HUMAN FACTORS AND TRAFFIC CRASHES

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ABSTRACT

A major focus of transportation engineers and all engineers in general is safety. Currently, an estimated 41,000 people die annually in automobile crashes *(1)*. There are many factors that contribute to crashes with the main instigator of crashes being driver error. Driver error makes designing safe roadways difficult and challenging for engineers since every driver is different. The list of possible human errors is long. However, this paper focuses on three distinct factors that may cause a driver to commit an error while driving.

The first factor is the effect of alcohol on the driver and his or her performance. Studies dealing with alcohol impaired driving have indicated that the number of alcohol related fatalities may be underestimated. Studies also show that some drivers become impaired well before the blood alcohol content (BAC) of 0.10 is reached. Several methods of deterrence of drunk driving have proven to be effective. One of the more effective measures is the use of sobriety checkpoints.

The second factor discussed is driver fatigue. Research has shown that fatigue can be caused from such activities as business of social activities, holiday events, and family gatherings. Research has also shown that the majority of the fatigue related crashes occur between 8 P.M. and 6A.M. Legislation and enforcement of fatigue related driving is difficult since fatigue is not an easy concept to define or place limits on. Several solutions have been proposed to reduce fatigue-related accidents including additional rest areas and stricter limits on the trucking industry.

The third factor discussed is driver distraction by the use of cellular phones. Research has shown that the risk of an accident increases when cellular phones are combined with driving. It has been shown that driver reaction time and mental workload both increase with cellular phone usage. Several countries around the world have already banned the use of cellular phones while driving while other areas consider enacting legislation.

INTRODUCTION

Crashes have occurred since the invention of the automobile. In February of 1966, Lyndon B. Johnson said that the death and injury occurring on highways was "…the greatest problem before the nation next to war in Vietnam *(2)*." Currently, an estimated 41,000 people die annually in traffic accidents *(1)*. This number has decreased slightly over the past few years but still accounts for a large number of deaths in the United States. Some reasons for the slight decrease in automobile crash fatalities may include legislation requiring seatbelt usage, the use of airbags, better vehicle and roadway designs, advances in emergency and medical response, and better road maintenance in poor weather conditions. The reason these remedies have a minimal impact is simple; they deal with only safety features regarding the roadway and the vehicle while error on part of the drivers accounts for 90 percent of all traffic accidents *(3)*. Safer cars and roadways can be produced through design, but making drivers safer is much more difficult. Driver error can include a number of topics including misinterpretation of traffic control devices, road rage, driver expectancy, driver age, and mental workloads. This paper focuses on three factors that contribute to driver error and crashes. Two of the topics covered are problems that have contributed to accidents since cars were first produced. The first is drivers operating under the influence of drugs and/or alcohol and the second is driver fatigue (i.e. drivers falling asleep behind the wheel). The third topic, which will be discussed briefly, is a problem that is relatively new to the transportation field but has become more of an issue with time. This topic is driver distraction due to the use of cellular phones and how they made contribute to a crash.

IMPAIRMENT DUE TO ALCOHOL/DRUGS

Background

It is estimated that two out of every five Americans will be involved in a crash in which alcohol is involved. In 1995, alcohol fatalities accounted for 40 percent of all fatal crashes (17,274 deaths) nationally as well as over 300,000 injuries. This death rate is equivalent to an alcohol fatality rate of one every half-hour and is up 4 percent from 1994 totals *(4)*. In Iowa, 27 percent of all fatal accidents in 1997 was alcohol related.

A significant number of these accidents involve younger inexperienced drivers. Motor vehicle deaths are the number one cause of death for people 15 to 20 years of age *(5)*. Figure 1 shows the number of motor vehicle fatalities for this same age group and the number of fatalities in which alcohol was present. As can be seen, nearly half of the fatalities on weekends and almost one-third on weekdays are alcohol related *(5)*. Between 1992 and 1997, 30 percent of all alcohol related accidents involved intoxicated drivers 16 to 25 years of age *(4)*. In 1995, 55 percent of the fatal accidents involved intoxicated drivers 21 to 34 years of age. If past trends continue, it is estimated that in the next ten years nearly 400 people under the age of 25 will be killed in alcohol related accidents *(4)*.

