

**Policy Implications of Ubiquitous Technologies in the Car:
Privacy, Data Ownership, and Regulation**

by

Alex Fernando Narváez Bustamante

Bachelor of Science in Electrical Engineering
Worcester Polytechnic Institute, 2000

Submitted to the Engineering Systems Division
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Technology and Policy

at the

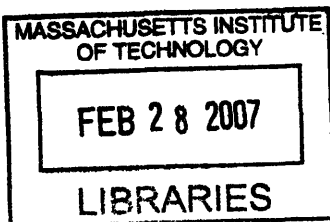
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
September 2006

©2006 Massachusetts Institute of Technology
All rights reserved.

Signature of Author.....
Technology and Policy Program, Engineering Systems Division
August 11, 2006

Certified by.....
Joseph F. Coughlin
Director MIT AgeLab
Engineering Systems Division
Thesis Supervisor

Accepted by.....
Dava J. Newman
Professor of Aeronautics and Astronautics and Engineering Systems
Director, Technology and Policy Program



ARCHIVES

Policy Implications of Ubiquitous Technologies in the Car: Privacy, Data Ownership, and Regulation

by

Alex Fernando Narváez Bustamante

Bachelor of Science in Electrical Engineering
Worcester Polytechnic Institute, 2000

Submitted to the Engineering Systems Division on August 11, 2006
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Technology and Policy

Abstract

Motor vehicle travel is the primary means of transportation in the United States, providing freedom in travel and enterprise for many people. However, motor vehicle accidents are the largest component of unintentional injuries and contribute to a high degree of morbidity and mortality for all ages.

This thesis analyzes the relationship between feedback technologies and driver behavior. Based on the findings, policy recommendations were made to help ensure that the privacy and trust of the public are not compromised, as ubiquitous technologies become a reality in automobiles.

The thesis provides an overview of the most modern mechanisms available in cars today. Furthermore, this thesis takes the first steps to combining existing technologies into a single system that not only tracks driver behavior, but also provides feedback in the hopes of improving drive performance and safety.

The qualitative discussion includes a stakeholder analysis of the prime interests and effects of all parties that are impacted by ubiquitous technologies in the car. The qualitative discussion also contains the results of four focus groups that were conducted to gain first hand insights about the view of the drivers about monitoring technologies in the car.

This study finds that most drivers have a symbiotic relationship with the technologies that exist in their car; however, drivers feel uncomfortable with a fully automated system. Their concerns rise from the belief that fully automated systems take control away from the driver. Drivers were also concerned about the privacy and security of the data collected and stored by these technologies in their vehicles. These concerns can be addressed within the existing legal framework, but additional regulations also need to be designed because as the technology changes so will the concerns. Therefore, it is important to design policies that are flexible, rather than completely depending on current regulations to address future concerns.

Thesis Supervisor:
Dr. Joseph Coughlin
Director MIT AgeLab
Engineering Systems Division

Acknowledgements

This marks the end of a unique experience in my life. This experience would not have been unique without the support of very special people.

This research was conducted at the MIT AgeLab and was supported by the USDOT New England University Transportation Center, The Hartford, and Ford Motor Company.

I would like to dedicate this achievement and also thanks Dr. Joseph Coughlin for believing in me and for his guidance, support, and encouragement not just as an academic advisor but also as a mentor and a friend.

Deseo tambien agradecer a mis padres Francisco y Martha, y en especial a mi hermano Xavier por todo el apoyo, comprension y ayuda durante este tiempo.

My genuine gratitude to my dear friends Jayeeta Kundu, Jasmin Lau, and Carlos Osorio for their friendship, help, and unconditional support throughout this experience.

Many thanks to my friends from TPP: Reynaldo Sandoval, Mike Berlinski, Ned Calder, Salem Esber, Theo Patramanis, Meghan Sweeney, and Mark Bohn for all the great moments we spent together.

Thanks to Lisa D'ambrosio, Bryan Reimer, and my colleagues and friends from the AgeLab: Roz Puleo, Paula Magliozzi, John Long, Michelle Pratt, Alex Pina, and George Gennis, for their friendship, support, and humor

My sincere appreciation to Sydney Miller for all her concern, help, and support and to the people devoted to TPP: Dava Newman, Frank Field, and Yoko Urano.

Last but not least, to Jennifer Stine, Beverly Foxx, Dianne Molino, and Margaret McCabe, for all their support and guidance on the first steps of this memorable experience.

