REVISED ESTIMATES OF THE U.S. DROWSY DRIVER CRASH PROBLEM SIZE BASED ON GENERAL ESTIMATES SYSTEM CASE REVIEWS

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ABSTRACT

A revised estimate of the incidence of crashes involving driver drowsiness/fatigue is provided based on analysis of General Estimates System (GES) data and a review of 562 GES cases from 1993. Cases selected for review had coded characteristics suggesting a "Drift-Out-Of-Lane" scenario but were not cited as drowsiness-related in GES. The case review identified some "definite," "probable," and "possible" drowsy driver crashes not captured by the normal GES data coding process. It indicated that drowsiness/fatigue is a discernible causal factor in 1.2 to 1.6% of Police Accident Reports, as compared to the baseline GES estimate of 0.9%.

The annual incidence of crashes known to be related to driver drowsiness, fatigue, or "asleep-at-the-wheel" was 56,000 for the years 1989-93 based on General Estimates System (GES) data Knipling and Wang, 1994]. This was 0.9% of the average total of 6.3 million police-reported crashes occurring annually during this five year period.

Police Accident Report (PAR)-based estimates of the involvement of drowsiness/fatigue in crashes, such as those provided by GES, are widely regarded as conservative [e.g., National Commission on Sleep Disorders Research, 1993]. Knipling and Wang (1994) summarized several reasons for regarding such estimates as conservative. Reporting practices for the citing of driver drowsiness on the PAR vary from state to state. Regardless of the state's reporting format, drowsiness may be

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underreported due to a lack of firm evidence upon which to base a police finding. Officers may be unaware of the role of drowsiness in the crash or may regard available evidence as circumstantial and not verifiable. Crash-involved drivers themselves may not be aware of the role that drowsiness played in their crashes and thus may not report it to police when interviewed.

Even if drowsiness is indicated on a PAR, either in a check-off box or the narrative, there is a chance that the factor will be missed by the GES data coder. These data coders review PARS obtained from 26 different states, each with their own format and coding practices. For each crash case, they complete data forms consisting of 90 variables with thousands of possible elements (data values). Since drowsiness is just one element of the coding regimen, it is reasonable to expect that even the most conscientious data coders will miss some known drowsiness cases. Finally, GES requires that a case be explicitly cited as drowsiness-related on the PAR for it to be coded as such in the GES file. Less objective criteria, such as the inclusion of crashes that appear to be drowsiness-fatigue-related based on conditions of occurrence, crash trajectories, and the elimination of other possible factors, are not practicable in this type of data system.

The current effort was undertaken to examine selected GES cases to identify drowsiness-related crashes not captured by GES coding, and to derive a revised estimate of the size of the drowsy/fatigued driver crash problem size based on this analysis. A specific impetus for the study was a crash problem size analysis in New South Wales (NSW), Australia [Fell, 1994]. Fell used broadened, "inclusive" criteria for the identification of drowsiness-related crashes. Crashes were classified as drowsiness-related if either of two criteria were met: 1) driver drowsiness was cited on the PAR (the traditional "narrow" criterion of crash data files), or 2) the pre-crash maneuver of the vehicle "suggest[ed] loss of concentration by the controller [driver] due to fatigue." The latter category included all lane departures not related to other known contraindicating maneuvers (e.g., passing, evading another crash threat) or causal factors (e.g., excessive speed). Under the specified conditions of the second criterion, drowsiness was deemed by default to be a causal factor in the crash.

Based on the two alternate criteria, fatigue was implicated in 6% **of all** crashes, 15% of fatal crashes, and 30% of rural fatal crashes occuring in New South Wales in 1992. These statistics contrast sharply with U.S. national statistics (e.g., the 0.9% statistic from GES for all crashes) and have been widely publicized in the U.S. with the implication that they better capture the true magnitude of the drowsy driver crash problem [e.g., Pack, 1994; Brady, 1994; Recer, 1994; AAA Foundation for Traffic Safety, 1995; National Sleep Foundation, 1995].

Inclusive definitions such as that used by Fell offer the possibility of capturing drowsiness-related crashes that are "missed" by drivers themselves, police, or data coders. On the other hand, they run the risk of being over-inclusive by including crashes which superficially "look like" drowsiness-related crashes but which in fact are due to awake inattention or other non-drowsiness crash causes. This concern is exacerbated by the known diversity of causal factors involved in lane departure (e.g., single vehicle roadway departure and head-on) crashes [Najm et al, 1995]. Clearly there is a need to differentiate target from non-target crashes within the conditions/ trajectory-defined subgroup.

