Interactive Qualifying Project

(IQP)

Driving Fatigue and Drowsiness (DFD)

Morteza Azargoon

Charly El-Khoury

Hamza Kataya

5/6/04

Prof. Stephen Bitar

Prof. Alexander Emanuel

WPI

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Abstract

The goal of the project is to discuss the problem of Driving Fatigue and Drowsiness (DFD). A survey of 269 people helped determine the major causes of DFD. It was found that long distance drive, time of drive, and drugs/alcohol abuse are the three major contributing factors that lead to sleep related crashes. The basics physiological mechanism that governs microsleep were researched and possible mitigations methods were discussed. Finally, recommendations for drivers and for the government were proposed.

Acknowledgment

This IQP is dedicated to Dr. Denise Nicoletti whose death because of DFD was a big inspiration to us, and motivation to begin our project. The IQP team would like to extend its gratitude to the following people who helped us accomplish this project. These include our advisers Professor Stephen Bitar and Professor Alexander Emanuel, as well as Dr. Ann Mitchell for her co-operation, the engineer Robert Camera for his programming assistance and all the people who filled out our online survey. Last but not least, we want to thank 'GOD' for our existence.

1 Introduction

1.1 Overview

There are many life-threatening hazards in people's daily lives. Those threats can be categorized in three groups: hazards that cannot be contained, hazards that might be able to contain, and hazards that can be eliminated. Since the technology that provides mitigation is not fully developed the majority of these types of dangers fall in the second category. In order to identify the different threats on people's lives, most countries conduct statistics and research on the different causes of death, recognize the new threats that face the nation, and assess which ones are the most critical to find solutions for. As the technology develops, as new tools, new habits and new material are adopted, new hazards usually appear.

One of the most common threats to life and limb is the driving accident, especially in a country where the highway is one of its most developed forms of transportation like the United States and where public transportation left a lot to be desired. Numerous studies were conducted to determine the reasons and causes that resulted in driving accidents. Automobile manufacturers, insurance companies, and the American Automobile Association (AAA) are among the many foreign agencies that conduct research concerning DFD. Fig. 1.1 shows the results of a study done by the Australian Transport Safety Bureau from 1990 through 1998.

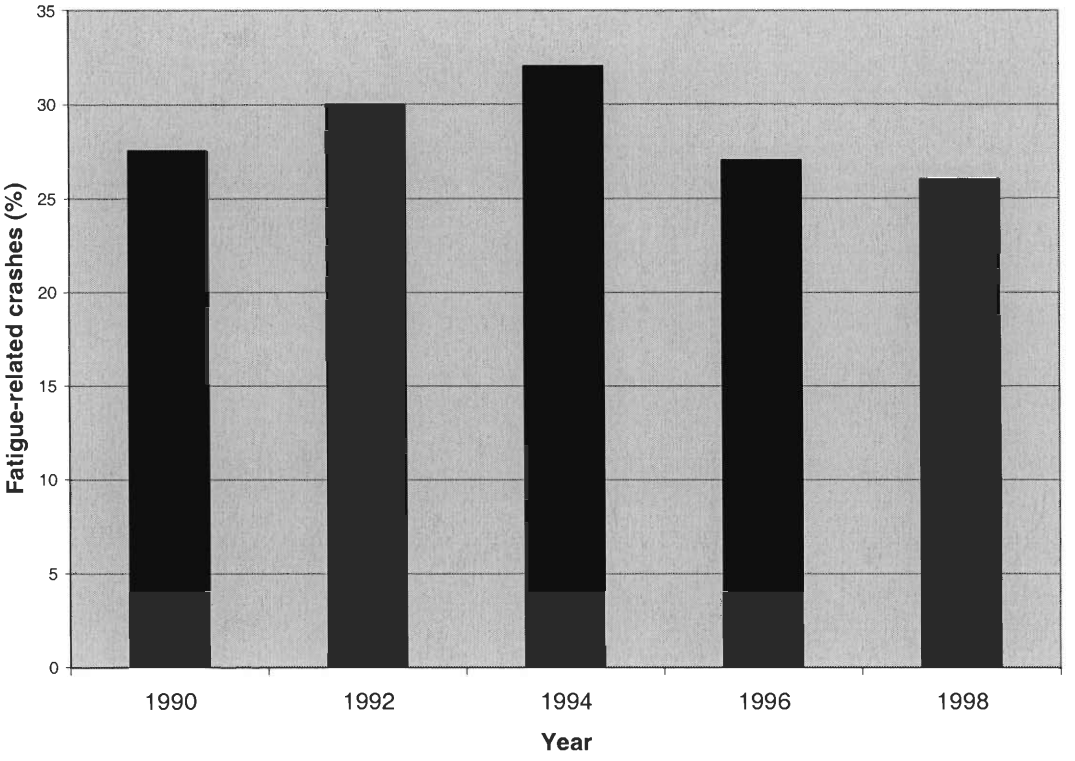

Fig. 1.1: Fatigue-related crashes as a proportion of all fatal crashes [13]

The graph clearly shows that the number of fatigued related crashes exceed 25% of all fatal automobile accidents [4]. The objective of this project is to conduct research on the significance of DFD, its effect on people's lives and the stringency in finding a particular solution. The project provides an analysis of different causes that lead to drowsiness while driving. This analysis points out to the most common causes and it is intended to help researchers reach an effective resolution for the issue. This project also provides a tool that helps promote awareness of the DFD problem among affected drivers, thereby reducing its occurrence.

1.2 Objectives

This study was conducted as an Interactive Qualifying Project (IQP) that focuses on Traffic Safety with the intention that others could use it to learn more and reduce the number of sleep related crashes. The study had the following goals:

1. *To illustrate the gravity of this problem.* We were especially interested in examining the extent to which special population groups (shift workers, young adults, persons with sleep disorders, etc.) are more in danger, versus the general driving population.

2. *To identify the various contributing factors.* Why did these people fall asleep while driving? Is it due to chronic sleep deprivation, or merely due to lack of sleep in general, just plain fatigue or other reasons?

3. *To define the physiology of sleep.* What happens? What changes in the human body once we get to the first stage of sleep? Does anything change that could be measured?

4. *To show the current technology.* See how the actual automobile manufacturers are handling this problem and what type of solutions they are creating.

5. *To come up with some recommendations.* What might be the best thing to do to prevent falling asleep at the wheel?

2 Background

2.1 National Statistics

Research conducted by the National Sleep Foundation determined that "32% of American adults sleep 6 or fewer hours per night, while 64% sleep less than the recommended 8 hours". In addition; the AAA Omnibus poll showed the following alarming statistics:

- 67% of adults reported a sleep problem
- 7.7% said they had a diagnosed sleep disorder
- 38% reported excessive daytime sleepiness severe enough to interfere with their jobs
- 57% of those interviewed said that they had driven while drowsy in the past year
- 23% said that they had actually fallen asleep at the wheel [4].

Similar results found by the Omnibus Poll have been reported in other studies, both in the United States and abroad. In a survey of New York State drivers:

- 55% admitted that they had driven while drowsy in the past year
- 23% reported that they had fallen asleep at the wheel but not crashed
- 3% that they had fallen asleep at the wheel and crashed
- 2% that they had crashed when driving while drowsy [2].

In Great Britain, 29% of respondents to a mail survey reported that they had felt close to falling asleep while driving in the past year. In Norway, one in 12 drivers reported that they had fallen asleep while driving over the past 12 months, with 5% of these episodes resulting in a crash [4].

The National Highway Traffic Safety Administration (NHTSA) estimates that drowsiness is the primary causal factor in 100,000 police-reported crashes each year,

resulting in 76,000 injuries and 1,500 deaths. These numbers represent 1 to 3% of all police reported crashes and 4% of fatalities [3]. Other sources have reported higher estimates. "In the United Kingdom, 16 to 20% of motor vehicle crashes were sleep related based on police-reported data, and 9 to 10% based on drivers' self reports of factors contributing to their recent crashes" [4].