Table of contents

ABSTRACT	2
ACKNOWLEDGEMENTS.....	3
TABLE OF CONTENTS	4
LIST OF FIGURES.....	6
LIST OF TABLES	7
CHAPTER 1. INTRODUCTION AND OBJECTIVES.....	8
1.1. FEEDBACK BY TECHNOLOGY	8
1.2. DRIVING BEHAVIOR CHANGE VIA TECHNOLOGY FEEDBACK.....	8
1.3. POLICY IMPLICATIONS	8
1.4. THESIS OBJECTIVES	8
1.5. THESIS OUTLINE.....	9
CHAPTER 2. BACKGROUND AND MOTIVATION	10
2.1. RATE AND COSTS OF ACCIDENTS INVOLVING MOTOR VEHICLES IN THE UNITED STATES.....	10
2.2. EFFECTS OF DISTRACTION IN THE OPERATION OF MOTOR VEHICLES	12
2.3. THE NEED FOR OBJECTIVE DATA ABOUT DRIVING BEHAVIOR TO IMPROVE MOTOR VEHICLE SAFETY	13
2.4. CURRENT APPROACHES TO MOTOR VEHICLE SAFETY	14
2.5. IMPROVING MOTOR VEHICLE SAFETY TROUGH TECHNOLOGY	15
CHAPTER 3. TECHNOLOGY ATTEMPTS FOR MOTOR VEHICLE SAFETY.....	17
3.1. EVENT RECORDING MECHANISMS.....	17
3.1.1. Motor vehicle Event Data Recorders (MVEDR).....	17
3.1.1.1. General Motors (GM) Sensing and Diagnostic Module (SDM).....	18
3.1.1.2. Ford Motor Company Restrain Control Module (RCM).....	19
3.1.2. Motor vehicle Event Parameters from the On-Board Diagnostic (OBD) Port.....	19
3.1.2.1. Electronic devices for measuring and recording driving exposure: Progressive Insurance TripSensor™.....	20
3.2. ROAD-WARNING MECHANISMS	21
3.2.1. Route Guidance Systems (RGS).....	22
3.2.2. Speed Adaptation Systems (SAS).....	23
3.2.3. Lane Keeping System (LKS).....	23
3.2.4. Collision Avoidance Systems (CAS).....	24
3.3. CONTEXT-AWARE MECHANISMS	24
3.3.1. Context aware ubiquitous computing in the car.....	24
3.3.2. Research platform: AgeLab's Driver Aware Car (ADAC)	25
3.3.2.1. Conceptual model	25
3.3.2.2. Technology model	28
CHAPTER 4. LITERATURE ON PERSONAL TRADE-OFFS IN CONTEXT-AWARE UBIQUITOUS COMPUTING IN THE CAR.....	34
4.1. UBIQUITOUS COMPUTING AND ITS THREAT TO PRIVACY	34
4.2. PRIVACY IMPLICATIONS OF UBIQUITOUS COMPUTING IN THE CAR	34
4.3. CHALLENGES IN BUILDING PRIVACY-SENSITIVE UBIQUITOUS COMPUTING APPLICATIONS.....	35
4.4. DATA OWNERSHIP OF INFORMATION COLLECTED VIA UBIQUITOUS COMPUTING APPLICATIONS IN THE CAR.	36
4.5. PRIVACY AND PUBLIC POLICY IN CONTEXT-AWARE UBIQUITOUS COMPUTING	36
CHAPTER 5. SYSTEMATIC APPROACH TO STAKEHOLDER ANALYSIS.....	38
5.1. STATEMENT OF RESEARCH QUESTIONS	38

5.2. STAKEHOLDERS ANALYSIS	38
5.2.1. Identification of interest and effects on stakeholders	38
5.3. QUALITATIVE ANALYSIS.....	39
5.3.1. Participants.....	40
5.3.2. Focus groups	41
5.3.3. Data analysis procedure	41
5.4. FINDINGS.....	42
5.4.1. Characteristics of safe and good drivers.....	42
5.4.2. Receptivity about getting feedback on driving performance	43
5.4.3. Experience with technology to enhance and improve driving.....	43
5.4.4. Benefits and drawbacks of technology as means of giving feedback on driving behavior	45
5.4.5. Preferences of feedback delivery through technologies in the car	46
5.4.6. Attitudes towards privacy, trust, data sharing/ownership.....	48
5.5. DISCUSSION	51
5.6. IMPLICATIONS.....	52
5.6.1. Implications for technology innovation	53
5.6.2. Implications for public policy.....	54
CHAPTER 6. FUTURE RESEARCH AND APPLICATIONS BEYOND THE CAR	56
BIBLIOGRAPHY	58
APPENDIX A	62
APPENDIX B	66
APPENDIX C	73