The current analysis employs a conditions/trajectory-defined criterion, similar as that used by Fell in NSW, to identify candidate U.S. GES crashes for inclusion as drowsy driver crashes. Two different candidate groups were defined and identified based on two different degrees of similarity to the classic "drift-out-of-lane" scenario characteristic of drowsy driver crashes. None of these candidate crashes was cited as drowsiness-related in GES. Subsequent analyses compared the statistical profiles of these crashes to comparable drowsiness-cited crashes, and then, most importantly, reviewed individual case PARs to discern any salient association with drowsiness, either stated or implied by circumstance. Thus, the methodology attempts to replicate the NSW approach using U.S. data and three methodological refinements: use of two different subgroups of candidate crashes rather than one, comparison of the statistical profiles of comparable drowsiness-cited and non-drowsiness-cited crashes, and review of individual PARs to identify apparent causal factors.

METHODS

The major steps in the current analysis were as follows:

1. Definition **and** Quantification. Candidate target crash subsets were defined by conditions of occurrence and trajectory, and their average annual problem sizes for the years 1989-93 were determined. There were two subgroups of these drowsiness-not-cited @NC) crashes: "pure" and "other" Drift-Out-Of-Lane (DOOL) crashes; they are defined below.

2. Statistical Comparison. The statistical profiles of DOOL/DNC crashes were compared to DOOL/drowsiness-cited crashes to assess the degree **of** similarity between the two subgroups.

3. Case Review. Individual candidate PARs were reviewed to ascertain the percentage that were "definitely, " "probably, ' or "possibly" drowsiness-related. (Note: Quotations are used around these adjectives to reinforce the fact that these were judgmentally assigned based on available information rather than determined through a quantitative analysis of probabilities.) The authors reviewed 185 "pure" DOOL/DNC case files and 377 "other" DOOL/DNC case files. Case samples for review were random samples of 1993 GES PARs. The 185

"pure" DOOL/DNC cases represented 20% (unweighted) of the 1993 total of such cases while the 377 "other" DOOL/DNC cases represented 12%. An implicit assumption was made that these samples were representative of all 1989-1993 GES cases meeting their respective definitions. The 562 PARs were each reviewed and classified into one of 11 causal factor categories using the taxonomy provided in the Appendix. This taxonomy emphasizes the assessment of the role of driver loss-of-alertness (LOA) in crashes, including LOA due to drowsiness, "awake" inattention (e.g., distraction), and physiological causes (e.g., seizures, heart attacks). Cases were each reviewed by two different analysts (the authors) who discussed questionable cases before arriving at a final classification.

4. Revision **of National Estimates. The** percentages obtained from Step 3 were applied to existing national problem size estimates to obtain revised target crash problem size estimates. Since the taxonomy included categories that were "definite" and less-than-definite ("probable" or "possible") in relation to drowsiness, the revised problem size estimates are stated here as ranges rather than point estimates.

RESULTS

DEFINITION AND QUANTIFICATION. Figure 1 presents a Venn diagram of three similar and overlapping GES crash subpopulations, defined as follows:

Drowsiness-Cited. Crashes in which drowsiness was cited as a crash factor (1989-93 average: 56,000)

All Drift-Out-Of-Lane (DOOL) Crashes. Crashes characterized by an apparent "drift-out-of-lane" (DOOL) scenario; i.e., single vehicle roadway departure or encroachments into the oncoming traffic lane (resulting in head-on or opposite-direction crashes) where there was no coded "active" pre-crash maneuver (e.g., stopping, starting, turning, changing lanes, merging, passing, avoiding other crash threat). GES data for 1989-93 indicate that in the years 1989-93 there were an annual average of 934,000 such crashes.

"Pure"-DOOL Crashes. Crashes meeting the above and several additional criteria: the driver was the only occupant of subject vehicle, no alcohol/drugs cited, speed limit between 45-65mph, no violation charged which would imply alert driving (e.g., reckless driving), dry surface, clear weather, no vehicle defects, and no coded avoidance maneuver (e.g., braking or steering) before impact. For the purposes of this report, these crashes are termed "pure-DOOL" crashes; there were an average of 71,000 such crashes in 1989-93.

Figure 1 shows the degree to which these three crash subpopulations overlap. Of course, the pure-DOOL crashes are a subset of all DOOL crashes. The drowsiness-cited category (56,000) is much smaller than the overall DOOL category (934,000) and smaller even than the pure-DOOL category (71,000).

Of interest are several crash subsets defined in relation to the above s&populations: Pure-DOOL/drowsiness-cited: 9,000; Pure-DOOL/DNC 62,000; Other-DOOL/drowsiness-cited: 31 ,000; Other-DOOL/DNC: 832,000; Non-DOOL/drowsiness-cited: 16,000; Non-DOOUDNC (i.e., all other crashes): 5,350,OOO. The sum of these categories represents all police-reported crashes: 6.3 million annually.

