices	11
3.6 Wait Time	11
3.7 Impacts of Health, Age and Level of Fitness on Sleepiness	12
3.8 Impact of Long Split Shifts on Driver Health	12
3.9 Log Book Falsification	13
3.10 Increased Safety Risk	13
4. Conclusions and Recommendations	14
References	16
Figure 1 Example schedules demonstrating application of the 16-hour and 18-hour windows	5

Abbreviations

TDC - Transportation Development Centre
CRA - Standing Committee on Compliance and Regulatory Affairs
CCMTA - Canadian Council of Motor Transport Administrators
CTA - Canadian Trucking Alliance
SWS - slow wave sleep
REM - rapid eye movement
HOS - hours of service
BAC - blood alcohol content

1 INTRODUCTION

This report presents the results of a review conducted by an expert panel convened by the Transportation Development Centre (TDC) of Transport Canada to provide an expert scientific assessment of an elapsed time window duration of 18 hours when compared with the 16 hours currently contained in the proposed revisions to the Canadian hours of service (HOS), and to provide a recommendation on the preferred option to implement.

1.1 Mandate

The mandate accorded to TDC was provided by the Standing Committee on Compliance and Regulatory Affairs (CRA) of the Canadian Council of Motor Transport Administrators (CCMTA). It resulted from a directive of the Council of Ministers to CCMTA “to conduct an objective evaluation of the impacts of the 18-hour window in consultation with all stakeholders, including drivers, and report back to the Council of Deputy Ministers in 60 days.” In response to this directive, the CCMTA Board directed CRA to undertake the task. CRA also provided TDC with a list of proposed members for the expert panel that it considered would encompass a balanced set of professional skills, knowledge and perspective (document titled *Hours of Service, 18-Hour Window Impact Analysis Review – Terms of Reference*, dated 4 October 2004).

Because of the short time frame involved for CRA decision making, the Expert Panel was requested to report back to CRA with a written summary of its assessment, conclusions and recommendations by November 19th, followed by submission of the complete final report by November 26, 2004. The Expert Panel has already submitted its *Summary Statement on Results of Expert Panel Deliberations Concerning Options for Elapsed Time Window Duration in Proposed Canadian Hours of Service Regulations*, dated November 19, 2004. This document is the final report of the Expert Panel.

1.2 Hours Of Service Proposal Considered

The proposed Commercial Vehicle Drivers Hours of Service Regulations (Canada Gazette Part I, 15 February 2003) include a provision for a 16-hour working window of elapsed time since reporting for work after the last principal period of rest (which must be a minimum of 8 consecutive hours). The establishment of a working window prevents a driver from driving 13 consecutive hours at the end of one day immediately followed by 13 consecutive hours of driving at the beginning of the next day. Within this window, a driver may be on duty for 14 hours, of which 13 hours may be driving, and must take any additional off-duty hours required to meet the daily 10-hour off-duty provision. The Canadian motor carrier industry, through the Canadian Trucking Alliance (CTA), has requested that consideration be given to extending the currently proposed 16-hour working window by 2 hours, thus lengthening it to 18 hours. As a result, two options for the elapsed time working window are under consideration - 16 and 18 hours.

1.3 Expert Panel Review Process

The expert panel held a number of teleconferences and had a one-day meeting to review and discuss the matter at hand and a package of related documentation and scientific/technical literature provided to them by the chair. A CCMTA Briefing Note (document titled *Briefing Note: National Safety Code Hours of Service, Council of Ministers and Deputy Ministers*, dated 10 September 2004) was also provided as background to the review and as a brief overview of two views on the issue. Further, the expert panel was provided with feedback on the two options from CCMTA Associate Members (document titled *CCMTA Driver Operating Window Impact Analysis, Summary of Feedback from Associate members*, by SHERCON Associates Inc., dated 17 November 2004) and from driver focus groups held across Canada (document titled *Hours of Service Focus Group Research, Report on Findings*, by ENVIRONICS Research Group, dated 15 November 2004). Additional documentation and scientific/technical material were developed and identified by the various expert panel members during the course of the teleconferences and the meeting. During the first teleconference, CRA representatives gave a presentation to the expert panel on proposed changes to the HOS regulations and answered questions on a variety of related matters. Particulars of the expert panel and the meeting are as follows:

Expert Panel

Members: Ronald J. Heslegrave, PhD
Chair, Research Ethics Board, University Health Network, University of Toronto

Claire Laberge-Nadeau, MD, MAH, MSc, Public Health Specialist
Researcher, Department of Social and Preventive Medicine
Laboratory on Transportation Safety, Université de Montréal

Harvey Moldofsky, MD, Dip.Psych., FRCPC
Professor Emeritus, Faculty of Medicine, University of Toronto
Director of Sleep Disorders Clinic, Centre for Sleep and Chronobiology, Toronto

Adam Moscovitch, MD, FRCPC, DABPN, DABFM, DABSM
Medical Director, Canadian Sleep Institute
Associate Clinical Professor, Faculty of Medicine, University of Calgary

Alison Smiley, PhD, CCPE
President, Human Factors North

Chair: Sesto Vespa, P.Eng, M.Sc.
A/Chief Technology Applications
Transportation Development Centre, Transport Canada

Reporter: Wayne Rhodes, PhD, CPE
President, Rhodes & Associates Inc.

Meeting

Date & time: November 19, 2004, 09:00-16:30

Location: Transportation Development Centre (TDC)
Policy Group, Transport Canada
800 René Lévesque Blvd. West, Suite 600, Montréal, Quebec H3B 1X9

2. SCHEDULE CONSIDERATIONS

2.1 Hours of Service Provisions

The proposed Commercial Vehicle Drivers Hours of Service Regulations (Canada Gazette Part I, 15 February 2003) include the following provisions:

Daily Driving and On-duty Time

12. (1) No motor carrier shall request, require or allow a driver to drive and no driver shall drive after the driver has accumulated 13 hours of driving time in a day.