List of figures

Figure 1: Proportion of Motor vehicles Involved in Traffic Accidents.....	10
Figure 2: Example of GM (SDM) pre-crash information.....	18
Figure 3: Example of Ford MVEDR (RCM) pre-crash information.....	19
Figure 4: OBD-II port provides access to on-board vehicle sensors via ECMs ...	20
Figure 5: Data Elements available from the OBD-II port.	20
Figure 6: Overview of TripSensor™ system.....	21
Figure 7: System model for AgeLab’s Driver Aware Car (ADAC)	25
Figure 8: Method to stimulate and predict driver behavior	26
Figure 9: Driver Aware Car (ADAC) - Top Level Architecture	28
Figure 10: Context-Aware Car (ADAC) - Architecture Interface	29
Figure 11: Block Diagram of On-Board Sensors.....	30
Figure 12: Block Diagram – Peripherals Devices.....	31
Figure 13: Collection Agent - Peripheral Devices Architecture.....	32
Figure 14: Modules – Data Retrieval Algorithm	32
Figure 15: Technology Enabled Pathway to Information Access.....	53

List of tables

Table 1: Economic Costs of Motor Vehicle Accidents	11
Table 2: Comprehensive Costs of Motor Vehicle Accidents.....	11
Table 3: Examples of Motor vehicle Safety Mechanisms	14
Table 4: Examples of modern road-warning mechanisms	22
Table 5: Algorithm / Method to simulate and predict driver behavior.....	27
Table 6: On-Board Sensors List*	29
Table 7: List of Peripheral Devices	30
Table 8: Overview of Stakeholders Analysis.....	39
Table 9: Characteristics of Good Drivers	42
Table 10: Characteristics of Bad Drivers.....	42
Table 11: Main Definition of Good and Safe Drivers.....	43
Table 12: Technologies to Enhance Safety and Driving Behavior	44
Table 13: Interests of Participants about Technologies in the Car.....	44
Table 14: Perceived Impact of Monitoring Technologies in the Car	45
Table 15: Perceptions Where Technologies are Most Helpful	46
Table 16: Feedback Domains.....	47
Table 17: Relevant Feedback Categories among Groups.....	48
Table 18: Willingness to Share Personal Information - Younger / Bad Driver Groups	49
Table 19: Willingness to Share Personal Information - Older / Bad Driver Groups	49
Table 20: Willingness to Share Personal Information - Younger / Good Driver Groups	50
Table 21: Willingness to Share Personal Information - Older / Good Driver Groups	50
Table 22: Perceived Incentives to Share Personal Information	51
Table 23: Legal Mechanisms for the Protection of Privacy and Personal Information	55
Table 24: Public Questions and Policy Concerns Surrounding Ubiquitous Technologies	57

Chapter 1. Introduction and Objectives

1.1. Feedback by technology

Technology exists today that has the capability to provide feedback about specific environmental settings. Using the automobile as the environment, these technologies collect information about the driver, road condition, and the vehicle itself through a series of sensors and diagnostics capabilities that already exists in the modern vehicle. The real value these technologies bring is in their ability to collect a variety of data from various sources simultaneously and distill this data into valuable information to assist the driver.

While many sensing technologies exist today, many more are in development and will begin to appear in automobiles in coming years. The research presented in this thesis takes the first steps to integrating these technologies into a single system that not only tracks driver behavior, but also provides feedback in the hopes of improving drive performance and safety. Moreover, this thesis seeks to identify key policy considerations as these technologies and services enter the automobile.

1.2. Driving behavior change via technology feedback

Whether or not sensing technologies in automobiles are able to add value depends on how they are received by the driver. These technologies are only valuable if drivers use the information provided by them to improve their driving behavior. Given this fact, one of the goals of this thesis is to examine what aspects of sensing technologies drivers find useful and which ones they do not find beneficial. Focus groups and a stakeholder analysis were conducted to gather information about drivers' view about different sensing technologies. The results from these analyses are used to shape the policy recommendations made in this thesis.