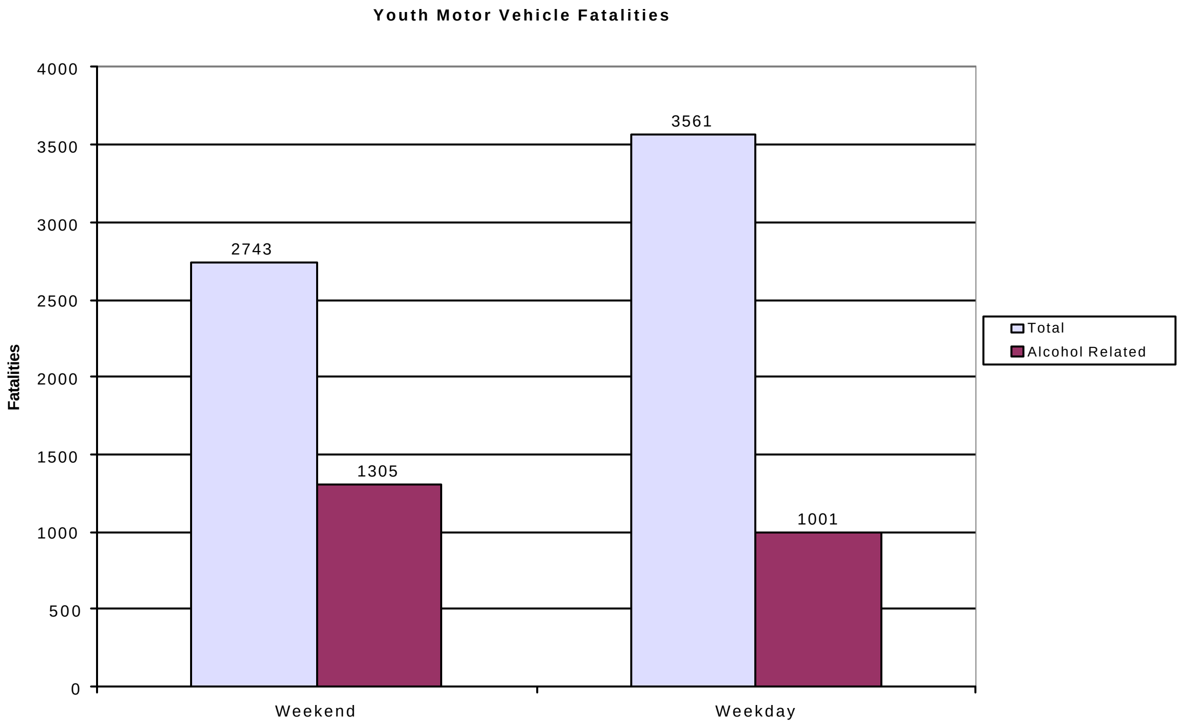

Figure 1-Youth Motor Vehicle Fatalities *(5).*

A Study on Driver Fatalities and Alcohol Involvement

The number of actual alcohol related fatalities might be underestimated. A group of researchers, Olga J. Pendlton, Nancy J. Hatfield, and Ron Bremer, of the Texas Transportation Institute and Texas A & M University conducted a study in which fatal crashes and driver intoxication levels were compared *(6)*. The purpose of the study was to determine how accurately fatal crashes are investigated and traffic accident reports prepared by police with respect to the involvement of alcohol.

The methodology used by the researchers included the comparison of toxicology and autopsy reports with traffic accident reports. The goal was to determine the degree of accuracy of traffic accident reports when compared to reports prepared by medical examiners. The blood alcohol content (BAC) of the fatally injured driver was used to make the comparison between the two reports. BAC is measured as a percentage in terms of the amount of alcohol in a volume of blood. For example, a BAC of 0.10 (the legal limit in Iowa) means that there is one-tenth of a percent of alcohol in the blood by volume. Pendlton, Hatfield, and Bremer collected BAC content data from medical examiners in nine Texas counties that perform postmortem BAC tests on fatally injured drivers. Though only nine counties in Texas were studied, over half of the population of Texas was included in the study area. The data collected came from crashes that occurred between January 1, 1984 and December 31, 1984. In total, 1,260 driver fatalities were studied.