(2) No motor carrier shall request, require or allow a driver to drive and no driver shall drive after the driver has accumulated 14 hours of on-duty time in a day.

Mandatory Off-duty Time

13. (1) No motor carrier shall request, require or allow a driver to drive and no driver shall drive after the driver has accumulated more than 13 hours of driving time unless they take at least 8 consecutive hours of off-duty time before driving again.

(2) No motor carrier shall request, require or allow a driver to drive and no driver shall drive if more than 16 hours of time has elapsed between the conclusion of the most recent period of 8 or more consecutive hours of off-duty time and the beginning of the next period of 8 or more consecutive hours of off-duty time.

Daily Off-duty Time

14. (1) A motor carrier shall ensure that a driver takes and the driver shall take at least 10 hours of off-duty time in any day.

(2) Off-duty time other than the mandatory 8 consecutive hours may be distributed throughout the day in blocks of no less than 30 minutes each.

A 16-hour working window is built into these proposed rules. The CTA has requested that an 18-hour working window be considered. This would result in a 26-hour day.

2.2 Work/Rest Cycles Under 16- and 18-Hour Windows

For illustration purposes, the spreadsheet in Figure 1 provides schedules that show how the proposed HOS rules would work applying the 16-hour and 18-hour windows. These schedules are intended to show what the rules would allow rather than typical or representative schedules. They are not intended to illustrate all possible applications or all of the elements of the HOS regulations, but only those elements that were deemed essential by the expert panel to the deliberations herein.

Figure 1 shows that if a driver works to the maximum limits of the proposed 18-hour window, he/she, by comparison with the maximum limits under the 16-hour window, will:

- accumulate 88 shift-hours compared with 80 shift-hours after 5 days (look in column designated 'Day 5' and row designated "cumul shift hours" for the 18-hour and 16-hour window portions of Figure 1, respectively)

- start each day of the week 2 hours later rather than maintain the same start time as is possible with the 16-hour window (shift in start time each day is more disruptive to the physiology);
- accumulate fewer on-duty hours but longer split shifts, which will result in longer times awake if effective sleep cannot be obtained during the off-duty periods within the split-shift working window (shift structure is less efficient and more fatiguing from a human performance perspective);
- increase driving time during the vulnerable (from an alertness perspective) nighttime hours of midnight to 6 a.m.

These are serious limitations that must be weighed before considering adoption of an 18-hour working window.

2.3 Issues Associated With 18-Hour Working Window

Several provisions of the proposed HOS regulations are based on recommendations put forth by an expert panel constituted by Transport Canada that reviewed the hours of service rules and proposed options for changes (Vespa et al., 1998). These options included a core recommendation for a 24-hour work/rest cycle that would better allow drivers to work schedules that are more consistent with their physiology. A 24-hour cycle was also recommended by the U.S. expert panel on commercial drivers' hours of service (Transportation Research Institute, 1998) and has been incorporated in the current U.S. hours of service rules (U.S. Department of Transportation, 2003). This core recommendation was based on a solid scientific basis and should not be set aside.

The Canadian trucking industry has requested that the HOS regulations allow an additional 2 hours to be added to the cycle (i.e., allowing a 26-hour cycle), which would result in this core rule being abandoned. Its reasoning for such a change is based on accommodation for operational constraints unique to Canadian trucking operations (CCMTA, 2004):

- the duration of transit times for frequent routes (e.g., Toronto to Montreal), resulting in limited operating windows (12 to 13 hours of driving for two-way trips); and
- unpredictability of the duration of turnaround times and long waits at depots and border crossings

It must be considered, however, that moving to an 18-hour working window will cause the following effects on drivers:

- elimination of the opportunity for drivers to maintain regularity in their work/rest cycle;
- further disruption of circadian rhythms due to a two-hour shift in start times;
- extension of the working day by two hours, despite the fact that the present working day is considered by many scientists as already too long;
- unfounded expectations that drivers will be able to obtain useful sleep during waiting periods, in conditions that are not conducive for recuperative sleep; and
- increase in the amount of driving during the vulnerable nighttime hours (midnight to 6 a.m.), particularly worrisome when this occurs at the end of the driver's driving time.