Falling asleep at the wheel is a major contribution to crash occurrence however, mere drowsiness will also contribute to crashes due to reduced individual performance levels [4]. As summarized by AAA "One of the most perplexing problems faced by the National Transportation Safety Board accident investigators is how to determine what role, if any, fatigue played in a specific accident?" [4]. The NHTSA estimates that one million crashes each year result from driver inattention. Although not all of these involve sleepiness or fatigue, "sleep deprivation and fatigue make such lapses of attention more likely to occur" [3].

2.2 Population at high risk

The human population is facing an increasing risk, which involves sleep-related crashes. Most of the crashes include people who are sleep deprived, who drive at high-risk times or conditions, or others who are on prescribed medications or who make irresponsible and abusive use of drugs and alcohol [4].

Sleep deprivation happens for many reasons: A nationally famous sleep expert, William Dement, explained that the effects due to loss of sleep can accumulate over time and do not dissipate. Even skipping 30 or 40 minutes a night of what it is needed during normal week hours can result in three to four hours of lack of sleep by the weekend [4].

The two groups who are most likely to be sleep deprived are young people and workers who work unusual shifts. Some young people consider less sleep to be fashionable, and others find that sleeping early is too difficult, even when they know they have to get up early the next morning. "It has been estimated that 26 percent of men and 18 percent of women in the U.S labor force perform some sort of shift work." Shift workers, especially those who work at night or work rotating shifts, often experience poor quality of sleep time as well as insufficient quantity further contributing to DFD [4].

Another group who suffers sleep-deprivation consists of the people with untreated sleep disorders. The National Sleep Foundation has estimated that, "40 million Americans suffer debilitating sleep disorders, most of them undiagnosed" [4].

There are also those who drive at night, who drive on long trips, who drive on long stretches of monotonous roadway, and who drive by themselves that may be considered high-risk for sleep-related crashes. These conditions by themselves do not cause DFD however, when combined with sleep-deprivation persons will have difficulty staying awake [4].

2.3 Case Study

About one-half of adult drivers – 51% or about 100 million people – say they have driven a vehicle while feeling drowsy in the past year, and almost two in 10, (17% or 32 million people), have actually fallen asleep at the wheel, according to the National Sleep Foundation's (NSF) 2002 Sleep in America poll. One percent – approximately two million drivers – admits they have had an accident because they dozed off or were too tired to drive [19].

According to a first-of-a-kind study by the University Of North Carolina Highway Research Safety Center, drivers who work night shifts, long hours, or more than one job are at increased risk for being involved in a crash caused by fatigue or falling asleep at the wheel. Other factors strongly associated with having a drowsy driving crash include sleeping less than six hours per night, being awake for 20 hours or longer and frequent driving between midnight and 6 a.m. The National Highway Traffic Safety Administration conservatively estimates that 100,000 police-reported crashes are the direct result of driver fatigue each year. This results in an estimated 1,550 deaths, 71,000 injuries, and $12.5 billion in monetary losses. These figures may be the tip of the iceberg, since currently; it is difficult to attribute crashes to sleepiness [19].

Drowsiness/fatigue may play a role in crashes attributed to other causes such as alcohol. About one million such crashes annually are thought to be produced by driver inattention/lapses. Nearly three-quarters of adults in America (71%) drive a car to and from work, and many are drowsy drivers, according to NSF's 2001 Sleep in America poll. More than one-fourth of these respondents (27%) said they have driven drowsy to or from work at least a few days a month, 12 percent drove drowsy a few days a week, and four percent said they drove drowsy every day or almost every day.

One of the examples of this issue is the tragic death of Dr. Denise Nicoletti who was a Professor in Worcester Polytechnic Institute (WPI). She was killed by some one who was not alert while driving. Her husband is presently seeking legislation to make drivers more responsible for their actions, so they will not drive if they are over-tired or fatigued. Here is a part of his letter to the government: "You probably don't know of me or my family's situation. Given your recent filing of the subject House Docket, Senator

Stephen Brewer asked for my thoughts on it since my wife, Denise Nicoletti, was killed by someone who claims to have fallen asleep at the wheel. I thought it best to send this letter directly to you. Some background information first...At 8 Am on July 22, 2002 Denise was killed when she was hit head on by a truck on Rte 122 in Barre, MA. The 18-year-old man who was driving that truck stated that he fell asleep at the wheel at which time his truck crossed into Denise's lane. Denise died at the scene from massive trauma. My 4-year-old twin sons were also injured in the crash, one of them sustained a life threatening head injury and was hospitalized for over two weeks in intensive care. The other twin was not seriously physically injured and unbuckled himself to get to his mother only to watch her die. My 6-year-old daughter was not in the vehicle. We all continue to struggle with Denise's loss [18].

Since the day of the accident, I have been trying to understand how a healthy 18-year-old man could have been so fatigued, at 8AM, that he could not drive 20 miles without falling asleep. Drugs, alcohol and/or sleep deprivation are the only explanations that seem plausible. Regardless of which of these it was, or which combination, this man should have never gotten behind the wheel of that truck because he was impaired to the point he could not drive safely. This was just one sample of what happens in this world everyday" [18].

3 Local Survey

In order to measure the extent of this problem in our local area, a survey was conducted by creating a website, which allows the people to respond online. By this method, the participants were able to read the questions and simply click on the answer that best describes their situation and experience (see appendix A). Our team was then able to download the results for processing.

3.1 Survey Questions

The survey has the following five basic sections:

I: Personal information: To identify the sample population and how prevalent is it to our study – using information like age, gender, status, profession etc, thus allowing as to compare the spread of DFD throughout different groups.

1. GENDER:
2. AGE:
3. STATUS:
4. PROFFESSION:

II: Work/Sleep Schedules: Number of jobs worked, total hours on the job, work schedule, school attendance, etc. This information is used to determine the amount of sleep deprivation.

5. HOW MANY HOURS PER WEEK DO YOU WORK?
6. HOW MANY JOBS DO YOU HOLD NOW?
7. HAVE YOU EVER FELT DROWSY, ALMOST ASLEEP WHILE DVINING?
8. IF YES, HOW OFTEN?

III: Sleep Quality: Knowing the number of hours of sleep per day, and if it is considered enough for each typical person.

9. HOW MANY HOURS OF SLEEP DO YOU GET ON A TYPICAL NIGHT?
10. DO YOU FEEL LIKE YOU ARE GETTING ENOUGH SLEEP?

IV: Driving Exposure: Annual miles driven, driving as part of job, total time spent driving each day, percentage of driving done at different hours.

11. WHAT KIND OF CAR DO YOU DRIVE?
12. HOW OFTEN DO YOU USE CRUISE CONTROL?
13. HOW LONG HAVE YOU BEEN DRIVING?
14. DURING WHAT PERIODS OF THE DAY DO YOU DO MOST OF YOUR DRIVING?
15. HOW MANY MILES DO YOU DRIVE PER WEEK?

V: Various effects on DFD: Different contributing factors like long distance drive, time of drive, drugs, alcohol etc. that provide peak indicators for each category.

16. DO YOU THINK THAT ALCOHOL OR DRUGS MAKE PEOPLE SLEEPY?
17. OF THE FOLLOWING, SHOW THE DEGREE OF RELAVANCE TO SLEEPING WHILE DRIVING?

A few additional modifications were made after the first few surveys were completed to clarify some of the questions and to provide guidelines that are more specific for the interviewers.

3.2 Sample Population

The first task was to identify the population to be surveyed, and to categorize it based on our survey questions. The considered age range was 16 plus to correlate with the legal driving age range.