Of the 1,260 accidents reviewed, Pendleton, Hatfield, and Bremer determined that 51 percent of the drivers had a BAC of 0.10 or greater according to the toxicology reports. This means that over half of the 1,260 drivers killed were legally intoxicated at the time of the accident. When the accident reports were reviewed, only 20 percent of the crashes were listed as alcohol related. In other words, the investigating officer misinterpreted about 30 percent of the crashes. Therefore, the number of alcohol related fatal crashes that occurred that year were greatly underestimated. Pendleton, Hatfield, and Bremer also investigated the discrepancies between toxicology reports and accident reports with the law enforcement agency responsible for the investigation of the fatal crashes. It was determined that investigating officers with the Texas Department of public Safety failed to list alcohol as a contributing factor for 30 percent of the accidents they investigated while the local police agencies mis interpreted 76 percent of the accidents that they investigated with respect to alcohol involvement. This discrepancy between law enforcement agencies may indicate a difference in, or lack of, training and education in the investigation of crashes and in determining what factors contributed to the crash. It is also worth noting that the study indicated that the investigating officers for the Texas Department of Public Safety over reported alcohol as a contributing factor in crashes by 15 percent while local police agencies over reported alcohol related accidents by 6 percent.

An accurate estimate on the number of fatal accidents in which alcohol was a contributing factor can be very difficult to determine from merely traffic accident reports. These reports are both subjective and non-quantitative in nature. A highly reliable estimate can be obtained from determining the BAC of all drivers of all vehicles involved in an accident. The BAC value is non-subjective and quantitative *(6)*. However, this data is often unavailable. This may be due to several reasons. First, the lack of legislation requiring postmortem BAC tests on all fatally injured drivers. As of 1986 only 35 states required postmortem BAC tests by law *(6)*. Second, the lack of facilities and staff needed to perform BAC tests on all fatally injured drivers *(6)*. And the third reason is there may be an excessive period of time that elapses between the time of the accident and the time of the autopsy, which can lead to erroneous test results *(6)*.

Effects of Low BAC's on Drivers

There have been numerous studies performed over the years that deal with alcohol and it's impact on drivers. An obstacle encountered in all of these research studies is the fact that each individual person will respond differently at a given BAC. Two main factors that cause these variations are a person's metabolism and the rate at which the alcohol is absorbed into the bloodstream.

The Committee on Benefits and Costs of Alternative Federal Blood Alcohol Concentration Standards for Commercial Vehicle Operators, a committee of the National Transportation Research Board, published a special report titled *Zero Alcohol and Other Options*, which, contained research data from various studies dealing with the impact on driving functions and BAC levels. One study performed by G. Wilson and R. Mitchell showed that drivers were unable to separate fine visual details as accurately or judge distances between themselves and other vehicles with BACs as low as 0.04 to 0.06 *(7)*. Another study listed by the National Transportation Research Board Committee was one performed by R.G. Mortimer. Mortimer studied how BAC effected a drivers tracking ability. The study revealed that with BAC as low as 0.01, tracking was greatly impaired when combined with low illumination (i.e. nighttime driving) and a glare (i.e. oncoming headlights). As BAC increased, the tracking ability of the driver decreased for any illumination situation *(7)*. These studies suggest that many drivers become impaired at a low BAC.

Deterrence of Drunk Driving and Alcohol Related Fatalities

There are two distinct levels of deterrence, general and specific. General deterrence is "the effect of threatened arrest and punishment upon the total driving population *(8)*." Specific deterrence is defined as "efforts to prevent single offenders from drunk driving again *(8)*." The following sections provide some examples of general and specific deterrence that can be implemented to reduce the number of alcohol related accidents.

Adjustment of the Legal BAC

Minnesota was the first state in the United States to create "illegal per se" legislation. In 1976 the state of Minnesota made it "illegal per se" to drive a vehicle while under the influence of alcohol defined as having a BAC of 0.10 or higher. Iowa followed in the footsteps of Minnesota and in 1982 made it illegal to drive with a BAC of 0.10 or higher. This "illegal per se" idea has spread throughout the United States and the world.