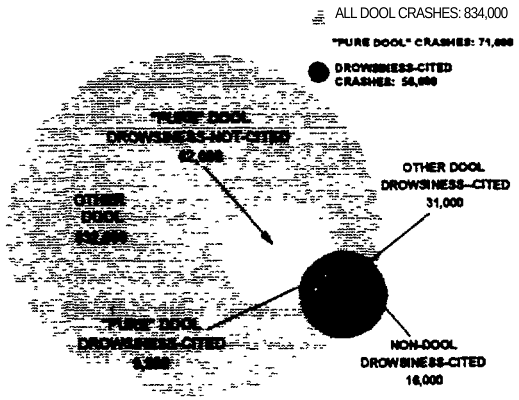

Figure 1. **Drowsiness-Cited and Drift-Out-Of-Lane Crashes (1989-1993 Annual Average)**

A crash typology similar to the above was presented in Knipling and Wang (1994). However, the current conditions/trajectory-defined groups are based on slightly more restrictive definitions; specifically, GES Accident Type 12 (single vehicle strikes stationary object in the roadway) was excluded from the current analysis. Thus, the conditions/trajectory-defined crash subpopulations of this analysis are slightly smaller than those of Knipling and Wang (1994).

STATISTICALCOMPARISON. Drowsiness might seem to be a reasonable default causal explanation for pure-DOOL crashes, even when it is not cited on the PAR and captured by GES data variables. One test of this supposition is to examine the diurnal (24-hour) distribution of these crashes, since daily periods of drowsiness and associated accidents are predictable based on circadian cycles [Office of Technology Assessment, 1991]. If the two crash subgroups (pure-DOOL/drowsiness-cited versus pure-DOOLJDNC) were in fact equally related to drowsiness, they would likely have similar time-of-day frequency distributions.

Figure 2 shows time-of-day distributions for four crash subgroups: pure-DOOL/drowsiness-cited, other-DOOL/drowsineas-cited, pure-DOOL/DNC, and other-DOOL/DNC. Distributions for the two drowsiness-cited categories are nearly identical and show the predicted circadian pattern of sleepiness, peaking sharply in the early morning with a smaller peak in the mid- to late-afternoon. In contrast, both classes of DNC crashes were more evenly distributed throughout the 24-hour day. The pure-DOOL/DNC class shows a Peak in the afternoon rush hour between 16:00 and 18:59. The other-DOOL/DNC class shows the least 24-hour. variation of the four classes; its broad peak begins in the late afternoon and extends through the evening.

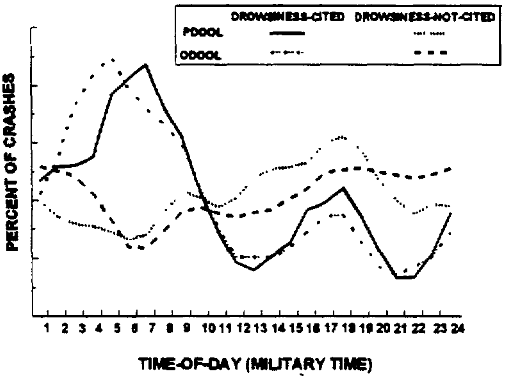

Figure 2. **Time-of-Day Comparison Between "Drowsiness-Cited" and DNC Pure and Other DOOL Crashes: 3-Hour Rolling** *Averages.* **Source: 1989-93 GES**

Other statistical characteristics of the pure-DOOL drowsiness-cited and pure-DOOL/DNC crash categories were compared. Notable differences were found. A greater percentage of the DNC crashes occurred on curves. in non-urban areas, and involved control/traction loss. A smaller percentage of the DNC crashes occurred on divided highways and involved a male driver. Regarding travel speed, a larger percentage of pure-DOOL/DNC crashes involved travel speeds significantly above the roadway speed limit, even though, by definition, no speed-related traffic violation was charged. Finally, a larger proportion of the pure-DOOL/DNC crashes were found to be slope rollovers, while a smaller proportion were tracking/fixed object crashes, a finding consistent with a larger role of speeding on curves and on rural two-lane roads in the DNC subgroup [Viner, 1995].

Analogous statistical comparisons between of the two other-DOOL crash subgroups were not made since these subgroups are by definition more heterogeneous and thus could be expected to be even less similar to each other.

CASE REVIEW. The case review determined the principal causal factors of the 185 pureDOOL/DNC and 377 other-DOOL/DNC crashes. Results **are** shown **in Table 1.** **The** values shown are <u>weighted</u> percentages of each sample where each case's **weight** reflects the number of U.S. crashes it represents according to the GES case sampling and weighting scheme **[NHTSA, 1992].** **These** case weights can vary dramatically; in the current sample they ranged from 2 to 311.