The classification of the population was based on gender as well as age groups. Fig. 3.1 shows the participation of both females and males in each age category as a percentage of the studied population. Most of the participants were in the ranges 16-21 and 21-27 and that could be explained by the fact that the study group was mainly comprised of WPI students. Another observation that could be concluded from the chart below is that the percentage of female participation is lower than the percentage of male participation in the young age ranges (16-21, 21-27) while it is higher in the older age ranges (27 and up).

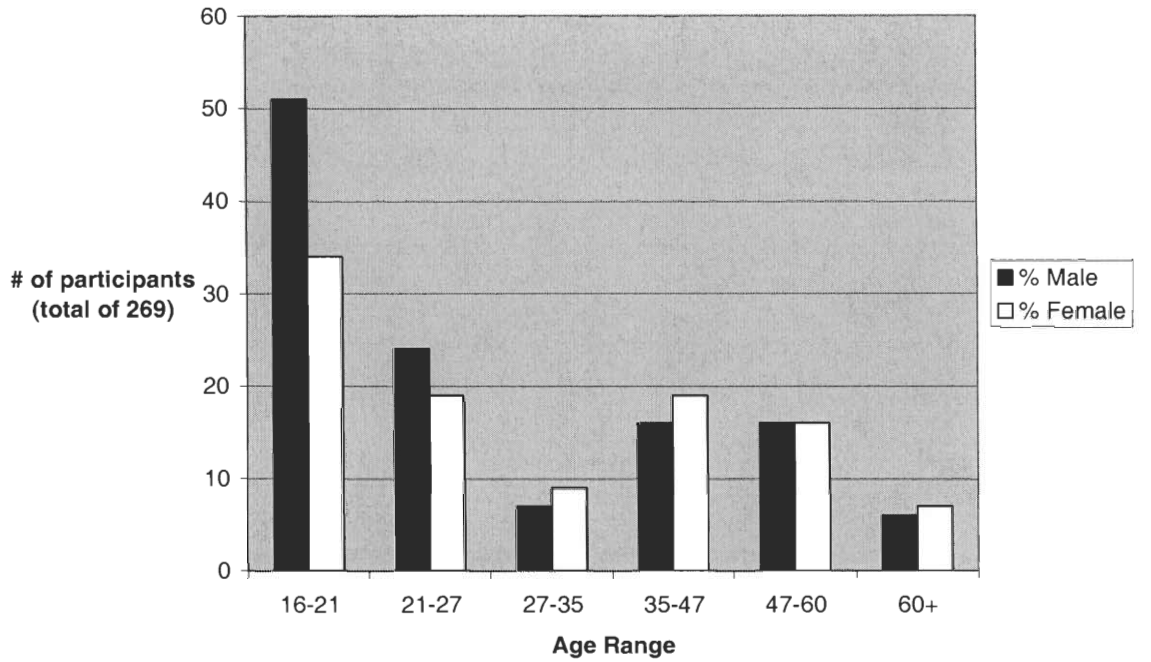

Fig. 3.1 – Identifying the studied population

4 Survey Results

4.1 Age and Gender Comparison

Since the studied population has already been identified, the results of the survey can be presented and analyzed. A quantification of how many people were affected by DFD (meaning that they had at least slept once when driving) is provided in the Fig. 4.1 below. This first cut of the data is based on both gender and age similarly to the classification of the population in order to perceive if these two factors have an impact on the problem.

This chart shows different percentages between the male and the female who fell asleep while driving throughout different age brackets. This chart uses two colors to distinguish between the male (black) and female (white). One way to read this chart is to say that around 73% of the males, age between 16 and 21, fell asleep at least once while driving. Furthermore, 67% of female, age between 47 and 60, fell asleep at least once while driving.

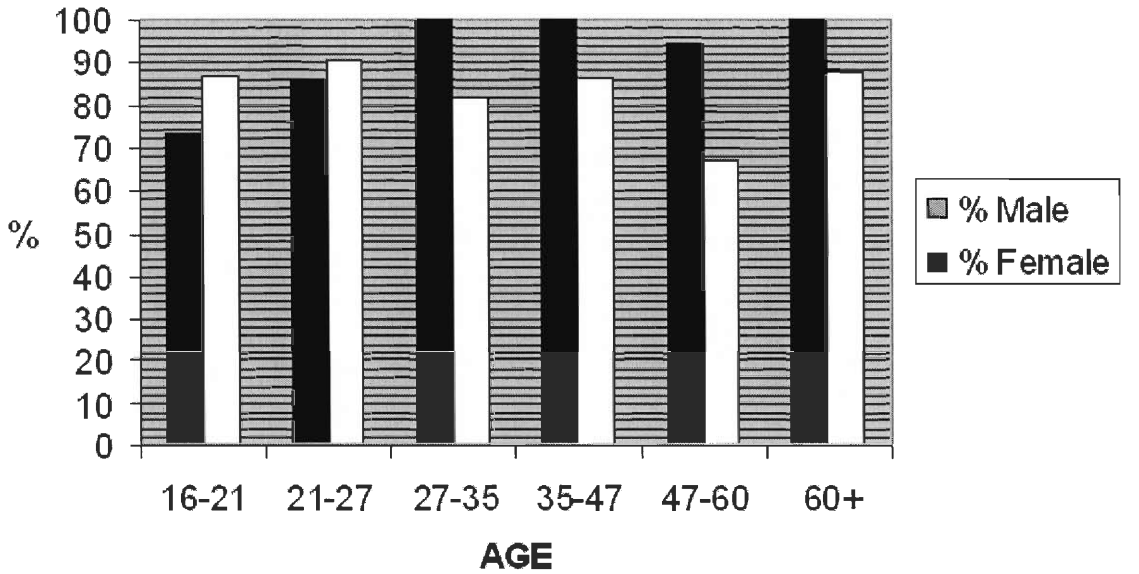

Fig. 4.1 Percentage of male and female who suffered DFD at different ages

4.2 Contributing Factors

To gather some solid ground on what contributes more to falling asleep while driving, one of the questions of the online survey was 'OF THE FOLLOWING, SHOW THE DEGREE OF RELEVANCE TO SLEEPINESS WHILE DRIVING'. This question provided the opinion of the people who completed the survey about how relevant some factors are to falling asleep while driving. These factors are: long distance drive, familiar roads, temperature, time of driving, cruise control and finally the drugs/alcohol effect.

The question was ranked from one to five depending on the importance each factor (one being least important, five being most important). The results received varied between one factor and another, one of the best ways to compare these factors together was to create a formula to weight each of the ranked answers and then put them in one chart as a percentage, which is presented in the chart below (See explanation below).