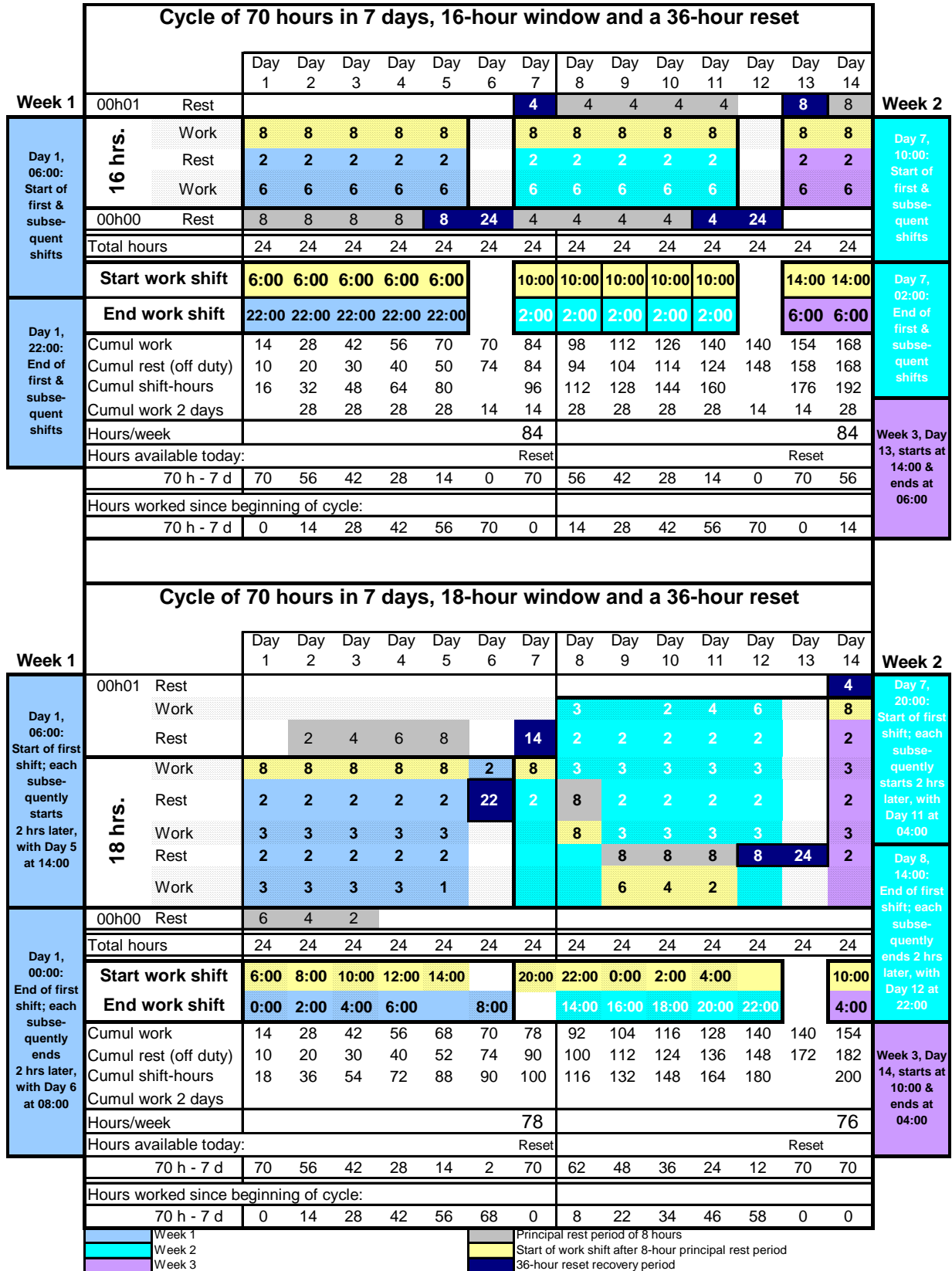


Figure 1: Example schedules demonstrating application of the 16-hour and 18-hour windows

These effects raise several important questions:

- Will the circadian disruption be a significant problem?
- Will the level of disruption expected under the 18-hour window be enough to affect performance to the point where it falls below acceptable standards?
- Will drivers be too sleepy at the end of their 18-hour window, including the period when driving home?
- Will drivers actually be able to obtain adequate recuperative sleep during the additional off-duty time to counter the longer time awake?
- Will the driver have access to adequate conditions to obtain sleep?
- What health consequences will result from the longer working window?
- How much recuperative sleep will drivers actually get prior to the on-duty time and during the working window?
- Is CTA's claim that drivers will be able to sleep while waiting for a load valid?
- Will ending a driver's driving in the early hours of the morning be a significant problem?
- Is it reasonable to think that keeping the 16-hour window will force shipping companies to do a better job of increasing operating efficiencies so drivers do not have to wait as long as they do now?
- How efficient can shippers become (i.e., what are the factors that determine their schedules)?

The expert panel considered these questions in light of the scientific literature, and the knowledge, experience and professional judgment of its members.

3. SUSTAINED WAKEFULNESS AND PERFORMANCE

3.1 Phase Shifting the Work/Rest Cycle

Rotating shifts that cause delays in the starting time for each subsequent shift can cause some *disrhythmia*, depending on the extent of the change in starting time (Folkard, 1996). Provisions 12 (1) and (2), 13 (1), and 14 (1) and (2) of the proposed HOS regulations attempt to maintain a 24-hour work/rest day, which allows drivers to maintain their circadian rhythms at their normal or near normal patterns. Provision 13 (2) provides some flexibility for companies to allow the driver to include time off due to loading and unloading delays. However, this provision allows drivers to work within the 24-hour work/rest cycle. This also allows the company and the driver to more easily regulate the schedule to conform to the biological rhythms of the driver. Drivers affected by these provisions would not be using sleeper berths, for which different rules apply. They also would be more likely to be driving long regular routes (i.e., a single two-way trip per day) or several short or medium-distance routes (more than one depot per day).

Although a number of these drivers would be driving at irregular times throughout the day, many would be able to maintain some regularity in driving times. For example, the depot could either dictate when drivers would be scheduled to load or unload, or arrange to have a load available at a particular time for the driver, according to when the driver was expected to arrive at the depot. The latter approach would allow a driver to maintain a regular sleep/wake cycle by making the trip to the depot the same time each day. The former approach would result in a more irregular sleep/wake cycle for the driver, causing more sleep loss and disruption of biological rhythms.