Table 1: Alertness/Attention-Related Causal Breakdown of Pure and Other DOOL/DNC Crashes Based on PAR Case Review
(Note All percentages are weighted based on GES case national weights; LOA = Loss-of-Alertness; Shaded areas are regarded as definitely, probably, or possibly drowsiness-related and are used to determine revised problem size estimates.)

Principal Causal Factor Category	*Pure DOOL (N=185)* Weighted %	*Other DOOL (N=377)* Weighted
Drowsiness/Fatigue (Definite/Highly Probable)	9.3%	1.3%
Drowsiness/Fatigue (Probable)	0.4%	0.0%
Physiological (Definite/Highly Probable)	6 8%	1.1%
Physiological (Probable)	0.0%	0.2%
Awake Inattention (Definite/Highly Probable)	12.6%	5.2%
Awake Inattention (Probable)	16.6%	6.3%
Unspecified Inattention/LOA (Definite/Highly Probable)	1.1%	0.4%
Unspecified Inattention/LOA (Probable)	4.4%	1.2%
Other Principal Cause(s) (Definite/Highly Probable)	26.0%	52.7%
Other Principal Cause(s) (Probable)	17.9%	26.0%
Unknown/Insufficient Information to Classify	4.7%	5.6%
Total	99.8%	100.0%

Table I shows that 9.3 % of the pure-DOOL sample were "definitely" drowsiness-related (dark-shaded row). An additional 5.9% fell into categories (see the light-shaded rows) which could be considered probably or possibly drowsiness related: drowsiness probable (0.4%); unspecified inattention/ definite (1.1%); and unspecified inattention/probable (4.4%). Thus, the estimated percentage contribution of drowsiness as a principal crash causal factor discernible from PARs for the pure-DOOL/DNC sample is 9.3% to 15.2 %.

The second column of percentages in Table 2 shows similar data for the 377 cases of the other-DOOL/DNC sample. Based on the case review. I .3 % of this sample were "definitely" drowsiness-related. An additional 1.6% fell into categories which could be considered probably or possibly drowsiness related: drowsiness probable (0.0%); unspecified inattention/definite (0.4%): and unspecified inattention/probable (1.2%).

No cases were reviewed from the largest subpopulation of crashes: i.e., non-DOOL/DNC crashes. Although-some of these crashes are undoubtedly drowsiness-related, the percentages are likely quite small and thus a huge number of cases would need to be reviewed to obtain reliable e&mates. Instead of directly estimating the number of such cases through case review, an extrapolation method was used (see below).

Note the large percentages of "awake inattention" and "other principal causes" in Table 1. **Awake** inattention-related crashes were most often associated with distraction due to objects or people inside the vehicle or to aspects of the roadway environment. **A key defining** characteristic of crashes with "other principal causes" was an active driving maneuver or behavior such as a lane-change or evasive maneuver not apparently caused by driver LOA. Often these active maneuvers and behaviors are not captured in the GES data coding. Speeding, either over the speed limit or "unsafe for conditions" was frequently noted, even when no speeding violation was charged. Another key characteristic of crashes classified in the "other principal causes" category was the lack of any narrative or trajectory-related data implying that the crash was LOA-related. In general, it was found that crashes in the "other principal causes" category did not have "drift" trajectories at ah; rather they had loss-of-control trajectories that were related to unsafe vehicle movement (e.g., speed) or to some unexpected event.

Also note that the pure- and other-DOOL/DNC crashes were dramatically different from each other in their principal causal factors. A majority (51.2%) of the pure-DOOUDNC crashes "definitely" or "probably" involved some form of LOA (i.e., drowsiness, physiological, awake inattention, or unspecified) versus only 15.7% of the other-DOOL/DNC crashes. This finding demonstrates the value of separating these two subgroups for the purposes of analysis.

REVISION OF NATIONAL ESTIMATES. Revised GES estimates of the drowsy driver crash problem size were obtained by applying the case review percentages to the national totals from Figure 1. Three crash categories **were** addressed and **are** shown **in Table 2:** pure-DOOL, other-DOOL, and non-DOOL. For the pure-DOOL crashes, recall that 9.3% to 15.2% of the pure-DOOL/DNC sample was judged to be drowsiness-related. Applying these percentages to the 62,000 annual crashes in this subpopulation yields an estimated 6,000 to 9,000 additional drowsy driver crashes. Similarly, 1.3 to 2.9% of the other-DOOUDNC sample was drowsiness-related. Applying these percentages to the 832,000 annual crashes in this subpopulation yields an estimated 11,000 to 16,000 additional drowsy driver crashes. Although the drowsiness-relevant percentages for the other-DOOL/DNC sample are much smaller than for the pure-DOOL/DNC sample, this category actually contributes more new drowsiness crashes to the revised estimate due to the huge sire of this subpopulation.