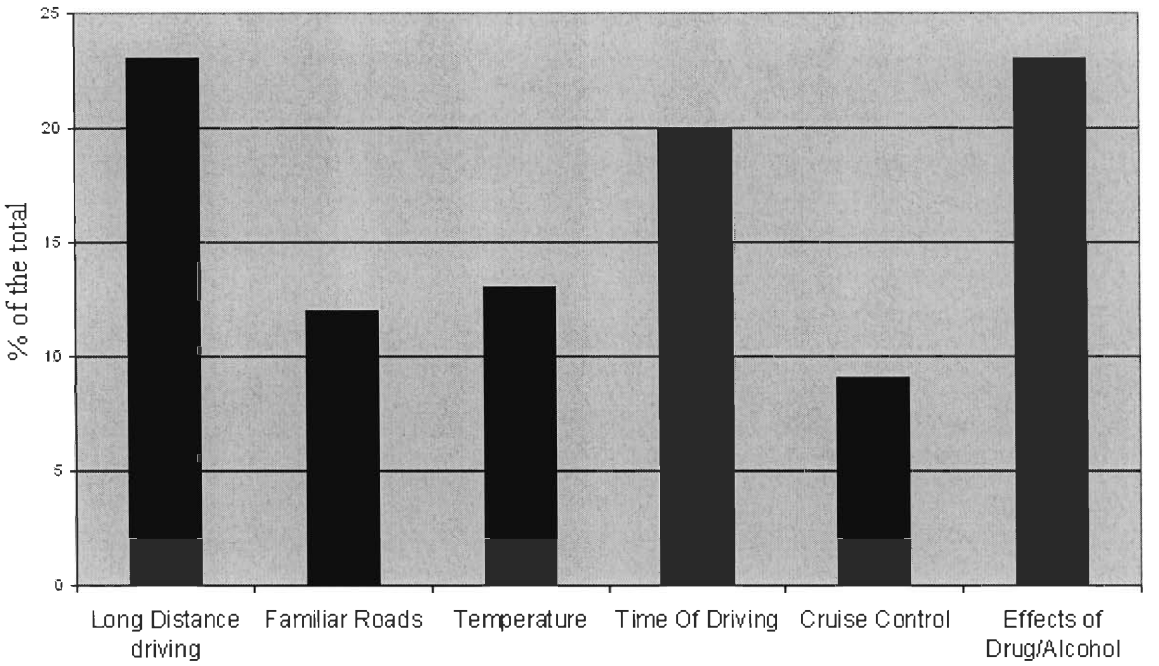

Fig. 4.2 People's opinion about various effects on sleeping while driving

The formula consisted of multiplying the number of the people who answered "five" by two to the power five. The number of the people who answered "four" by two to

the power four and so forth until we get to the number of the people who answered one and then divide each by the sum of the weight factor (two to the five plus two to the four plus … two to the one). The addition of the percentages of each of the contributing factor results to a hundred percent.

The results after this weighting process lead to distinguish three major factors that effects on drowsiness at the wheel. For example: Long Distance Driving (23%), the Time of Driving (20%), and the Effect of Drugs & Alcohol (23%) almost add up to 66% of the reason why people might fall asleep while driving.

By looking at Long Distance Driving as one of the major factors, when persons are sleep deprived, having to drive for a long period of time especially on monotonous highways, can lead to DFD. "A recent, substantial United Kingdom survey by covering 4600 respondents, found that 29% admitted to having felt close to falling asleep at the wheel in the previous year, and 17.9% had accidents during the previous 3 years. Of these, and for those accidents on motorways, 15% were DFD related. Also it showed that company car drivers had, as might be expected, a greater likelihood of suffering from DFD by virtue to their greater exposure to Long Distance Driving" [14].

Another major factor is Time of Drive. According to Sleep Research Laboratory, University of Loughborough, UK "In the United Kingdom there are clear times of day effects on DFD with peaks around 2:00-6:00am and 2:00-4:00pm. This has been found for other countries, such as the United States, Israel, Finland, and France. If the variations of traffic density over the day are taken into consideration, then the probability of DFD in the early morning is even greater. For example, at around 6:00am drivers are over 20 times

more likely to fall asleep at the wheel than at around 10:00am. At about 4:00pm they are three times more likely to do so than at about 10:00am or 7:00pm, the time when the circadian rhythm of sleepiness is least. Periods of the day vulnerable to DFD are distinct from the peak times for all road accidents in the United Kingdom, which occur during the commuting periods of around 8:00-9:00am and 5:00-6:00pm" [14].

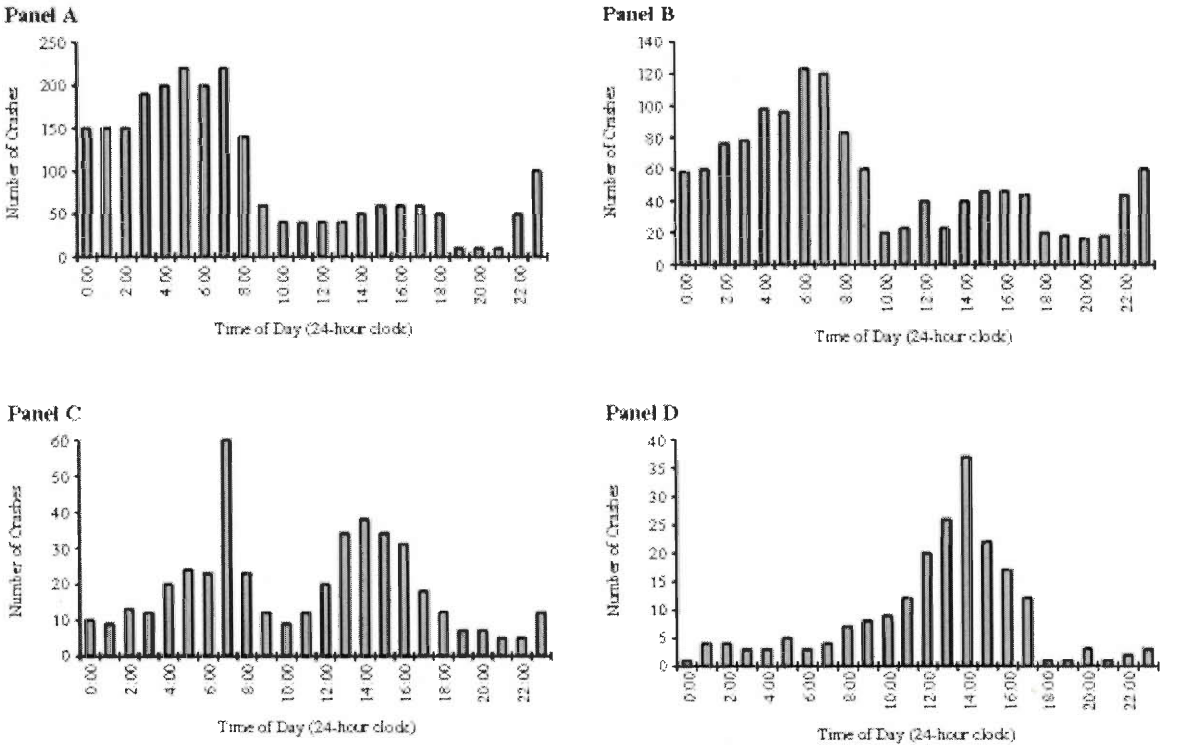

Fig. 4.3 Different time of crashes distributed on four different age groups [16] (Panel A: age 25 or less, B: age 26 to 45, C: age 46 to 60, D: age more than 60)

The last most important factor is the Effects of Drugs and Alcohol. Similar to our survey results, the Sleep Research Laboratory, University of Loughborough, UK stated that "Sleepiness produced by prescribed drugs, alcohol, and other substances, is influenced by the circadian changes in sleepiness. Alcohol consumed early in the afternoon is about twice as potent in producing sleepiness and driving impairment as the same dose taken in the early evening. In both situations, Blood Alcohol Concentrations (BAC) were similar. Even a working lunch with relatively small amounts of alcohol,

leading to BAC well within United Kingdom driving limits, can produce considerable driving impairment under motorway conditions. The business lunch involving moderate alcohol consumption, well within the legal driving limit, presents increased risk for motorway driving that afternoon" [14].

4.3 How Common Is DFD?

The pie chart presented in Fig 4.3 illustrates how common DFD is. The pie is divided into six pieces that indicate how often each category of the population falls asleep while driving; whether it is often, sometimes, rarely, very rarely, once in life or never. The number seen in each piece of the pie represents the percentage of each category out of the surveyed population that includes 269 participants. As an example, in the green section of the pie chart, the number 27 represents the percentage of the people that fall asleep at the wheel once a year out of the surveyed population (269 participants).