1.3. Policy implications

Sensing technologies work by collecting data on the driver, as well as the environment. Because the driver information is personal, this type of data collection raises concerns about privacy, security and trust. It is the roles of policy to help mitigate any concerns that the public may have about private information collection. In the realm of sensing technologies in automobiles policy must be designed to ensure the security of the data collected on the driver and protect the privacy of the individual. This thesis identifies potential barriers to innovations (i.e. privacy,) as well as making policy suggestions to help achieve the goal of securing the public trust on these technologies.

1.4. Thesis objectives

Motor vehicle travel is the primary means of transportation in the United States, providing freedom in travel and enterprise for many people. Motor vehicle accidents are the largest component of unintentional injuries and contribute to a high degree of morbidity and mortality for all ages.

The motivation for this thesis comes from the fact that more than 42,000 Americans die in motor vehicle accidents, making this the leading cause of unintentional

injury deaths in the United States (Traffic Safety Facts, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System, 2004.) As motor vehicle accidents are predictable and preventable, many of these fatalities could have been avoided with in-vehicle applications leveraging on technologies that already exist. However, such technologies have yet to be applied to the standard passenger vehicle.

For this thesis, ubiquitous in-vehicles technologies based on context-aware models were researched as a concept-mechanism for the collection of information about driver behavior to provide real-time feedback to enhance motor vehicle safety. This concept-mechanism is recommended as a framework for future developments of in-vehicle technologies.

It is common for applications of this nature to face a plethora of policy barriers, including privacy, data-ownership, and regulation. Therefore, to understand these barriers and, an exploratory research based on qualitative methods is included addressing the following questions:

- Can context-aware ubiquitous technologies in the car collect data about drivers to provide real-time monitoring and post-process feedback about their driving behavior?
- Can driving behavior be changed by post-processing feedback from data collected by context-aware ubiquitous technologies in the car?
- What policy implications in a) privacy, b) data ownership, and c) regulation will be raised by the use of context-aware ubiquitous technologies in the car for the collection and sharing of real-time information of motor vehicle drivers?

1.5. Thesis outline

This thesis contains six major sections. Chapter 1 is the introduction, and Chapter 2 gives the motivation and background to this thesis. Chapter 3 provides a discussion on the current state of motor vehicle technologies and also offers a glimpse into the future of ubiquitous technologies in the automobile industry. Chapter 4 contains a summary of previous research that has been done on the issues of privacy, data ownership, and trust in the area of ubiquitous computing. Chapter 5 contains a stakeholder analysis and the results of the focus groups, as well as providing policy recommendations based on the findings of the research presented in this thesis. Finally, Chapter 6 presents future areas of expansion for this research.

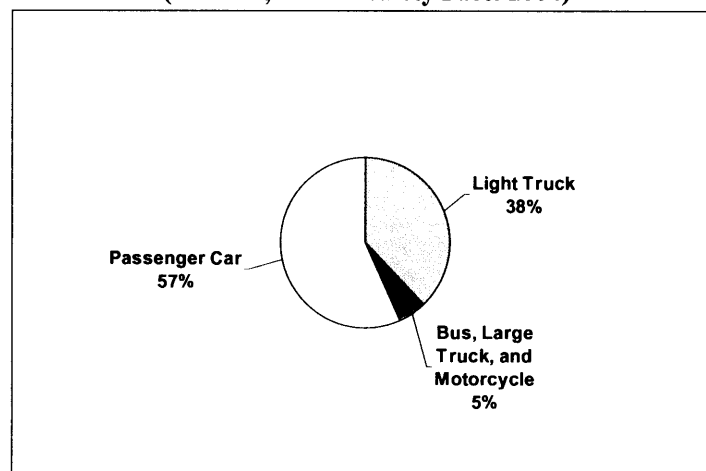
Chapter 2. Background and Motivation

2.1. Rate and costs of accidents involving motor vehicles in the United States

Accidents involving motor vehicles in the United States result in tens of thousands of fatalities and millions of injuries each year. The high rate and costs of these accidents demonstrate the necessity for continued efforts to find innovative ways to increase the safety of transportation operations in the United States.

A compilation of 2004 United States data calculated on numbers stated in a National Highway Traffic Safety Administration report (NHTSA) showed that Nearly 6.2 million police-reported motor vehicle crashes occurred in the United States in 2004. Almost a half of these crashes - nearly 2.8 million - resulted in an injury, with 42,363 of them resulting in a death (Traffic Safety Facts, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System, 2004.) Involved in these crashes were approximately 11 million vehicles, where nearly 95 percent of them were passenger cars of light trucks (Figure 1) and 99 percent of them resulted from highway crashes (U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, 2005.)