Some agencies and legislatures would like this legal BAC limit lowered to 0.08. There are many states that currently have a legal BAC limit of 0.08. These states have shown a "significant statistical correlation in lowered alcohol-related fatalities" since the BAC limit was lowered to 0.08 *(4)*. As was discussed previously, studies have shown that some drivers do become impaired before a BAC of 0.10 is achieved. This is a strong argument for lowering the BAC from 0.10 to 0.08.

Licensing and Revocation

As was mentioned earlier, the leading cause of death in people of 15-20 years of age is automobile accidents. Currently, many schools and organizations attempt to educate students on the effects of alcohol and drugs. Though this has been shown to decrease fatalities, 30 percent of all the fatal alcohol related accidents from 1992 to 1997 involved 16-25 year old drivers *(4)*. One way to decrease the number of young people killed in alcohol related accidents are to keep the young people off of the road. This can be accomplished by a graduated drivers license system. A graduated drivers license system would require new drivers to progress through a gradual program that limits the time of day, destination, and number of passengers in the car. A driver can graduate from one level to next with a clean driving record over a fixed period of time until the point where full driving privileges are reached. Studies have shown that alcohol plays a large role in the number of fatal traffic accidents that occur on the weekends. An application of a graduated license system could be to limit when young people are allowed to drive over the weekend (i.e. during daylight hours only). This may help reduce the fatal alcohol related accidents involving young people.

Another way to reduce alcohol related accidents among young people would be to keep them alcohol free. To discourage minors from purchasing alcohol, the minor's driver's license could be revoked and anyone under the age of 21 who purchases or attempts to purchase alcohol with a valid, invalid, altered or fake identification could have there driving privileges revoked for a specified amount of time. A fine or citation may also accompany this revocation. Illinois currently has similar legislation that revokes the driving privileges for up to one-year *(4)*.

Revocation may also include the seizure of the vehicle being driven at the time of an alcohol related offense. Immediate seizure of the vehicle may be the best way to keep an operating while intoxicated (OWI) offender from driving while their license is suspended. However, seizure of vehicles has proven to be somewhat ineffective. The main reason for the ineffectiveness is there is only "sporadic" enforcement since vehicle seizure is included in the sentencing of a guilty party and not all judges order the seizure *(4)*.

Drinking and Driving Citation

Another solution may be the issuance of a drinking and driving citation. This citation would be issued to drivers who have a BAC below 0.10 but higher than 0.04. This citation would be a simple misdemeanor with a fine. If a citation were issued to drivers who have BAC of 0.04 or greater, the use of designated drivers would be encouraged. For citations to be effective, criminal operating while intoxicated (OWI) charges cannot be lowered to a simple citation. If this were to happen, an opposite effect would take place and drivers might be encouraged to drive wile intoxicated.

Sobriety Checkpoints

Another method proven to effective in decreasing the number of alcohol related crashes is the use of sobriety checkpoints. This idea was first implemented in Scandinavia. With the use of sobriety checkpoints, every driver, sober or intoxicated, has the potential to be stopped by law enforcement officers. The location and times of the checkpoints are determined by the law enforcement agency based on past OWI arrests, alcohol related crashes, and locations of moderate to heavy traffic to contact as many drivers as possible. Either all traffic passing through the checkpoint or vehicles on a pre-established basis (i.e. every tenth vehicle) will be stopped by police officers. After being stopped, the officers will make contact with the driver checking for license, registration, and proof of insurance. If the officer has any suspicions of alcohol impairment, the driver will be directed to another area where roadside OWI tests can be performed (i.e. a Breathalyzer test). The checkpoints become very effective when the results of the checkpoints are made public and the public is made aware of the possibility of random checkpoints in the future.

In 1978, the City of Melbourne, Australia performed such a sobriety checkpoint campaign. Researchers reported that because of the sobriety checkpoints, there were "59 percent fewer nighttime fatalities, 39 percent fewer serious injury crashes, and 30 percent fewer crash-involved drivers with BAC's greater than 0.05 percent *(8)*." In Montgomery County, Maryland, sobriety checkpoints were established between July 1982 and July 1983. During that year, only 7 alcohol related fatal crashes occurred compared to 28 crashes the previous year, a decline of 75 percent *(8)*.