It can be determined from this chart that 82% of the population surveyed has fallen asleep at least once while they were driving, 52% more than twice a year and 9% more than once a month, which means that 82% of the population are in an ongoing danger and are causing problems for the society by endangering other drivers. These results are real, important and very serious, which lead to the fact that it is imperative to find a solution to the DFD.

The chart below helps enlighten the whole population on the gravity of the DFD problem and especially the persons subjected to it. As a result, they will be more worried and will be terrified and fearful for their lives.

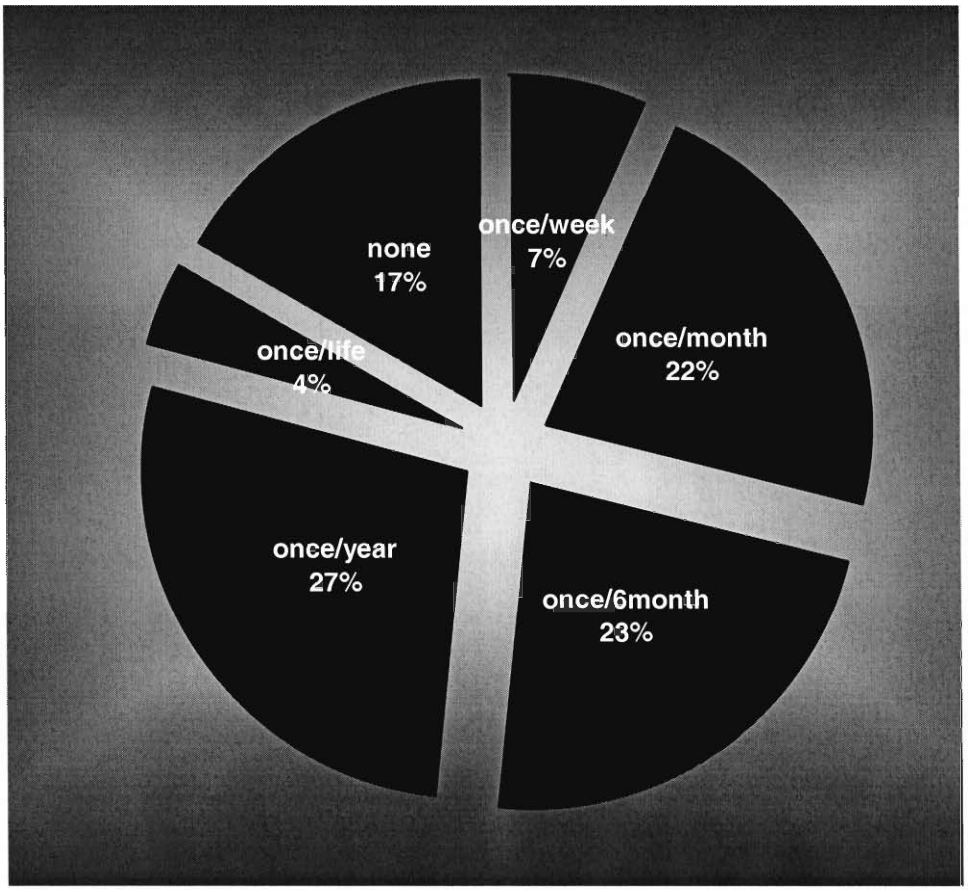

Fig. 4.4 How Common Falling Asleep at the Wheel is among the studied population

4.4 Solution's Importance

Driving is a major part of almost everyone's life routine and each individual driver could have a different problem. One of the common issues is sleeping while driving. In this survey, the people were asked their opinion about how imperative this problem is and how significant it is to solve the sleeping while driving problem? The pie chart Fig. 4.4 represents the result for this particular question.

It was found that only 54% of the surveyed people feel that this is a very important issue and 41% of them think it is important. A minority of 5% did not see it as a big problem. However, most of this minority experienced DFD or at least knew someone who has been suffering from it. On the other hand, 95% of the people who consider DFD an

important issue are concerned especially when dealing with people's life in this particular problem.

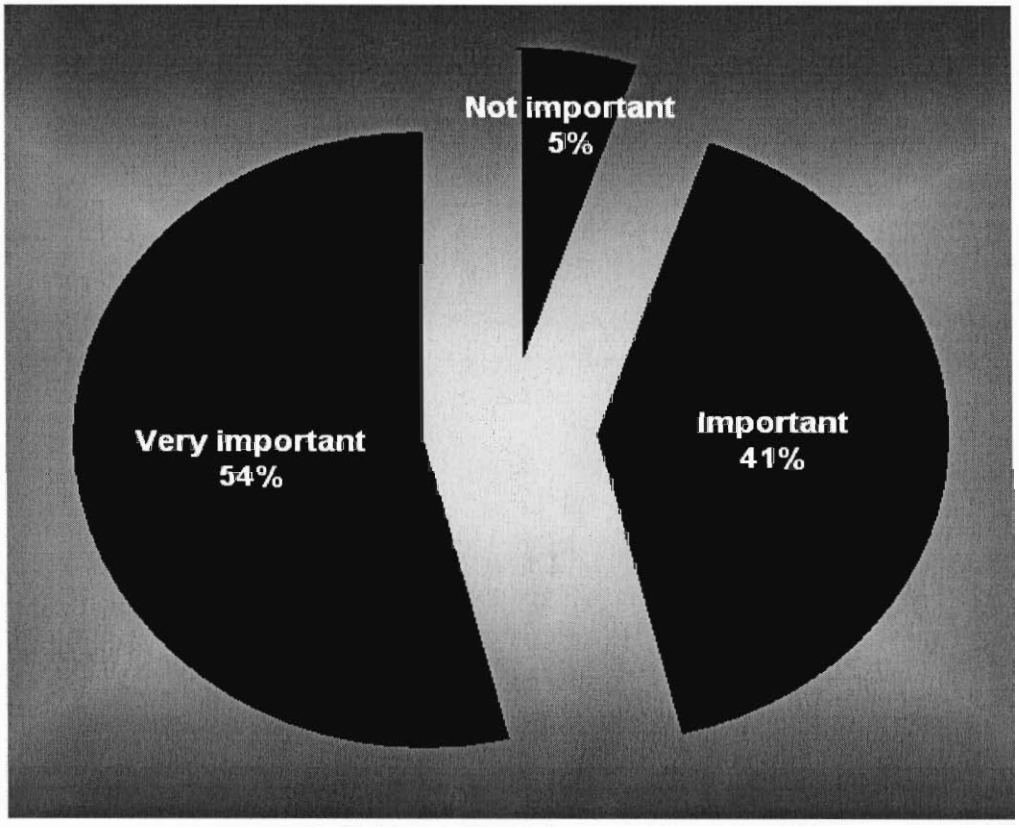

Fig 4.5 Importance of finding a Solution as perceived by the studied population

5 Sleep Physiology

Some people believe that sleep is a restorative behavior, allowing the body and the mind to rejuvenate, re-energize, and restore such that as a person sleeps, the brain performs vital house-keeping tasks including organizing long-term memory, integrating new information, etc. In this theory, sleep allows the body to rest and the mind to sort out past, present, and future activities and feelings. Yet others see sleep as a protective adaptive behavior. Nearly every animal sleeps to some degree. Thus, it only makes sense that predators sleep more than animals that are preyed upon. For humans, the amount and quality of sleep achieved is directly proportional to the amount and quality of the next day's productivity [11].

Restorative or adaptive, regardless of climate, or the amount of daylight, all humans follow similar sleeping patterns. Research has revealed the neurophysiology of sleep as a natural process that begins when the pineal gland in the brain releases melatonin, a hormone signaling time for sleep, in response to circadian rhythms (biological clock). As a person readies for sleep, breathing slows, muscles become limp, the heart rate slows, and body temperature decreases slightly. In contrast, the human brain never decreases in activity. Studies have shown that the brain is as active during sleep as it is when awake. During a night's sleep the brain functions to adjust bodily functions. The body temperature, heart rate , blood pressure, blood cell count, metabolism, kidney function, among other unconscious physiological activities will be adjusted to a state of rest [17].