The 18-hour window will cause, at minimum, a 2-hour delay in the subsequent shift's start time. Also, the 18-hour window pushes a proportion of the driver's driving/on-duty time – as well as driving to work or home before or after the work shift – into the vulnerable period between midnight and 6 a.m. (the lowest point in the circadian rhythm and the time of lowest alertness). Driving performance at the time of lowest alertness is naturally lower than during the day (Wylie et al., 1996). Using objective measures, drowsiness is about eight times greater at night than during the day (Wylie et al., 1996). As the driver works more days, the finish time is advanced at least two hours each day. This means the finish time will occur well into early morning after just two or three days. Furthermore, this advancing schedule will continue throughout each work cycle. The driver's core sleep times will occur at increasingly later times each day. This may lead to reduced alertness near the end of each day's bout of driving. It should also be noted that the problem will still be of concern, regardless of finish time, due to the fact that in addition to circadian disruption and circadian effects, drivers may have been awake for a very long period by the end of their working day. It should also be recognized that drivers will be carrying a sleep debt, particularly if they have to sleep during the day. Daytime sleep is never as effective as nighttime sleep. Although the 18-hour window will cause forward shifting of the biological rhythms (i.e., delay the clock by at least two hours), which is less disruptive than shifting it in a backward direction (i.e., advancing the clock), the benefit will be overridden by the greater potential for increased sleep debt and having to remain awake longer. The amount of sleep debt for the 16-hour window will be less because drivers will be better able to obtain more nighttime sleep and will be less fatigued by ending their day sooner (i.e., not remaining awake for the extra two hours).

The 16-hour working window is not likely to result in a significant backward shift in biological rhythms since the drivers will be ending each day very near the 24th hour (8 hours of continuous off-duty time and 16 hours of split shift). Only marginal shifts in a backward direction will be expected. The greater opportunity for nighttime sleep and a shorter day will override any effect of circadian disruption.

3.2 Extending the Time Awake

The 16-hour working window will effectively allow drivers to remain awake for at least 16 hours before they will be able to take their 8-hour rest period, if they cannot sleep during the off-duty time occurring within the window. In reality, this would likely translate into at least 18 hours of being awake before being able to sleep (accounting for commuting to work, if applicable, meals, attending to personal hygiene, chores, etc. occurring before starting duty). The research comparing the effects of alcohol on driving performance and that of time awake all point to a performance level similar to that occurring with 0.05% BAC when subjects were awake for 18 hours (Lamond and Dawson, 1999; Williamson et al., 2001; Arnedt et al., 2001). Thomas et al. (2000) show that this reduction in performance is directly related to actual physiological changes in those parts of the brain that control alertness, attention and higher-order cognitive processes. The results of these studies demonstrate that the driver operating a vehicle after being awake for 18 hours would be performing as if he/she had a BAC of 0.05%. It is a likely scenario that the last hour or so of driving may be less acceptable with respect to public safety (i.e., more risky). Extending this working window to 18 hours could result in drivers operating their vehicles while having been awake for almost 20 hours or more. The research shows that a person operating a vehicle after being awake for more than 20 hours will be closely approaching levels of performance similar to that occurring while having a 0.08% BAC, the legal limit for allowable alcohol concentration in the blood. A driver operating the vehicle in such a state would be at an unacceptable level of risk, particularly if driving during the hours between midnight and 6 a.m. In addition, the driver is likely to already have a significant level of sleep debt, losing two to three hours of sleep each day (Wylie et al., 1996). This sleep debt will build with each day worked and will worsen the effects of long periods of wakefulness.

The research described above started the subject's day at 8 a.m. and ran the experiment up to 35 hours awake. The subjects were well rested prior to starting their period awake. Some circadian effect would be expected to occur after the subjects had been awake for about 15 to 16 hours. This would cause some accentuation of the drop in performance. However, the decrements found during the studies continued to drop even more after the nadir period (lowest point in the circadian rhythm or highest point in the pressure to sleep). Although daytime circadian effects would be expected to boost alertness slightly, starting the duty period at night would still result in significant performance decrements overall. For drivers working through the night and ending their driving in the daytime, the longer waking time of the 18-hour window and the additional effects of sleep debts occurring from daytime sleep will also result in significant reductions in driving performance. Driving through the night, the circadian low point that occurs between 2 a.m. and 6 a.m. will cause these drivers to experience a reduction in their performance at that time as well. Expanding the length of time a driver will need to be awake in any case will result in diminishing performance regardless of the driver's schedule. It should

also be noted that the Expert Panel that examined the Canadian industry proposal for single driver sleeper berth split rest also warned of the importance of not extending the day (Vespa et al., 2003).

3.3 Impact of Sleep Debt

The above research, which compares the effects of sustained wakefulness with those of alcohol, tested subjects who had obtained 7.5 to 8 hours of sleep prior to starting each session (Lamond and Dawson, 1999; Williamson et al., 2001; Arnedt et al., 2001). Most of the research on commercial drivers indicates average sleep periods as being considerably lower than the ideal sleep required to feel completely rested. In the Driver Fatigue and Alertness Study (Wylie et al., 1996), for example, although the drivers in the study reported an ideal sleep time of 7.2 hours, they obtained about 2 hours less time in bed and 2 ½ hours less actual sleep than their reported ideal daily sleep requirement. A very high correlation (0.95) has been found between the length of free time between shifts and sleep duration. Most shift schedules have 16 hours of free time between consecutive shifts, and at least this amount is needed for sleep duration of 7 or 8 hours (Kurumatani et al., 1994; Akerstedt, 1997). Increasing the number of very long shifts in a week can increase the chances for inadequate recovery from acquired sleep debt due to two related effects: cumulative sleep debt increases with the number of shifts, and duration of off-duty period available as opportunity for sleep decreases (Vespa et al., 1998).

Sleep debts up to 6-8 hours can be expected by the end of three or four days of irregular shifts of long duration. Shifting the time for the start of duty each day constitutes irregular work hours, and long duration involves anything beyond 12 hours. Adding the impact of circadian rhythms to a building sleep debt will result in higher levels of sleepiness. Continuing to work after being awake for over 18 hours while carrying a sizable sleep debt, and finishing the driving part of the day early in the morning, will result in decrements in performance much higher than those seen in the literature. As shown by Phillip et al. (2004), younger drivers will be affected by lack of sleep more than older drivers. Hence, the effects discussed above will be more acute for younger drivers.