DRIVER FATIGUE AND TRAFFIC ACCIDENTS

Background

Fatigue has been defined as "a progressive decrement in performance which if not arrested, will end in sleep and is related to the level of arousal of the driver *(9)*". A fatigued and tired driver can be as dangerous on the road as a driver operating under the influence of alcohol. National studies have shown that male drivers between the ages of 16 to 25 are most likely to be involved in these types of crashes most of which occur around 2 A.M. *(10)*. Many researchers feel that the accident rates for which fatigue was a contributing factor is underestimated due to the fact that it is hard to define a level of fatigue. A study in New South Wales stated that police officers investigating an accident only reported it as a fatigue related crash if the driver himself or passengers in the car admitted to being tired or falling asleep *(11)*. It is currently unknown how many crashes occur each year because of fatigued drivers.

The Causes of Fatigue

The causes of fatigue vary from person to person making fatigue a difficult concept to define. Dallas Fell conducted a research study in New South Wales which consisted of a questionnaire that was sent out to 1,000 automobile drivers. Quotas were set for sex and age groups to assure that an adequate comparison could be made. Of the 1,000 drivers questioned, 280, or 28 percent, of the drivers admitted to having an accident or a near accident that they felt was due to their own driver fatigue *(11)*.

When the results of the questionnaire were studied, several interesting trends were reported. First, about 25 percent of the 280 drivers were going to or from holiday gatherings, family gatherings, or were on business or social trips, all of which have the potential for being long trips *(11)*. The results indicated some activities that might lead to driver fatigue. About 33 percent of the accident or near accident trips began between 8 P.M. and 6 A.M. compared to 19 percent of the non-accident trips *(11)*. The peak time for fatigue related traffic accidents occur during the night when the environment is conducive to sleep and fatigue related impairment. People traveling during nighttime hours are subjected to dark conditions with little if any driver stimulation from the surrounding environment. The density of traffic at these times also decreases which allows a driver to become less alert. The questionnaire study conducted by Fell indicated that about 20 percent of the 280 crash or near crash drivers had been driving 5 or more hours at the time of the incident. However, the majority of the 280 drivers were involved in an incident within the first two hours *(11)*. However, this last statistic may be misleading. Those crashes or near crashes that occurred within the first two hours of the trip, should be compared to the time when the trip began. If a number of these trips began late at night (i.e. between 11 P.M. and 4 A.M.), the number of crash or near crash incidents that occurred may be more related to the lack of driver stimulation rather than the number of hours driven. Another interesting trend determined from the questionnaire study was when asked if the driver had gotten enough sleep prior to the trip, the answer for more than 50 percent of the subjects was no *(11)*.

A Study on Fatigue Related Accidents and Rest Areas

Many fatigues related studies focus on the trucking industry due to the fact that truck drivers often drive long hours and perform irregular schedules. In 1992, the Federal Highway Administration Office of Motor Carriers supported a study on the adequacy of locations for truckers to stop and rest. The study determined that there was a problem and that the current system was unable to accommodate some 28,400 truckers' nationwide *(12)*. When these 28,400 truckers became tired and needed to stop, there were no parking spaces for them at nearby rest areas. Either these drivers continued to drive even though they were "impaired" or they pulled off the side of the road. Trucks parked on the shoulder of Interstate highways or ramps are a completely different safety issue. These parked trucks add another hazard along the roadside that other drivers could strike should they leave the roadway.

A study performed by William C. Taylor and Nakmoon Sung of Michigan State University compared the number of rest areas, their location with respect to one another, and how the rate of fatigue related accidents was effected by the rest area location. The objective of the study was to relate how single vehicle nighttime crashes involving a heavy truck (truck tractor combination used for transporting property) to current rest area spacing *(12)*. The single vehicle accidents were limited to those that occurred between 10 P.M. and 6 A.M. and involved only one truck. Routes that were studied only consisted of rural freeways since those were likely to be used by trucks traveling long distances. Taylor and Sung used a hazard function to measure the probability of a crash occurring in a predetermined distance interval (i.e. every 10 miles) from the previous rest area. The hazard function was set up to define "an estimate of the potential for a crash in the designated interval, given that a crash will occur and that it has not occurred in a prior interval *(12)*". To do this, average daily truck traffic (ADTT) compiled by the Michigan Department of Transportation Bureau of Transportation Planning was combined with truck crash data from 1994 to 1995. The study included 333 single vehicle accidents that occurred on a total of 1,080 miles of Interstate highway and included all of the major rural Interstates in Michigan *(12)*. All of the rest areas studied were spaced at least 50 miles apart. The majority of the single vehicle truck accidents used in the study occurred between midnight and 8 AM. It was assumed that all of the accidents studied were fatigue related.