Figure 1: Proportion of Motor vehicles Involved in Traffic Accidents (NHTSA, Traffic Safety Facts 2004)



Data about the rate of accidents involving motor vehicles drivers, the fact that 193.3 million people drive in the United States, and there are more than 249 million register vehicles in the United States (National Safety Council (NSC), Injury Facts, 2006,) a high percentage of members in our society are at risk due to of motor vehicle accidents. Statistically speaking, motor vehicle accidents are the largest component of unintentional injuries which is ranked as the fifth leading cause of death exceeded only by heart disease, cancer, stroke, and respiratory diseases (Minino A.M., Heron M.P., Smith B.L., 2006.)

A 2004 U.S. Department of Transportation (DOT,) Transportation Statistics Annual Report (Research and Innovative Technology, Bureau of Transportation Statistics,

2004) calculates the economic cost of motor vehicle accidents occurring in 2000 to be \$231 billion, or about \$820 per person on 2 percent of the Gross Domestic Product (GDP). Costs include wage and productivity losses, medical expenses, administrative expenses, motor vehicle property damage, and employer costs.

In reality, the real costs associated with motor vehicle accidents are higher. For instance, there are two methods commonly used to measure the costs of motor vehicle crashes. The first one is the economic cost framework, and the other is the comprehensive cost framework (National Safety Council (NSC), Injury Facts, 2006).

On the one hand, economic costs may be used by a community or state to estimate the economic impact of motor vehicle crashes that occurred within its jurisdiction in a given time period. It is a measure of the productivity lost and expenses incurred because of the crashes. On the other hand, comprehensive costs include not only the economic cost components, but also a measure of the value of lost quality of life associated with the deaths and injuries, that is, what society is willing to pay to prevent them. The values of lost quality of life are usually obtained through empirical studies of what people actually pay to reduce their safety and health risks, such as through the purchase of safety devices such as air bags or smoke detectors

A 2006 report from the United States National Safety Council (NSC) indicated that the average economic costs (Table 1) in 2004 per death was nearly 1.2 million dollars, for nonfatal disability injury exceeded the 130 thousands dollars, and the property damaged (including minor injuries) to be about 75 hundred dollars (National Safety Council (NSC), Injury Facts, 2006.)

**Table 1: Economic Costs of Motor Vehicle Accidents
(National Safety Council, 2006)**

Death	\$ 1,130,000
Nonfatal Disabling Injury	\$ 49,700
Incapacitating Injury	\$ 58,000
Nonincapacitating evident injury	\$ 18,900

The same report also indicated that the average comprehensive costs in 2004 per death was nearly 3.8 million dollars, for incapacitating injury exceeded the 185 thousands dollars, for non-incapacitating evident injury exceeded the 48 thousands dollars, for possible injury about 23 thousand, and for no-injury to be approximately 22 hundred dollars (National Safety Council (NSC), Injury Facts, 2006.)

**Table 2: Comprehensive Costs of Motor Vehicle Accidents
(National Safety Council, 2006)**

Death	\$ 3,760,000
Incapacitating Injury	\$ 188,000
Nonincapacitating evident injury	\$ 48,200
Possible Injury	\$ 22,900
No Injury	\$ 2,100

2.2. Effects of distraction in the operation of motor vehicles

Modern automobiles contain a wide variety of interactive accessories. Although these accessories are designed to enhance the driving experience, they can sometimes draw attention away from the real job behind the wheel, piloting the vehicle. While elaborate stereo systems, climate controls, and even cellular telephones can be used safely during most driving situations, in demanding situations these accessories can possibly become an untimely distraction (David K., Earle E., 2002.)

At the present, with the proliferation of interactive accessories into the vehicle and the social impact of this behavior, drivers must once again adapt their management techniques for these devices. Until now, that job has been left up to the driver alone to make the device management decisions.

The increasing number of traffic accidents due distraction from motor vehicle drivers has become a serious problem for society. According to the U.S. National Highway Traffic Safety Administration (NHTSA), driving inattention is responsible for at least 100 thousand automobile crashes annually (Traffic Safety Facts, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System, 2004.)