Research on commercial driver sleep (Balkin et al., 2000) shows that although short-haul drivers obtained near normal levels of sleep (7 to 7.5 hours per night), long-haul drivers tended to obtain their sleep in multiple sleep bouts that left them somewhat sleep deprived while waiting for an opportunity to obtain restful sleep. If this sleep opportunity does not occur, the driver will be carrying a significant sleep debt. If the sleep opportunity occurs during the daytime hours, less restful sleep will be obtained, also leading to increasing sleep debt.

The research on the impact of sleep debt on performance shows that drivers perform significantly worse when carrying a significant sleep debt than when they are well rested. Wylie et al. (1996) found that increased sleepiness due to restricted prior sleep (average time in bed was 5.2 hours – at least 2 hours less than ideal) correlated to significantly poorer driving performance. Belenky et al. (2003) demonstrated through a dose-response study that restrictions in sleep do result in clear performance declines. The research found that the greater the restriction in sleep (i.e., sleep debt), the greater the decline in performance. Other researchers report similar results showing that drivers on long-haul trips often show high levels

of sleepiness near the end of the return leg. This increase in sleepiness is borne out in self-reports by drivers of their sleepiness while driving long-haul trips (Feyer et al., 1997).

3.4 Use of the Off-Duty Period

Napping prior to completing a shift of long duration would be necessary to reduce the risk, but would be only a temporary measure and may not be effective enough to reduce the risk to an acceptable level. The timing and duration of the nap would be critical (Dinges, 1989; Sallinen et al., 1998). The driver would need to obtain adequate sleep prior to completion of the trip. The time of day is an important factor affecting the ease in which this sleep could be obtained. The duration between the nap and the subsequent driving time is also an important factor, as is the length of the final period of driving. If the off-duty time is not conducive to obtaining adequate sleep, the risk will remain high.

The conditions for obtaining recuperative sleep while waiting for a place at the loading dock may be less conducive than in a rest area, and if done while seated in the cab, may be even less effective than in a sleeper berth, which drivers operating under this working window rule will not have available to them. Sleeping in a cab not equipped with a berth may be considerably less comfortable and more prone to noise. Dinges (1989) reviewed literature on napping environments and found that sleeping in chairs or a seat, rather than lying down in a bed, resulted in significant reductions in slow wave sleep (SWS) and rapid eye movement (REM) sleep, and increases in Stage 1 (light) sleep and the number of awakenings. This indicates that sleeping while seated does result in lower-quality sleep than obtained when lying down.

The minimum duration of effective napping appears to be about 10 minutes (Stampi, 1992; Horne and Reyner, 1996; Tietzel and Lack, 2000). Longer naps may cause the napper to enter into Stage 4 sleep (SWS), from which a higher chance of significant sleep inertia (sluggishness) would occur upon awakening, (Bruck and Pisani, 1999; Gil, 2001). This sleep inertia can persist for several minutes to an hour, depending of the length of the sleep, individual response and the specific stage of sleep awakened from. Longer sleeps require some planning to allow sleep inertia to dissipate before beginning to drive. The strategy a driver would follow to obtain restful sleep will depend on the sleeping conditions, time of day and amount of time available. The sleeping conditions should be quiet, comfortable, dark, and free of distractions and disturbances. Nighttime sleep is significantly better than daytime sleep (Dinges, 1989), and the timing of the sleep is very important. For example, napping between 6 p.m. and 8 p.m. is very difficult unless an individual is severely sleep deprived. This period of time is considered the “forbidden zone” for sleep (Lavie, 1992), while other times are more conducive to sleep.

3.5 Working Environment Practices

Morrow and Crum (2004) show that a number of industry practices, such as a strong safety culture, improved dispatcher scheduling practices, and company assistance with loading and unloading, can reduce incidents and risks for drivers. Shipping companies can help to support good practices by improving their turnaround times, reducing waits to minutes instead of hours, and providing adequate dock staff to handle the loading and unloading. They can also maintain a strong safety culture that includes consideration of the health and safety of drivers as well as their own workers.

Crum et al. (2002) assessed several scheduling factors that have an impact on driver sleepiness. The authors found that the most influential factors were:

- irregularity of the schedule;
- long duration of wait times and their unpredictability;
- starting the work cycle already sleepy (i.e., state of sleepiness);
- inadequate duration of uninterrupted sleep;
- irregularity of the route;
- irregularity of the driving times;
- driving during the nighttime hours;
- no assistance for unloading/loading;
- penalties for late delivery; and
- pressure to accept trips.

The move to an 18-hour window will likely contribute to all but the last three factors. The last three factors are likely some of the reasons that the 18-hour working window is under consideration.

3.6 Wait Time

Wait time appears to be one of the most critical factors influencing the desire to move to an 18-hour working window. At depots this often requires that the driver be at the wheel for the whole time, inching ahead every few minutes. The driver would, under the rules, be considered on duty for the whole time. No actual sleep would be possible during this time. In most cases, once the truck was loaded, the driver would be obliged to head to the home or terminal depot to meet imposed deadlines. Alternatively, the driver might plan to have a sleep before heading back to the home depot. This would allow him/her to be alert by the end of the trip, which may occur in the early morning hours. But this would also depend on the availability of adequate accommodations to allow useful sleep.