By combining the crash data with the rest area locations, Taylor and Sung determined that there was no significant difference in crashes per mile over the first 30 miles between rest areas or the last 20 miles. This indicated that the spacing of the rest areas was a leading factor in the location of the single vehicle accidents and not any roadside or geometric factors *(12)*. After reviewing the research data, it was determined, that the probability of a single vehicle accident occurring on a rural freeway increases when the distance from the preceding rest area exceeds 30 miles and continues to increase to at least the 50 mile mark *(12)*. The results from this research study favor adding more rest areas to the rural Interstate system. A plot of the data found in the study can be seen in Figure 2.

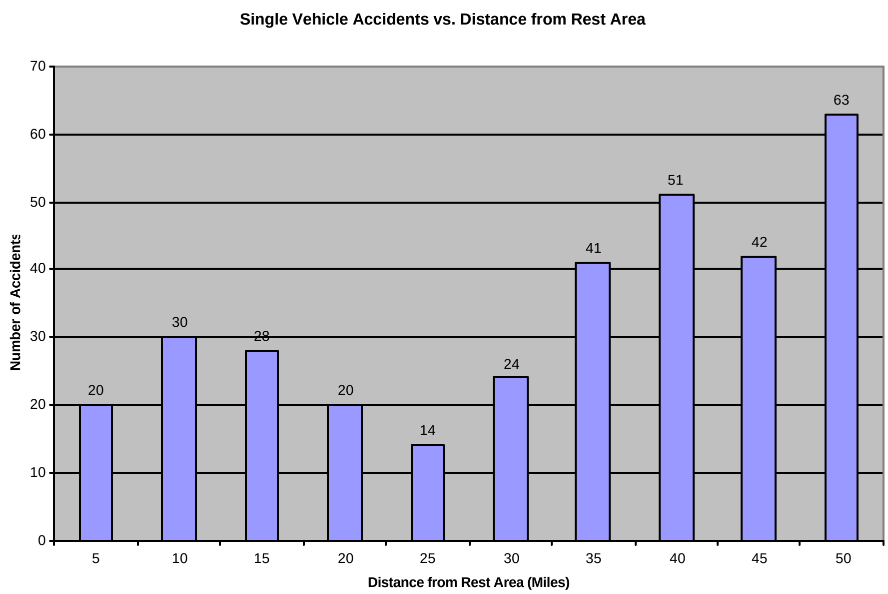

Figure 2-All single vehicle crashes as a function of distance from the previous rest area (12).

Methods to Reduce Fatigue Related Accidents

Additional Rest Areas

The study by Taylor and Sung along with a study performed by the Federal Highway Administration Office of Motor Carriers supports the addition of more rest areas to the nations highway systems in an effort to combat fatigue related crashes. Building additional rest areas along the nations Interstates would be an expensive solution. Many state Department of Transportation agencies may not have the needed money in their budget for this solution. However, if the government agencies were to provide some aide to the private trucking companies, the trucking industry may be willing to help pay for the construction of these rest areas.

Driver Awareness and Enforcement

Additional driver education in the areas of the causes of fatigue and the effects of driving while may reduce the number of fatigue related accidents. The additional information passed on to the public should stress the following *(11)*:

- Share the driving
- Take longer and more frequent breaks.
- Get a good nights sleep prior to the trip.
- If possible, avoid driving at night, at least during normal sleeping hours.

Legislation and enforcement dealing with fatigue on day to day travelers will be difficult since there is no way to define whether or not a driver is fatigued. However, enforcement of the trucking industry is possible through logbooks kept by the driver. Laws limiting the amount of time a truck driver is allowed to drive should also be strictly enforced. Fines and any citations should not effect only the driver of the truck but also the trucking company that employs that driver. This will force the trucking industry to take an active role in preventing fatigued driving.