Table 2: Summary of Categories of Estimated Annual Known and Possible drowsiness-Related Crashes Based on the 1989-93 GES and the Estimation Procedures Described

Certainty: Crash Trajectory Category	"GES-Baseline" Drowsiness-Cited Crashes	Drowsiness-Not-Cited	
		"Definitely" Drowsiness-Related	Probably/Possibly Drowsiness-Related
Pure-DOOL	9,000	6,000	4,000
Other DOOL	31,000	11,000	13,000
Non-DOOL	16,000	6,000	7,000
TOTAL	56,000	23,000	24,000

If resources permitted, one could extend the same procedure applied to non-DOOL drowsiness-not-cited crashes. This would represent the remainder of the crash universe -- 5.35 million crashes annually for 1989-93. Extending the procedure to non-DOOL crashes would likely result in the identification of some additional drowsiness-related crashes, but was impractical because of the expected low percentages involved and thus the huge number of cases which would need to be reviewed.

Nevertheless, it is probable that some such non-DOOL/DNC -- but still drowsiness-related – cases exist. To estimate their number, the obtained proportions of definite-to-baseline and probable/possible-to-baseline percentages for the other-DOOL crashes were applied to the non-DOOLcrashes. ‘The other-DOOL category was chosen as the basis for the extrapolation because these crashes are likely to be the most similar (of those in this study) to the non-DOOL crashes. Applying the other-DOOL proportions of additional cases to the baseline values, the estimates of 6,000 additional “definite” non-DOOL crashes (i.e., 16,000 * 11,000/31,000) and 7,000 additional probable/possible cases (i.e., 16,000 * 16,000/31,000) were obtained. These estimates, shown in Table 2, must be regarded as very rough estimates.

Combining the three categories of row estimates in Table.2 yields totals of 79,000 “definite” (56,000 + 23,000) and 24,000 additional probable/possible drowsiness-related crashes. Thus, a revised estimate of the annual number of drowsiness-related crashes is 79,000 to 103,000 annual crashes or 1.2 to 1.6 % of the national annual average of 6.3 million police-reported crashes for 1989-93. The fact that the revised estimate is stated as a range rather than a point estimate reflects the uncertainty of many PAR descriptions of these crashes.

DISCUSSION

Two major conclusions are drawn. First, the review of the individual case files of selected candidate drowsiness-&ted crashes has documented the fact that some such crashes are indeed drowsiness-related; therefore, current baseline GES estimates underestimate the size of the problem. Specifically, the actual incidence of drowsiness as a discernible factor in crashes based on GES PARs is estimated to be 1.2 to 1.6 % as compared to the baseline estimate of 0.9%. On the other hand, the analysis has shown that estimates derived from blanket "inclusive" crash definitions based on crash trajectories and conditions of occurrence [e.g., Fell, 19943 are likely to exaggerate the role of drowsiness in lane departure crash scenarios. **Such candidate crashes** differ in their statistical characteristics (e.g., time of occurrence) from comparable drowsiness-cited crashes, and the vast majority of them are either verifiably related to non-drowsiness crash causes or contain no positive indication, either in the narrative or the crash trajectory schematic, that drowsiness was involved in the crash. Problem size estimates of the drowsiness crash problem size cannot be refined by simply adding subset(s) of crashes defined based on coded **crash** conditions and trajectories.

The causal heterogeneity of the pure-DOOL/DNC subgroup is not surprising given the number of different causal factors known to be involved in single vehicle roadway departure and opposite direction (e.g., head-on) crashes. Summary statistics presented in Najm et al [1995] indicate that these two crash types are the most diverse **of all** major crash types in terms of principal causal factors.

The 79,000 to 103,000 (1.2 to 1.6%) estimate is admittedly more inferential and provisional than GES size estimates for other crash problems which arc more well-defined and easily-identified. However, it is based on a systematic t-e-examination of GES data and is consistent with the results of other broad-sample studies of the percentage incidence of drowsiness as a principal causal factor in crashes. For example, statistics from the 1982-84 National Accident Sampling System (NASS) Continuous Sampling Subsystem (CSS) indicated that 1.5 percent of the 3 1,000 crashes investigated were drowsiness-related. These medium-depth NASS CSS investigations included PAR reviews, vehicle inspections, scene inspections, and driver interviews. The NASS CSS sample, like the current GES sample, was obtained from numerous sampling locations nationwide and was rigorously nationally-representative. Rnipling and Wang (1994) reviewed several other U.S. studies employing broad crash samples (in terms of crash locations, crash types, and/or vehicle types) and found that all yielded percentage estimates of between one and four percent for the incidence of drowsiness as a principal causal factor in crashes. Some other studies have yielded much higher percentage estimates, but they have involved narrow, high-risk crash subpopulations and/or inclusive target crash definitions.