In another scenario, the driver may be told to leave and come back later to load or unload. This of course begs the question as to where the driver can go to get some useful sleep. The driver may be able to get a 10-minute nap sitting up in the cab. This type of sleep would only have limited benefit. Scientists (Dinges, 1989; Horne and Reyner, 1996; and Stampi, 1992, for example) have shown that a 10-minute nap, taken when sleepy, will help an individual maintain their existing performance level for another hour or so. But then performance will begin to

rapidly drop off. This type of nap could be taken an hour or so prior to arriving at the home depot but would be ineffective if taken any sooner, such as prior to leaving the terminal depot. A much longer sleep would be necessary to help a driver extend the day and arrive alert at the home depot near the end of the 18-hour working window. However, obtaining good quality sleep of longer duration will require that the driver find a bed to sleep in at an appropriate accommodation (i.e., comfortable bed, no disturbances, etc.).

Another example involves crossing the U.S.-Canada border in a lengthy process that will probably become even lengthier in the near future once new U.S. home security legislation is implemented. Unfortunately, drivers will not be able to obtain sleep during these times. The usual situation is that the driver move up every few minutes in a queue. In such a case the driver will be considered on duty during this time and will not be able to sleep. Any dozing during this time would essentially be ineffective as a countermeasure.

3.7 Impacts of Health, Age and Level of Fitness on Sleepiness

The previous discussions assume that the driver is healthy and fit. Less fit drivers will be less able to obtain adequate good quality sleep during their principal sleep period, and will be more prone to sleepiness. Drivers who suffer from sleep disorders such as sleep apnea, insomnia, or other disorders will have a more difficult time remaining alert (George, 2004; Howard et al., 2004) and may not be able to effectively sleep in less ideal conditions (e.g., in the seat of the cab, during the daytime hours). They may be able to fall asleep very quickly at times, but will have difficulty remaining asleep or may obtain fitful sleep (Broughton, 1989). The result will be increased sleepiness as the day continues.

Although younger drivers (18 to 30) are likely to be healthier than older drivers, younger drivers can fall asleep more easily, and are more susceptible to dozing when sleep deprived (Pack et al., 1995).

3.8 Impact of Long Split Shifts on Driver Health

Working long days and irregular hours with little time to obtain enough restful sleep does lead to health problems (Costa, 1996; Wedderburn, 2000; Spurgeon, 2003). Personnel who experience these kinds of working patterns have higher incidents of:

- cardiovascular disorders and diseases;
- gastro-intestinal disorders;
- depression; and
- colds, flu, infections.

Some research has found that lack of sleep results in a suppression of the immune system (Spurgeon, 2003). Reduced immune response puts the individual at a higher risk of infection, which can lead to more diseases and disorders compared with the rest of the population.

3.9 Log Book Falsification

The increase of the working window to 18 hours may provide a greater opportunity for log book falsification. The results of the focus groups (Environics, 2004) show that drivers are of the opinion that the increased time for “rest” provided by the 18-hour window will provide more opportunity for drivers to falsely report driving time as “rest” time. There is a strong likelihood for such violations to occur, given the reality that exists. In the U.S., McCartt et al. (1998) found that 43% of drivers admitted to the fact that they often or always drive more than what their logs show. The Insurance Institute for Highway Safety found that more than 60% of drivers falsify their logs (Braver et al., 1992).

3.10 Increased Safety Risk

The effects described in sections 2 and 3 will contribute to an increase in the safety risk that the trucking industry poses to its drivers and the public. This becomes an even greater concern when considering the movement of hazardous materials and the potential for disastrous outcomes.

4. CONCLUSIONS AND RECOMMENDATIONS

The Expert Panel strongly supports the preservation of the 24-hour day, which was a core, scientifically supported recommendation of both the Canadian and U.S. expert panels of 1998. The Expert Panel recognizes that a limitation on the elapsed time window is required that is consistent with the 24-hour day. The Expert Panel does not find any evidence to support an 18-hour window as consistent with safeguarding the health and safety of the driver and the public. Although the 18-hour window is worse than the 16-hour window, it should also be noted that neither the 18-hour nor the 16-hour split shift durations are supportable from human health and performance perspectives. However, considerable evidence does exist to show that long shifts such as considered under both options herein have an adverse effect on health, performance and safety. Industry operational problems and concerns (such as scheduling, loading and unloading delays, and sufficient accessibility to rest/sleep areas) need to be dealt with by industry and government through proactive measures and not through the use of extended split shifts.

Regarding driver health and public safety, the following issues, among others, are a concern with respect to the 18-hour split shift (i.e., window) option:

- It is not consistent with the 24-hour day, which was a core, scientifically supported recommendation of both the Canadian and U.S. expert panels of 1998.
- It pushes drivers, under all operational schedules that include the window, into using the midnight to 6 a.m. nighttime period at the start, middle or end of a shift. There was strong consensus by both the Canadian and U.S. expert panels of 1998, and which is confirmed by this Expert Panel, that driving during this time period of circadian low (with lower alertness and performance) should be minimized.
- Without the use of a sleeper berth, the additional two hours off duty is unlikely to be used for recuperative sleep.
- As a result of the aging population, sleep-related health problems will increase and thus many more drivers will be expected to experience problems working with the 18-hour split shift.
- Focus group drivers suggested this may increase falsification of logs, since the 18-hour window will allow more opportunities for falsification. On-board recorders, which would make it more difficult to violate the HOS, have not been included for consideration, although this should be addressed.
- It reduces incentives for industry to become more efficient, such as by reducing delays due to loading/unloading, scheduling, etc.

The following concerns should also be noted with respect to both the 16-hour and 18-hour window options:

- The Expert Panel is not aware of any studies that have directly compared the 16-hour and 18-hour windows; however, there are ample studies that show the deleterious effects on performance of these long hours of sustained wakefulness

- Although the HOS and related documentation reviewed by the Expert Panel speaks about – and uses – words such as “rest” and “off-duty”, it is essential to understand that these are sometimes misinterpreted in the context of fatigue and sleepiness. With respect to safety, the key issue is the actual amount of sleep obtained. Without sleeper berth or other appropriate sleeping facilities, there is the practical issue of transferring opportunities for rest into sleep. Proactive measures to address operational problems should be proposed which safeguard the health and safety of drivers and the public, rather than long split shifts
- Medications are being used more broadly in the general population. Some of these have an adverse effect on sleep and cognitive performance, which may increase the likelihood for health and safety risks.