DRIVER DISTRACTIONS DUE TO CELL PHONE USAGE

Background

The use of cellular telephones has increased dramatically over the last several years. In 1995, the rate of new cellular phone subscribers exceeded the birth rate in the United States *(3)*. A number of these people who now have cell phones use them while they are driving. For many people, talking on their cell phone while driving has become part of their job while others do it simply for convenience. Several countries around the world have banned the use of cellular phones in vehicles because it is felt that this added driver distraction can lead to an increased number of crashes. Some of these countries include Australia, Brazil, and Israel. A Canadian Study has shown that people who talk on cell phones while driving are nearly as impaired as drunk drivers *(15)*. In the United States, some states already have adopted regulations regarding the use of cellular phones while driving. In fact, in Iowa a state lawmaker has recently proposed a law that would allow the driver to make calls of up to one minute but calls of over one minute would be considered a criminal offense punishable by a fine of $100 and up to 30 days in jail.

Studies on Cellular Phone Usage and Traffic Accidents

Several studies have been conducted in the area of cellular phone usage while operating a motor vehicle. Donald A. Redelmeirer M.D. and Robert J. Tibshirani P.H.D. conducted one such study. The purpose of their study was to "evaluate potential associations between the use of a cellular telephone and the risk of a motor vehicle collision in real-world circumstances *(3)*". In other words, this case-crossover study attempted to determine whether or not the use of a cellular phone prior to an accident increased the likelihood of the accident occurring as compared to the risk expected by chance only. The study was conducted in Toronto, Canada where there were no current laws restricting cellular telephone usage. The study focused on 742 people who were involved in crashes that resulted in substantial property damage as specified by police. The 742 test subjects were given a short questionnaire concerning personal characteristics and characteristics of the accident. The subjects' cellular telephone bills were obtained, as were the accident reports prepared by the investigating police officers. Using the questionnaires, accident reports, and calls for emergency personal listed on the phone bills, the time of the crash was estimated. A hazard time, a specified period of time prior the traffic accident, was determined for the analysis. Hazard times of 1, 5 10, and 15 minutes were used.

From the analysis, Redelmeirer and Tibshirani determined that 170 of the subjects, or about 24 percent, had used cellular phones in a 10-minute interval prior to the estimated time of the crash. For this hazard interval (10 minutes), a relative risk factor of 4.3 was determined. In other words, the chance of an accident occurring quadrupled when cellular phones were used while driving *(3)*. The risk of an accident also appeared to be inversely proportional to the length of the calls made. Risk factors of 4.8 and 1.3 were determined for calls placed within five minutes before the crash and for calls placed more than 15 minutes before the accident respectively *(3)*. There appeared to be no significant difference in relative risk rates for persons using hand held phones versus hands free phones nor were there any differences found between the "…subjects' age, education, socioeconomic status, or other demographic characteristics *(3)*". The fact that there was no significant difference between the hands free and hands on phones indicated that a leading factor in the crashes was the driver's inattention and not the driver's hands.

The above study attempted to determine how the risk or chance of a crash occurring is effected by the use of cellular phones but does not investigate what actually causes the driver to become involved in a crash. Roberto A. Tokunaga, Toru Hagiwara, Seiichi Kagaya, and Yuki Onodera of Hokkaido University in Japan performed a study on how a driver's reaction time and mental workload are effected by using cellular phones while driving. The study was comprised of 31 subjects ranging in age of 22 to 65 years of age. All of the subjects had at least 3 years of driving experience and were familiar with the use of cellular phones. The tests were conducted on the Central Expressway in Hokkaido Japan. The experimenters drove a leading vehicle at a controlled speed of 90 kilometers per hour (km/h). A test subject, who was instructed to maintain a distance of 50 meters behind the leading car, drove a trailing vehicle. Each vehicle was equipped with devices to measure reaction times and a hands free cellular phone was mounted on the dashboard of the test subject's vehicle. The driver's reaction time was measured using a multiple data recording system, which included a camera mounted in the back window of the subject's vehicle. The driver of the leading car would randomly turn on his warning lights for a period of five seconds. The test subject was instructed to push a bottom on the steering wheel when the warning lights of the leading vehicle were turned on. The camera mounted in the trailing car was placed so that the warning lights of the leading car as well as the test subject could be seen.