5.1 What are the Stages of Sleep?

During sleep, people usually pass through five phases: stages 1, 2, 3, and 4 (non-REM), and REM (rapid eye movement) sleep. These stages progress in a cycle from stage 1 to REM sleep, then the cycle starts over again with stage 1. In an eight hour period of sleep the brain cycles through these stages 4 or 5 times. Approximately 75% of the sleep cycle is spent in non-REM sleep (50 percent in stage 2 sleep and 30 percent in other stages) and about 20 percent in REM sleep [10].

Stage 1 sleep (drowsiness): is a transition period from wakefulness to sleep. In this stage the person is less aware of her/his surroundings than just a few minutes ago. Although the muscles and breathing rate begin to relax, s/he may be awakened by even a whisper, or low level noise. The transition from awake to sleep occurs within minutes of the onset of slow rolling eye movements and lasts only a few minutes [10].

Stage 2 (light sleep): is often considered the official onset of consolidated sleep. In terms of brain activity it has the most complex forms of activity more than other stages. Approximately 45% of non-REM sleep is spent in Stage 2. Eye movement stops and brain activity and heart rate become slow and body temperature decreases [10].

Stages 3 and 4 (deep sleep): During these stages there are no eye movements or muscle activities. People who get awakened during deep sleep do not adjust immediately. They often feel groggy and disoriented for several minutes after they wake up [10].

REM sleep: This is the dreaming stage and the brain activity is quite similar to the awaken states. During REM sleep, breathing becomes more rapid, irregular, and shallow,

eyes jerk rapidly in various directions, and limb muscles become temporarily paralyzed as to stop the individual from acting out their dreams. Heart rate increases, blood pressure rises, and males develop penile erections. The first REM sleep period usually occurs about 70 to 90 minutes after we fall asleep. A complete sleep cycle takes 90 to 110 minutes on average. The first sleep cycles each night contain relatively short REM periods and long periods of deep sleep. But by morning, people spend nearly all their sleep time in stages 1, 2, and REM [17].

5.2 How is Sleep Affected?

Since sleep and wakefulness are influenced by different neurotransmitter signals in the brain, foods and medicines that change the balance of these signals affect whether we feel alert or drowsy and how well we sleep [17].

- Caffeinated drinks such as coffee and drugs such as diet pills and decongestants stimulate some parts of the brain and can cause inability to sleep.
- Heavy smokers often sleep very lightly and have reduced amounts of REM sleep. They also tend to wake up after 3 or 4 hours of sleep.
- Many people who suffer from insomnia try to solve the problem with alcohol -- the so-called night cap. While alcohol does help people fall into light sleep, it also robs them of REM and the deeper, stages of sleep. It keeps them in the lighter stages of sleep, from which they can be awakened easily.

5.3 Why is Sleep Important?

The human body requires a certain amount of sleep each night to function effectively. Sleep appears necessary for our nervous systems to work properly. Too little sleep leaves us drowsy and unable to concentrate the next day. It also leads to impaired memory and physical performance and reduced ability to carry out math calculations. Some experts believe sleep gives neurons used while we are awake a chance to shut down and repair themselves. Without sleep, neurons may become useless in energy or polluted [17].

5.4 How Much Sleep do People Need?

The amount of sleep each person needs depends on many factors, including age. Infants generally require about 16 hours a day, Teenagers need about 9 hours on average, while for most adults, 7 to 8 hours a night appears to be just about enough, although some people may need as few as 5 hours or as many as 10 hours of sleep each day. Women in the first 3 months of pregnancy often need several more hours of sleep than usual. The amount of sleep a person needs also increases if he or she has been deprived of sleep in previous days. Getting too little sleep creates a "sleep debt," which is much like being overdrawn at a bank. Eventually, your body will demand that the debt be repaid. We don't seem to adapt very well to getting less sleep than we need. According to the experts if you feel drowsy during the day, even during boring activities, you haven't had enough sleep. If you routinely fall asleep within 5 minutes of lying down, you probably have severe sleep deprivation, possibly even a sleep disorder [17].

Many studies make it clear that sleep deprivation is dangerous. Sleep-deprived people who are tested by using a driving simulator or by performing a hand-eye coordination task, perform as badly as or worse than those who are intoxicated. Being sleep deprived magnifies the effects of alcohol and so the person becomes much more impaired than someone who is well rested. Since drowsiness is the brain's last step before falling asleep, driving while drowsy can - and often does - lead to disaster. Caffeine and other stimulants cannot overcome the effects of severe sleep deprivation. Whatever the evolutionary or physiological reasons behind sleep, getting enough sleep, especially REM sleep is of great importance. A good night's sleep and a healthy sleep pattern depend on many circumstances such as the bed, activity level, and medications. Therefore, by avoiding drinking alcohol or caffeine and smoking before going to bed, listening to one's body, and keeping a regular sleeping schedule one can improve the amount of quality sleep and thus increase the amount of energy for the next day [17].

5.5 Microsleep

"Fatigue is a general term commonly used to describe the experience of being 'sleepy', 'tired' or 'exhausted'. Fatigue has been conceptualized as both a physiological and a psychological experience." [6] Because fatigue decreases the ability to judge people's own level of tiredness, people usually fight fatigue and try to stay awake. Microsleep occurs when a fatigued person is fighting sleep while performing a boring task such as highway driving. By definition microsleep is an unintended, brief period (usually only a few seconds 20 to 30) in which the brain enters a sleep state regardless of the activity the person is performing at the time [5].

Microsleep is a common phenomenon; it usually attacks sleep-deprived people while in a monotonous situation. Most people would have experienced a microsleep at some point in their lives, often without being alert to the event [6]. This problem is obviously causing dangerous situations to drivers. For example, a person under microsleep would cross a red light without noticing it, or even not realize that the road has taken a curve [6].

There are many technologies used to detect Microsleep. Some of them use the eye movement, the head position, or even the polysomnography measures including electroencephalography (EEG) electromyography (EMG) and electro-oculography (EOG) to record actual changes in levels of consciousness, ranging from fully alert wakefulness to impairments due to attention lapses, drowsiness and actual brief episodes of sleep intrusions into consciousness [7].

Eye Facial Rating: The subject's entire face was monitored using a low light, closed-circuit television camera for recording eyes and eyelids. According to study performed by Wierwille, divers in automobile simulator exhibit characteristics when fatigued that can be easily observed in eye and facial changes [8]. Aware drivers were observed to have normal facial tone and fast eye blinks. However, drowsy driver were reported to have decreased facial tone, slower eyelid movement and longer eyelid closures followed by eye movements that rolled upwards and sideways [8].

Head Position Monitoring: Head position is known to change with the increasing level of fatigue. With increasing fatigue, a person may begin to lose muscle tone in the neck and the head may begin to bob, drop or roll, which can be characteristic signs of

fatigue. In addition, it is believed that head motion may change depending on the degree of alertness of the individual [8].

EEG Monitoring: Electroencephalogram (EEG) is a graphical record of electrical activity of the brain produce by an electroencephalograph (EEGraph). Electrodes, filled with a conductive gel are placed on different areas on a person's scalp and than plugged into the EEGraph or recording device. The brain waves picked up by the electrodes being extremely low level are amplified so that the resulting EEG can be easily examined [9].

Looking at the possible technological devices that detect microsleep or other phenomena that relate to a specific area like Eye Monitor Devices it is better now to examine those specific areas. In this manner we, as a group may be able to further the search for a possible solution that can, not only detect drowsiness or microsleep, but also do something that might help these people overcome these problems. Possible recommendations listed below should enable these problems to be resolved at a higher level.