With respect to health and safety, it must further be considered that truck driving is a relatively hazardous profession, with among the highest work-related fatality rates (U.S. Department of Labor, 2003). In this regard, the Expert Panel provides the following for further consideration by government and industry:

- We need to learn more about the prevalence and nature of workplace accidents attributable to driver health, which may be affected by long hours, and that may help lead to the development of effective countermeasures.
- We need to learn more about what commercial vehicle drivers are doing from the scheduling perspective. This is a necessary prerequisite to optimizing hours of service regulations in terms of efficiency, performance and safety.
- We need more data on driver health-related matters. We do not know, for example, about the use of drugs with sedating side effects nor stimulants designed to keep people awake but that may impair judgment. Another expert panel on medical issues should be struck to develop a comprehensive approach to proper monitoring and assessment of drivers for health- and sleep-related matters, including use of medications.
- We need to develop and implement fatigue risk management programs to deal more effectively with the overall issue of fatigue instead of strict reliance on regulatory prescriptive approaches.

ETHICAL AND PROFESSIONAL NOTICE

For ethical and professional reasons, it should be noted that the expert panel, based on the evidence presented herein, does not sanction either one of the options for elapsed time window duration (i.e., 16 and 18 hours), since it considers that both have potentially significant negative health and safety implications for drivers and the public.

REFERENCES

- Akerstedt, T. (1997). *Readily Available Countermeasures Against Operator Fatigue*. American Trucking Associations Foundation, International Conference Proceedings, Managing Fatigue in Transportation, April 29-30, Tampa, Florida, 105-122.
- Abrams, C., Schultz, T., and Wylie, C. (1997) *Commercial Truck Driver Fatigue, Alertness, and Countermeasures Survey*. Report MC-99-067, Washington DC; Federal Motor Carrier Safety Administration.
- Arnedt, J., Wilde, G., Munt, P., and MacLean, A. (2001) *How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task?* *Accident Analysis and Prevention*, 33 (3): 47-54.
- Balkin, T., Thome, D., Sing, H., Thomas, M., Redmond, D., Wesensten, N., Williams, J., Hall, S., and Belenky, G. (2000) *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance*. FMCSA report DOT-MC-00-133, Washington DC; Federal Motor Carrier Safety Administration.
- Belenky, G., Wesensten, N., Thorne, D., Thomas, M., Sing, H., Redmond, D., Russo, M., and Balkin, T. (2003) *Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose study*. *J. of Sleep Research*, 12:1-12.
- Braver, E., Preusser, C., Preusser, D., Baum, H., Beilock, R., and Ulmer, R. (1992) *Who Violates Work-Hour Rules? A Survey of Tractor-Trailer Drivers*. Arlington, VA: Insurance Institute for Highway Safety FMCSA Docket No. 1992-2350-273.
- Broughton, R. (1989) *Sleep attacks, naps, and sleepiness in medical sleep disorders*. In Dinges, D., and Broughton, R. (eds.) *Sleep and Alertness: Chronobiological, Behavioral, and Medical Aspects of Napping*. New York; Raven Press.
- Bruck, D., and Pisani, D. (1999) *The effects of sleep inertia on decision-making performance*. *Journal of Sleep Research*, 8: 95-103.
- CCMTA (2004) *Briefing Note: National Safety Code Hours of Service. Minister's agenda item 7 d) i) September 10, Ottawa; Canadian Council of Motor Transport Administrators*.
- Canada Gazette (2003) *Proposed Changes to the Commercial Vehicle Drivers Hours of Service Regulations, Part I, 15 February 2003*.
- Costa, G. (1996) *Shiftwork: Effects on Health and Well-being*. In Colquhoun, W.P., Costa, G., Folkard, S., and Knauth, P. (eds.) *Shiftwork: Problems and Solutions*. New York; Peter Lang.
- Crum, M., Morrow, P., and Daeker, C. (2002) *Motor Carrier Scheduling Practices and Their Influence on Driver Fatigue*. FMCSA report no. FMCSA-RT-03-005, Washington DC; Federal Motor Carrier Safety Administration.