The test subjects were called twice during the test via a cellular phone used by the experimenters in the leading vehicle. The test subjects were required to reach to the dashboard mounted cellular phone and hit the "On" button to receive incoming calls, but otherwise their hands were free to perform the driving task. Each of the two calls lasted approximately two minutes in length. These two phone calls were used to measure the mental workload of the driver while talking on the cellular phone. One of the calls was used to evaluate a simple conversation task. This consisted of a simple conversation about the driving conditions and the test section. The second call was more complex. The test subject was asked a series of simple mathematical problems (i.e. "How many is 7+1-1+1+1") *(16)*.

The results of the driver's reaction time analysis showed that driver reaction time increased when the cellular phones were in use. When the cellular phones were not in use, the driver's had an average reaction time of 0.76 seconds *(16)*. When the simple phone conversation took place, the reaction time increased and continued to increase when the complex phone conversation took place *(16)*. This indicated that the use of cellular phones while driving could have a negative impact on the driver's reaction time.

Methods to Reduce Cellular Phone Related Accidents

More research needs to be conducted before a conclusion can be made on the effects of driving while using a cellular telephone. The two studies mentioned both indicate that driver impairment does occur. A large factor in any legislation that may be passed limiting the use of cellular phones, short of banning their use, would be the difficulty of enforcement. For example, the legislation that was proposed in Iowa to limit cell phone calls while driving to a minute or less would be extremely difficult to enforce. In addition, the study by Redelmeirer and Tibshirani indicated that the risk of an accident is greater for calls of shorter duration. Legislation that would require the driver to pull off of the road and be completely stopped before using a cellular phone would be easier to enforce. However, this would increase the number of obstacles along the roadside. This problem was mentioned earlier in the discussion of fatigue and the trucking industry.

CONCLUSIONS

The first topic discussed dealt drivers operating under the influence of alcohol. A study by Olga J. Pendlton, Nancy J. Hatfield, and Ron Bremer, of the Texas Transportation Institute and Texas A & M University suggested that the number of alcohol related fatalities is underestimated. The underestimation is due to the lack of required postmortem BAC tests and the inability of police departments to correctly identify alcohol as a contributing factor to a crash. Studies by R.G. Mortimer, and G. Wilson and R Mitchell both indicated that some drivers could be impaired at BAC's as low as 0.04. This paper also discussed several methods to decrease the number of alcohol related crashes. These methods included more education, graduated drivers license system, license revocation, drinking and driving citations, and sobriety checkpoints.

The second topic discussed was fatigue and fatigue related crashes. A study by Dallas Fells indicated possible sources of fatigue. These sources include business of social trips, family gatherings, and holidays. It also showed that the majority of fatigue related crashes occur between the hours of 8 P.M. and 6A.M. A study performed by William Taylor and Nakmoon Sung suggested that additional rest areas should be built to accommodate the number of truck drivers traveling the nations highways. The study showed that the likelihood of a truck being involved in a fatigue-related crash, increase as the distance from the previous rest area increases. It has also been stated that prevention and enforcement measures dealing with fatigue related driving is difficult since fatigue is a difficult concept to define.

The final topic discussed in this paper is a relatively new safety issue to transportation engineers. The use of cellular phones has become popular in the United States. Studies have shown that using cellular phones while driving may increase the risk of being involved in a crash. A study by Donald A. Redelmeirer M.D. and Robert J. Tibshirani P.H.D. has shown that using a cellular phone while driving a car can increase the chances of a driver being involved in an accident by a factor of 4. This increased risk is especially true for calls of 10 minutes or less in duration. Another study performed by Roberto A. Tokunaga, Toru Hagiwara, Seiichi Kagaya, and Yuki Onodera has shown that using a cellular phone while driving increases the driver's mental workload and reaction time. Some countries currently have laws banning the use of cellular phones while driving while other areas are considering legislation that would put restrictions on cellular phone usage. Further research is needed on the use of cellular phones while driving.

The topics discussed in this paper are only a few of the many factors that lead to driver error. By decreasing the number of errors made by drivers, the crash rate would certainly decrease resulting in numerous lives being saved each year. Research needs to be continued on not only the factors discussed in this paper, but also on the many other factors that lead to driver error and ultimately automobile crashes.

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