This report has addressed the general population of U. S. police-reported motor vehicle crashes, of which there are approximately 6.3 million annually. However, other crash populations should be addressed to truly characterize the drowsy driver crash problem. One such crash population is non-police-reported (NPR) crashes. Fewer than one-half of all crashes are police-reported [Miller, 1991], and virtually nothing is known about the causes and other characteristics of these crashes. On the one hand, it seems plausible that a larger percentage of NPR crashes are drowsiness-related because many known drowsy driver crashes involve only a single vehicle and occupant -- the driver [Knipling and Wang, 19943. When such crashes do not cause debilitating injuries and/or vehicle damage, drivers may be inclined to leave the scene without reporting the incident to police. On the other hand, the known incidence of driver drowsiness in crashes is strongly ~~inversely~~ related to crash severity. The baseline GES percentages of drowsy driver crashes for 1989-93 for various KABCO crash severity levels (i.e., the most seven: injury in the crash) are as follows: fatal (K), 3.2%; incapacitating injury (A), 2.5%; non-incapacitating injury (B), 1.9%; possible injury (C), 0.7%; and no injury/property damage only (0), 0.6%. Based on the current case review findings and a simple assumption of proportionality to police-reported no-injury/property-damage-only crashes (see Wang and Knipling, 1994 for a more detailed explanation of the methodology), the annual number of NPR drowsiness-related crashes can be estimated to be between 67,000 and 89,000. This estimate assumes that the probability of drowsiness-related crashes beiig reported to police is the same as other crash types. If in reality this probability is significantly lower, then the estimate is conservative.

A subpopulation of crashes (both police-repotted and NPR) of priority importance for studies of drowsiness is those involving combiion-unit trucks [NTSB, 1995; Knipling and Wang, 1994]. Trucks and truck drivers have huge levels of mileage exposure relative to passenger cars and their drivers, and their long work hours and, for some, irregular work schedules put them at greater risk. The current methodology could be applied to truck crashes with the caveat that truck drivers may be less candid in their statements to police regarding crash causes. They may be more motivated to avoid any admission of culpability in a crash because of possible adverse economic consequences.

A crash subpopulation of paramount importance is fatal crashes. Data retrievals from the 1989-93 FARS indicated that drowsiness was cited as a factor in an annual average of 1,357 fatal crashes annually, representing 3.6% of all fatal crashes [Knipling and Wang, 1994]. As noted above, the comparable GES estimate for 1989-93 fatal crashes was 3.2%. The concerns already discussed about the accuracy of crash data apply to fatal crashes, with the added concern that many fatal crashes involve only one vehicle and only one person -- the fatally injured driver. Police must often speculate regarding crash causes based on conditions of crash occurrence (e.g., time-of-day), pre-crash vehicle trajectory (ii discernible based on physical evidence), other known causal factors (e.g., alcohol, slippery roads), and witness reports when available. Obviously, considerable conjecture is involved in these determinations. The current methodology could be applied to fatal crashes, but with a similar caveat to that expressed regarding heavy trucks. In the case of fatal crashes, there are likely to be no possible statements from the involved driver(s).

This analysis has addressed the special difficulties of assessing the drowsy driver crash problem. The GES case reviews identified crashes where drowsiness was manifest in the crash description; i.e., where it was cited as a factor and/or the crash trajectory and conditions of occurrence suggested its involvement. This approach cannot transcend the limits of the information contained in PARs but does purport to exhaust the information available in PARs relevant to determining driver pre-crash alertness. Of course, PAR reviews cannot capture subtle effects of fatigue, such as when fatigue predisposes an awake driver to fail to perceive a crash threat or properly judge a traffic situation.

Two current NHTSA data gathering efforts should provide additional insights into the role of driver inattention and drowsiness in crashes. First, the agency is currently using the more in-depth investigative capability of the NASS Crashworthiness Data System (which includes post-crash interviews with drivers) to obtain more information on this and related driver inattention-related crash causes. The 1995 CDS data collection regimen includes a data variable specifically addressing the role of driver inattention, including both drowsiness and many forms of distraction. These statistics will become available in late 1996.