6 Current technology for detecting and preventing DFD

Many automobile manufacturers such as **BMW** and **VOLVO** are trying to create a product that helps prevent drowsy-driving accidents.

6.1 BMW:

In Munich, the BMW Group Research is testing a system on ConnectedDrive research vehicles that will reduce the risk of microsleep. They developed a driving alertness assistant which can recognize how watchful or tired the driver of a vehicle is. The information on the degree of tiredness is derived from how the driver is blinking. If the system recognizes that the driver is getting tired or is tired, it immediately gives appropriate feedback via a visual display. It's a system that informs the driver in which of four alertness or tiredness stages he is currently in.

The alertness assistant should be of assistance of the driver and warn him if his alertness is decreasing. However, the alertness assistant functions when the driver takes his place at the wheel and look through the windscreen, so at this moment a camera integrated in the car focuses on his eyes and automatically follows the head movements of the driver and records his eyes again. The system recognizes the degree of alertness or tiredness of the driver through the frequency and speed of his blinking and how open his eyelids are. Basically, a person who is awake blinks less often, but very quickly. And the more tired we are the more often we blink and the slower our blinking becomes and at the same time our eyes are gradually closing [15].

Before microsleep, BMW Group differentiates between four stages of alertness or tiredness, the system recognizes that the driver is awake (stage 1), two green diodes light up. If the driver is less alert (stage 2) or tired (stage 3) one or respectively two yellow diodes light up. If the driver finally becomes drowsy (stage 4) two red LEDs give a

warning that there is an acute risk of microsleep at any time. The approach of the BMW Group is not to wait with the warning until the driver is already drowsy, but to warn him before this, when his alertness is only slightly diminished. The process of becoming tired should be recognized as early as possible (in stage 2) and the driver warned before going into stages 3 or 4 and falling into a microsleep. Driving assistance does not relieve drivers of their responsibility Drivers should be assisted by being warned as early as possible when their alertness is decreasing. However, it is up to the drivers themselves to pay attention to this warning and cancel out further tiredness at the wheel by taking the correct steps.

Furthermore, BMW Group's next step is the integration of different assistance and information systems and a visual display. For example, automatic information on the next car park or the next hotel could be played into the navigation system - before microsleep approaches. [15]

6.2 VOLVO:

"NEW YORK (AP) Volvo is trying to retain its image as a leader in safety with new technology designed to help drowsy drivers. Volvo and its owner, Ford Motor Co., released results of a study on the problem at the New York Auto Show and announced plans for the technology to be included in Volvo cars and SUVs. Because the features are still several years from being offered in cars for sale, Ford was cagey about details for competitive reasons. It described a few different products that had been developed and were being considered as options. Ford spokesman Mike Vaughn said they tested computerized optical scanning and a variety of warnings: a vibrating steering wheel, the

sound of a car driving over rumble strips and a visual warning projected on the windshield. Researchers also tested a so-called "active" system in which the vehicle would actually adjust the steering automatically if it veered too far one way or the other. "We've been able to demonstrate that we have the ability to alert a drowsy driver to a lane departure and improve their performance," said Jeff Greenberg, a technical specialist in Ford's research and advanced engineering department [16].

"We're confident we can do it in ways that drivers will accept," Greenberg said. "The new system will be adaptive and intelligent." The safety enhancements also could be used on other Ford brands after Volvo's startup, the company said. Luxury carmaker Infiniti said last month it will begin offering lane-departure warning systems in vehicles later this year, the first use of such accident-avoidance technology in North American passenger cars. Employing a small camera, speed sensor and warning buzzer, the system is designed to alert drivers of unintentional movement out of a designated traffic lane. It will be offered this fall on 2005 models of Infiniti's FX sport utility vehicle, then again next spring on the 2006 M45 luxury sedan.

Ford and others have experimented with devices and high-tech systems to help stifle drowsy driving for at least two decades. But Art Spinella, president of CNW Marketing Research in Bandon, Ore., said he's not aware of any carmakers offering an instrument specifically designed to alert drivers when they're dozing at the wheel. Spinella said automakers have studied systems that use cameras to scan drivers' eyes or sense when they're loosening their grip on the steering wheel beyond normal. The challenge, he said,

has been developing a marketable device without hitches. "The issue is liability," Spinella said. "It has to be literally 100 percent fool proof before an automaker will use it" [16]

7 Recommendations

This section of the report is addressed to the drivers and the government. It lists some helpful advice and recommendations, which would help reducing the number of incidences caused by DFD.

7.1 Recommendation to Drivers

If a driver is suffering of one or more of the following symptoms, he or she should be very careful. Answering yes when asked "If you:

- can't remember the last few miles driven
- have wandering or disconnected thoughts
- experience difficulty focusing or keeping your eyes open
- have trouble keeping your head up
- drift from lanes or hit a rumble strip
- yawn repeatedly
- tailgate or miss traffic signs
- find yourself jerking your vehicle back into lane

Then you may be suffering from DFD. Continuing to drive in this condition puts you and other at serious risk of being involved in a fatigue-related crash. You should pull over in a safe place and get some rest before resuming your trip (Also see appendix B).

7.2 Recommendations to the U. S. government

In order to reduce the DFD problem and to preserve the public's safety, there are some procedures that the government should take into consideration:

The government should start or even progress the legislation that forces car manufacturing companies to implement some kind of sleep detection in their cars to avoid DFD incidents. Also it should implement sleep bumpers between lanes (bumpers can be as wide as the white dashes and between them) which will prevent drivers' drifting between lanes involuntarily.

In addition, study showed that the best way to avoid DFD is to take a quick nap for 15 minutes. To that the government should provide more of the small rest areas were people can park and nap for a little while before pursuing a long journey. Also study proved that drinking coffee helps regaining alertness. An answer to that would be to have at least one coffee shop in each of these small rest areas.

Last thing the government should do is ask the large companies to provide a 15 minutes nap time after long hours of work and before drivers hit the road back home or anywhere else. Companies should be force to respect human rights by limiting work hours to eight as it's done in Europe. This will relieve the workers' fatigue and send safe drivers into the streets. [3]

8 Conclusion

This project is conducted as an Interactive Qualifying Project that deals with Driving Fatigue and Drowsiness. Work, study and other time schedules should be planned to minimize exposure to prolonged driving under monotonous conditions during the more vulnerable times of the day and night. The best and most accurate information drivers have at their disposal about their state of sleepiness comes from their own self-awareness of sleepiness. What many drivers fail to appreciate is that sleepiness leads to sleep, which can come on more rapidly than they realize, especially if the driver has reached the more profound stage of fighting off sleep.

This involves acts such as opening the vehicle's window, turning up the radio, the driver often moving around in the driving seat-actions whereby the driver must fully realize that he or she is very sleepy. At which point the driver should stop driving as soon as possible and take a break for at least 30 minutes, drink caffeinated coffee, and if feasible, take a brief nap [14]. The problem of sleeping-while-driving is very popular. A lot of people have experienced it, and thankfully some of them are still here to talk about it. In summary, we advocate heightened public awareness, greater employer responsibility, and better education of drivers about DFD, which cause numerous road casualties each year.