- Dawson, D., and Reid, K. (1997) *Fatigue, Alcohol, and Performance Impairment*. Nature, 388: 235.
- Dinges, D. (1989) *Napping patterns and effects in human adults*. In Dinges, D., and Broughton, R. (eds.) *Sleep and Alertness: Chronobiological, Behavioral, and Medical Aspects of Napping*. New York; Raven Press.
- Environics (2004) *Hours of Service Focus Group Research: Report on Findings*. Ottawa; Canadian Council of Motor Transport Administrators.
- Feyer, A-M., Williamson, A., and Friswell, R. (1997) *Balancing work and rest to combat driver fatigue: An investigation of two-up driving in Australia*. Accident Analysis and Prevention, 29 (4): pp. 541-53.
- Folkard, S. (1996) *Biological disruption in shiftworkers*. In Colquhoun, W.P., Costa, G., Folkard, S., and Knauth, P. (eds.) *Shiftwork: Problems and Solutions*. New York; Peter Lang.
- George, C. (2004) *Sleep 5: Driving and automobile crashes in patients with obstructive sleep apnoea/hypopnoea syndrome*. Thorax, 59 (9): 804-807.
- Gil, V. (2001) *Analysis and Interpretation of Polygraphic Sleep Recordings of Overnight Sleep and Two Hour Recuperative Nap*. DCIEM CR-2000-146, Downsview; Defence and Civil Institute for Environmental Medicine.
- Horne, J., and Reyner, L (1996) *Counteracting driver sleepiness: Effects of napping, caffeine, and placebo*. Psychophysiology, 33: 306-309.
- Howard, M., Desai, A., Grunstein, R., Hukins, C. Armstrong, J., Joffe, D., Swann, P., Campbell, D., and Pierce, R. (2004) *Sleepiness, sleep disordered breathing and accident risk factors in commercial vehicle drivers*. American Journal of Respiratory Critical Care Medicine, 170: pp. 1014-1021.
- Kurumatani, N., Koda, S., Nakagiri, A., et al. (1994). *The Effects of Frequently Rotating Shiftwork on Sleep and the Family Life of Hospital Nurses*. Ergonomics, 37. 995-1007.
- Lamond, N., and Dawson, D. (1999) *Quantifying the performance impairment associated with fatigue*. Journal of Sleep Research, 8: pp. 255-262.
- Lavie, P. (1992) *Circadian Regulation: Ultradian Components*. In Stampi, C. (ed.) *Why We Nap*, Boston; Birkäuser: pp. 102-117.
- Morrow, P., and Crum, M. (2004) *Antecedents of fatigue, close calls, and crashes among commercial motor-vehicle drivers*. Journal of Safety Research, 35 (1): 59-69.

National Transportation Safety Board (1995) *Safety study – Factors that affect fatigue in heavy truck accidents: Volume 1, analysis*. Report no. NTSB/SS-95/01, Washington, DC; National Transportation Safety Board.

Pack, A.I., Pack, A.M., Rogman, E., Cucchiara, A., Dinges, D., and Schwab, C. (1995) *Characteristics of crashes attributed to the driver having fallen asleep*. *Accident Analysis and Prevention*, 27 (6): 769-775.

Phillip, P., Taillard, J., Sagespe, P., Valtat, C., Sanchez-Ortuno, M., Moore, N., Charles, A., and Bioulac, B. (2004) *Age, performance, and sleep deprivation*. *Journal of Sleep Research*, 13 (2): pp. 105-110.

Sallinen, M., Härmä, M., Åkerstedt, T., Rosa, R., and Lillqvist, O. (1998) *Promoting alertness with a short nap during a night shift*. *Journal of Sleep Research*, 7: pp. 240-247.

Spurgeon, A. (2003) *Working Time: Impact on Safety and Health*. Geneva; International Labour Organization.

Stampi, C. (1992) *The effects of polyphasic and ultrashort sleep schedules*. In Stampi, C. (ed.) *Why We Nap*, Boston; Birkäuser: pp. 137-179.

Thomas, M., Sing, H., Belenky, G., Holcomb, H., Mayberg, H., Dannals, R., Wagner, H. Jr., Thorne, D. Popp, K., Rowland, L., Welsh, Balwinski, S. and Redmond, D. (2000) *Neural basis of alertness and cognitive performance impairments during sleepiness. I. Effects of 24 h of sleep deprivation on waking human regional brain activity*.

Tietzel, A.J., and Lack, L.C. (2000) *The recuperative value of brief and ultra-brief afternoon naps*. *Sleep*, 25: pp. A117-A118.

Transportation Research Institute (1998) *Potential Hours-of-Service Regulations for Commercial Drivers, Report of the Expert Panel on Review of the Federal Highway Administration Candidate Options for Hours of Service Regulations*. Office of Motor Carriers, Federal Highway Administration, U.S. Department of Transportation, DTFH61-96-C-00038, Task Order Number 3, 10 September 1998.

U.S. Department of Labor (2003) *Census of Fatal Occupational Injuries*. Washington, DC; Bureau of Labor Statistics, U.S. Department of Labor.

U.S. Department of Transportation (2003) *Federal Register – Part II – 49 CFR Parts 385, 390, and 395: Hours of Service of Drivers; Driver Rest and Sleep for Safe Operations; Final Rule*. Washington DC; Federal Motor Carrier Safety Administration.

Vespa, S., Rhodes, W., Heslegrave, R., Smiley, A., and Baranski, J. (1998) *Options for Changes to Hours of Service for Commercial Vehicle Drivers*. TDC report TP 13309E, Montréal; Transportation Development Centre of Transport Canada.

Vespa, S., Wylie, D., Mitler, M., and Shultz, T. (1998) *Study of Commercial Vehicle Driver Rest Periods and Recovery of Performance in an Operational Environment*. Managing Fatigue in Transportation: Proceedings of the 3rd Fatigue in Transportation Conference, Fremantle, Western Australia; Hartley, Laurence (editor).

Vespa, S., Rhodes, W., George, C., Lebèrge-Nadeau, C., and Moldofsky, H. (2003). *Report on Results of Canadian Expert Panel Deliberations Concerning Canadian Industry Proposal for Single Driver Sleeper Berth Split Rest*. Montréal; Transportation Development Centre of Transport Canada.

Wedderburn, A. (2000) *Shiftwork and Health*. BEST European Studies on Time series, Luxembourg; European Foundation for the Improvement of Living and Working Conditions.

Williamson, A., Feyer, A-M., Mattick, R., Friswell, R., and Finlay-Brown, S. (2001) *Developing measures of fatigue using an alcohol comparison to validate the effects of fatigue on performance*. Accident Analysis and Prevention, 33 (3): pp 313-326.

Wylie, C., Shultz, J., Miller, M., Mitler, M., and Mackie, R., (1996) *Commercial Motor Vehicle Driver Fatigue and Alertness Study: Final Report*. FHWA-MC-97-002. Washington, D.C.; Federal Highway Administration / TP 12875E, Montreal; Transportation Development Centre of Transport Canada.