Secondly, the agency is developing a capability to apply a more technological and empirical approach to assessing the driver attention/alertness issue. This approach will involve the use of sophisticated, unobtrusive vehicle instrumentation suites to obtain in situ data on safety-related driver performance and behavior, including driver drowsiness. In situ monitoring is expected to be the most valid approach to assessing the role of drowsiness in "real world" driving, given the difficulties of capturing and documenting the role of drowsiness through post hoc accident investigation. NHTSA is sponsoring R&D to design and fabricate portable instrumentation suites, including video recording of the driver and the roadway, psychophysiological monitoring (if unobtrusive to the driver), and various measures of driving performance [Carter and Goodman, 1994]. These studies have the potential to provide direct and sophisticated empirical data on "asleep-at-the-wheel" and the more general problem of driver inattention, drowsiness/fatigue,

and the relation of reduced states of alertness to driving errors and miscues associated with crashes.

REFERENCES

AAA Foundation for Traffic Safety. Facts about drowsy driving. 1995.

Brody, J.E. Avoiding the hazards of drowsy driving. The New York Times, P. ClO, December 21, 1994.

Carter, R.J. and Goodman, M.J. Driver **performance data acquisition** system for ergonomics research. Proceedings of the 12th Triennial Congress of the International Ergonomics Association. Toronto, August 15-19, 1994.

Fell, D. Safety Update: Problem Definition and Countermeasure Summary: Fatigue. New South Wales Road Safety Bureau RUS No. **5,** July, 1994.

Knipiing, R.R., and Wang, J.S. Crashes and Fatalities Related to Driver Drowsiness/Fatigue, NHTSA Research Note, November, 1994.

Miller, T.R., et al., The Costs of Highway Crashes, Urban Institute, Report No. FHWA-RD-91-055, June, 1991.

Najm, W.G., Mironer, M., Kozioi, J.S.Jr., Wang, J.S., and Knipling, R.R. Examination of Target Vehicular Crashes and Potential ITS Countermeasures. Report for Voipe National Transportation Systems Center, DOT HS 808 263, DOT-VNTSC-NHTSA-95-4, May, 1995.

National Commission on Sleep Disorders Research. Wake Up America: A National Sleep Alert; Executive Summary and Executive Report, . Dept of Health and Human Services, January, 1993.

National Highway Traffic Safety Administration National Center for Statistics and Analysis. Technical Note for 1988, 1989, 1990 National Accident Sampling System General Estimates System, DOT HS 807 796, February, 1992.

National Sleep Foundation. Drive Alert . . . Arrive Alive drowsy driving fact sheet. 1995.

National Transportation Safety Board (NTSB). Safety Study: Factors That Affect Fatigue in Heavy Truck Accidents. PB95-917001, NTSB/SS-95/01, January. 1995.

Office of Technology Assessment, U.S. Congress. Biological Rhythms:

Implication for the Worker, GTA-BA-463, September, 1991.

Pack, A.I. Scope of the problem and at-risk groups. Drive Alive . . Arrive Alive National Forum, National Sleep Foundation, Washington, DC, December 7, 1994.

Recer, P. Sleep is a killer on America's highways, researchers say. Associated Press release. AP v5189 re 3exec Asleep at the Wheel, Bjt, 660. December 7, 1994.

Viir, J.G. Rollovers on sideslopes and ditches. Accident Analysis and Prevention, 27, No. 4, 1995.

Wang, J.S. and Knipling, R.R. Single Vehicle Roadway Departure Crashes: Problem Size Assessment and Statistical Description, NHTSA technical report, Publication Number DOT HS 808 113, March, 1994.

Appendix: Driver Alertness/Attention-Related Causal Factor Taxonomy

The principal causal factor (or category) for each sample DOOL crash ("pure" and "other") was identified based on the taxonomy summarized in Table 4 and specified below.

Table 4: Summary **of Driver Alertness/Attention-Related Causal Factor Taxonomy**

Causal Category — Certainty:	Definite/ Highly Probable	Probable
Drowsiness	1/D	2/D
Physiological (e.g., medical illness)	1/P	2/P
Awake Inattention (e.g., distraction, improper lookout)	1/I	2/I
Unspecified LOA/Inattention	1/X	2/X
Other (*Non*-LOA/Inattention) Principal Cause(s)	1/O	2/O
Unknown	U	

Detailed Definitions of Causal Categories:

1/D: Drowsiness certain (or highly probable): Drowsiness/ fatigue/sleepiness/asleep-at-the-wheel explicitly cited or strongly implied. No contradictory evidence (e.g., indications of "active" driving just prior to crash). Includes “blackout” if there are no associated medical reasons or intoxication stated.