9 References

[1] Auto channel
www.theautochannel.com/F/news/press/date/19991119/press003384.html

[2] Drowsy driving and fatigue index
www.nysgtsc.state.ny.us/drow-ndx.htm

[3] NHTSA, National Highway Traffic Safety Administration
www.nhtsa.dot.gov

[4] American Automobile Association / Foundation for Traffic Safety / Omnibus Poll
www.aaafts.org

[5] Online dictionary where we looked up the work Microsleep
www.dictionary.com

[6] Road & Traffic Authority
www.rta.nsw.gov.au

[7] Microsleep Episode; The University of Iowa
http://ppc.uiowa.edu/

[8] Wierwille and Ellsworth 1994
www.nhtsa.dot.gov

[9] Supported by Argosy University www.alleydog.com

[10] The sleep disorder channel www.sleepdisorderchannel.net/stages

[11] Sleep disorders (what you need to know about)
www.sleepdisorders.about.com

[12] NTSB, National Transportation Safety Board
www.ntsb.gov/publictn/1999/SR9901.pdf

[13] Australian transport safety bureau www.atsb.gov.au

[14] Sleep Research Laboratory, University of Loughborough, UK
Occupational and Environmental Medicine Volume 56(5), May 1999, pp 289-294

[15] BMW website and research center
peachtreebmwcca.org/BMWPressNews/showquestion.asp?faq=5&fldAuto=211

[16] Smart Motorist www.smartmotorist.com/dro/dro.htm

[17] Sleep study www.sleepstudy.org/review/sleepEEG.htm

[18] Case Study Dr. Denise Nicoletti http://users.wpi.edu/~cdemetry/Parente1.htm

[19] National Sleep Foundation www.NSF.gov

Appendix A

This is the survey as presented online.

HAVE YOU EVER FALLEN ASLEEP WHILE DRIVING?

Dear Friends, we are a group of WPI students, who are working on an assigned project (IQP) that deals with the fact that sometimes drivers fall asleep while driving. We would like to investigate how prevalent this problem is. Your sincere answers to the following questions will be a great help to our project. All your answers will be kept confidential.

1. GENDER:

1. ☐ Male
2. ☐ Female

2. AGE:

1. ☐ 16 - 21
2. ☐ 21 - 27
3. ☐ 27 - 35
4. ☐ 35 - 47
5. ☐ 47 - 60
6. ☐ 60 or older

3. STATUS:

1. ☐ Single
2. ☐ Married
3. ☐ With children (how many) ____

4. PROFESSION:

____

5. HOW MANY HOURS PER WEEK DO YOU WORK?

6. HOW MANY JOBS DO YOU HOLD NOW?

7. HAVE YOU EVER FELT DROWSY, ALMOST ASLEEP WHILE DRIVING?

1. ☐ Yes
2. ☐ No

8. IF YES, HOW OFTEN?

1. ☐ Often (once/week)
2. ☐ Sometimes (once/month)
3. ☐ Rarely (once/6month)
4. ☐ Very rarely (once/year)
5. ☐ Other (please specify)

9. HOW MANY HOURS OF SLEEP DO YOU GET ON A TYPICAL NIGHT?

1. ☐ Less than 6 hours
2. ☐ 6 - 8 hours
3. ☐ More than 8 hours

10. DO YOU FEEL LIKE YOU ARE GETTING ENOUGH SLEEP?

1. ☐ Yes
2. ☐ No

11. WHAT KIND OF CAR DO YOU DRIVE?

Make Model Year

12. HOW OFTEN DO YOU USE CRUISE CONTROL?

1. ☐ Everyday
2. ☐ Sometimes
3. ☐ Other ____

13. HOW LONG HAVE YOU BEEN DRIVING?

1. ☐ 1 - 4 years
2. ☐ 4 - 10 years
3. ☐ Other ____

14. DURING WHAT PERIODs OF THE DAY DO YOU DO MOST OF YOUR DRIVING?

1. ☐ Morning
2. ☐ Mid day
3. ☐ Evening
4. ☐ Late night

15. HOW MANY MILES DO YOU DRIVE PER WEEK?

1. ☐ Less than 50
2. ☐ 50 - 150
3. ☐ 150 - 300
4. ☐ More than 300

16. DO YOU THINK THAT ALCOHOL OR DRUGS MAKE PEOPLE SLEEPY?

1. ☐ Yes
2. ☐ No
3. ☐ Sometimes

17. OF THE FOLLOWING, SHOW THE DEGREE OF RELEVANCE TO SLEEPINESS WHILE DRIVING:

	==> Importance ==>
	1==2==3==4==5
1. Long distance drive	☐ ☐ ☐ ☐ ☐
2. Familiar roads	☐ ☐ ☐ ☐ ☐
3. Temperature	☐ ☐ ☐ ☐ ☐
4. Time of driving	☐ ☐ ☐ ☐ ☐
5. Cruise control	☐ ☐ ☐ ☐ ☐
6. Effects of drugs/alcohol	☐ ☐ ☐ ☐ ☐

18. INCOME PER YEAR?

1. ☐ Less than $15,000
2. ☐ $15,000 - $35,000
3. ☐ $35,000 - $75,000
4. ☐ More than $75,000

19. HOW IMPORTANT IS IT TO SOLVE THE SLEEPING WHILE DRIVING PROBLEM?

1. ☐ Not important
2. ☐ Important
3. ☐ Very important

20. COMMENTS:

Appendix B

This table was made by the AAA research team. It has a list of causes and recommendation to drivers who suffers DFD.

Rank	Behavior
1	Letting someone else drive for 1-2 hours while you sleep in the passenger seat before driving again
2	Pulling off road to take a 30-45 minute nap
3	Pulling off road to take a nap for >1 hour
4	Pulling off road to take a 10-20 minute nap
5	Pulling off road to exercise for 10 minutes
6	Pulling off road to consume caffeinated beverage
7	Pulling of road to walk for 10 minutes
8	Conversing with someone in vehicle
9	Consuming caffeinated beverage while driving
10	Stopping by rest area to wash face with cold water
11	Taking legal stimulants while driving
12	Rolling down window of vehicle
13	Singing while driving
14	Listening to stimulating music while driving
15	Listening to loud music in vehicle
16	Talking on the car phone or CB radio
17	Letting someone else drive for 1-2 hours while you rest but do not sleep before driving again
18	Changing the temperature in the vehicle
19	Pulling off road to eat a snack
20	Chewing on ice while driving
21	Driving on an unfamiliar route
22	Listening to talk radio or sports talk show
23	Pulling off road to rest for 10-20 minutes without sleeping
24	Pulling off road to consume non-caffeinated beverage
25	Pulling off road to rest for 30-45 minutes without sleeping

26	Talking on cellular phone while driving
27	Performing hand, arm, or leg exercises while driving
28	Slapping/pinching oneself
29	Listening to a radio/tape story
30	Chewing gum while driving
31	Smelling something unpleasant while driving
32	Pulling off road to eat a meal
33	Consuming non-caffeinated beverage while driving
34	Chewing tobacco while driving
35	Rolling head and/or shoulders while driving
36	Smoking while driving
37	Eating something nutritious while driving
38	Eating a low calorie snack while driving
39	Sitting up straight while driving
40	Changing driver's seat position
41	Moving driver's seat upright
42	Playing mind games while driving
43	Eating something non-nutritious while driving
44	Tapping fingers to music while driving
45	Talking to yourself while driving
46	Having a peppermint scent release in vehicle
47	Eating a high calorie snack while driving
48	Looking at scenery while driving
49	Focusing intently on driving task itself
50	Having a menthol scent released in vehicle
51	Thinking while driving
52	Squeezing the steering wheel while driving
53	Smelling something pleasant while driving
54	Changing lanes on the highway
55	Turning light on in vehicle while driving
56	Increasing speed
57	Keeping a good attitude about yourself
58	Tightening seat belt
59	Loosening clothing

60	Taking shoes off
61	Loosening seat belt
62	Propping foot up on dashboard
63	Removing seat belt
64	Removing driver's head rest
65	Meditating while driving
66	Putting car in cruise control
67	Taking pain medication
68	Driving alone
69	Taking allergy medication
70	Continuing to drive (Doing nothing)