2/D: Drowsiness probable: Drowsiness not explicitly cited but is implied by the circumstances of the crash, including time-of-day, vehicle trajectory, etc. No contradictory evidence (e.g., indications of “active” driving just prior to crash).

l/P: Physiological Cause of Loss-of-Alertness (LOA) certain (or highly probable): LOA/“blackout” due to physiological/medical cause explicitly cited or strongly implied. No contradictory evidence (e.g., indications of “active” driving just prior to crash). (As noted above, the term “blackout” was coded D instead of P if there was no mention or indication of a physiological/medical condition.)

2/P: Physiological Cause of LOA probable: LOA/“blackout” due to physiological/medical cause not explicitly cited but is implied by the circumstances or other information about the crash. No contradictory evidence (e.g., indications of “active” driving just prior to crash).

l/I: Awake inattention certain (or highly probable): Explicit statement or strong implication that driver was awake but inattentive, and that au inattentional lapse was the principal cause. Examples include distraction due to interaction with person(s) or object(s) in vehicle. Includes crash scenarios precipitated by encroachment by (or of) non-contact vehicle caused by definite/highly probable driver improper lookout (“looked but didn’t see”; Treat, et al, 1979). Note that “careless driving” are not considered as driver inattention; a key notion was attentional lapse.

2/I: Awake inattention probable: Awake inattention not explicitly cited but is implied by the circumstances of the crash, including number of occupants in vehicle, time-of-day, vehicle trajectory, etc. Includes crash scenarios precipitated by encroachment by (or of) non-contact vehicle caused by probable driver improper lookout.

l/X: LOA/inattention certain (or highly probable) but unspecified [drowsiness possible]: Explicit statement or strong implication of either driver LOA or inattention, but no specific indication of which factor was involved. LOA/inattention also implied by the circumstances of the crash, including pre-crash maneuver, vehicle trajectory, etc. No contradictory evidence (e.g., indications of “active” driving just prior to crash). Use of “X” code implies that LOA (drowsiness) could have occurred but was not cited or directly implied.

2/X: Unspecified LOA/inattention probable [drowsiness possible]: Neither LOA (due to drowsiness or other causes) nor awake inattention specifically cited, but LOA/inattention implied by crash circumstances, including pm-crash maneuver, vehicle trajectory, etc. No contradictory evidence (e.g., indications of “active” driving just prior to crash). Use of “X” code implies that LOA (drowsiness) could have occurred but was not cited or directly implied. Includes crash scenarios precipitated by encroachment by non-contact vehicle caused by probable unspecified driver inattention where drowsiness is a possible plausible explanation. Note: Crashes involving factors such as alcohol, speed, and/or slippery roads could be classified as D, P, or X if other evidence was supportive of these classifications as significant causal factors. In other words, LOA/inattention and alcohol/speed/slippery roads were not regarded as mutually exclusive. Crashes involving speeding, alcohol, other unsafe driving behaviors, and/or slippery roads as principal causes are coded l/O or 2/0 (see below).

l/O: Other principal cause(s) certain or highly probable [LOA/ inattention definitely not a significant factor]: Explicit statement(s) that the driver was awake and attentive (e.g., driving actively), or circumstances (e.g., pre-crash maneuvers) preclude the possibility of driver LOA/inattention as a significant causal factor, or strong implication of some other principal causal factor (e.g., reckless driving, awake intoxication, visibility, slippery toads, evasive maneuver, etc.). Includes crashes were subject vehicle was apparently being driven in an "active reckless" manner, including lane departures when there is convincing evidence of speeding, other **unsafe maneuvers,** and/or alcohol impairment. Also includes crashes caused by the encroachment of **a** non-contact vehicle where the non-contact vehicle was known to be making an active maneuver not involving LOA/inattention or there was some other known principal cause for the encroachment (e.g., slippery roads).

2/0: Other principal cause(s) probable [LOA/inattention improbable]: Circumstances of the crash imply that the driver was awake and attentive (e.g., driving actively), or imply some other principal causal factor (e.g., speed, awake intoxication, visibility, slippery roads, evasive maneuver, etc.) with no implication of LOA/inattention as a principal crash cause. This category includes lane departures on curves when there is no known reason for the departure (e.g., no implication of LOA/inattention) or the crash is attributed to "unsafe speed for conditions" with no convincing evidence of speeding. Also includes crashes caused by the encroachment of a non-contact vehicle if the non-contact vehicle was probably making an active maneuver not involving LOA/inattention, where there is no known reason for the encroachment, or if the occurrence of the encroachment is questionable.

U: Unknown. Unable to classify. Includes cases with insufficient information and also those with contradictory information (e.g., both LOA/inattention and "active" pre-crash driving cited or implied). Not used if there are specific indications that the driver was alert and/or attentive or if there were specific indications that the driver was drowsy and/or inattentive.