The problem of driver distraction is exacerbated with the increasing cognitive stress related to the incorporation of vehicle gadgets such as cell phones or navigation devices in the vehicle. That is, the more assistant systems navigation or communication, the more sources of distraction from the most basic task of driving the vehicle. Moreover, there is evidence that driver inattention may be a growing highway safety problem. According to the National Sleep Foundation, the number of shift workers in the United States increases by 3 percent per year, and these workers face an increased risk of involvement in sleep-related crashes (National Sleep Foundation, 2005.)

Driver distraction can be manifested in several ways. For instance, lack of attention can be displayed in both degraded vehicle control and degraded object and event detection. People experiencing degraded vehicle control and event detection can show some easily observable visual behaviors from the changes in their facial features like the eyes, head, and face (Brown, I.D., 1994.) Typical visual characteristics observable from the images of a person with a reduced alertness level include a longer blink duration, slow eyelid movement, smaller degree of eye opening, frequent nodding, yawning, gaze, sluggish facial expression, and drooping posture (Bergasa, L.M., et. al, 2006.)

In addition to these visual characteristics, driver inattention can also be characterized by indirect driving behaviors like the lateral position, steering wheel movements, and time-to-line crossing. An inattentive driver may be distracted temporarily from the driving task by something inside or outside the vehicle, may be "lost in thought" or otherwise cognitively removed from the driving task, or may be fatigued or drowsy.

2.3. The need for objective data about driving behavior to improve motor vehicle safety

Motor vehicle and transportation safety is a multi-faced and a shared responsibility among manufacturers, consumers, and governments. The fact that we have yet to arrive at solutions to the problem is compounded by not having the ability to collect objective data about driving behavior.

Having data about driving behavior is essential to enhance motor vehicle safety through the development and introduction of advances that could provide reductions of injuries and fatalities. Research suggests that human factors contribute in up to 95% of all vehicle accidents, even though in a large number of cases unsafe driver behaviors are unintentional (Sabey, B. E., Taylor, H., 1980.) Therefore, the challenge nowadays is to collect objective data about driving behavior by combining technologies breakthroughs in communication and vehicle design to enhance the protection of motor vehicle occupants.

Currently, most of the information collected about motor vehicle accidents is mainly used to re-create the scenery of accidents, assist service technicians in conducting vehicle repair, and improve the vehicle configuration by product development engineers. This approach allows the information collected about accidents to be only applied in a passive manner, without providing drivers with feedback to improve their driving performance.

Human beings are prone to errors. It has long been recognized that an overload of information can cause problems when driving (Matthews, G., Sparkes, T., 1996.) Even though people could try to avoid motor vehicle accidents by being diligent, careful, and competent drivers, it may be unrealistic to assume that drivers will never make mistakes or will never become distracted. For instance, in critical driving situations most drivers are overburdened with the stabilizing task. Research has shown that the average driver can neither judge the friction coefficient of the road nor the grip reserves of the tires (Liebemann, E.K., Meder, K., Schuh, J., Nenninger, 2004.) The drivers are typically startled by the altered vehicle behavior in in-stable driving situations; as a result, a well-considered and thought-out reaction of the driver can not be expected.

The duration of a motor vehicle accident can be comparable to the blink of an eye and could be measure in the order of milliseconds. At that timeframe it becomes very difficult for humans such as eye-witnesses or transportation forensics to recreate with certainty a motor vehicle accident. As statistics have shown, there are millions of motor vehicle accidents each year (Traffic Safety Facts, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System, 2004) but none of these accidents are identical. As a result, without a human-independent mechanism to collect information about the behavior of drivers, it may be impossible to use information from past accidents to proactively avoid future motor vehicle accidents.

In the evaluation of motor vehicle accidents, additional emphasis has been placed on the vehicle and infrastructure and not on the driver. The reason for this imbalance could be rooted to the lack of objective data about the behavior of drivers. Thus, if

subjective accounts of eye-witnesses and transportation forensics about motor vehicle accidents cannot provide reliable data, other mechanisms involving the use of technology should be used to collect data for the purpose of accurately understand the behavior of drivers, recreate motor vehicle accidents, and improve the safety of motor vehicle transportation systems.

2.4. Current approaches to motor vehicle safety

Car safety can be described as the avoidance of car accidents or the minimization of harmful effects of accidents, in particular as relating to human life and health. Special safety features have been built into cars for years, some for the safety of car's occupants only, and some for the safety of others.

The current approach for providing safety in motor vehicles is not dependent on one of these features but on combination of them. Advances in motor vehicle technologies and government regulation have facilitated these advances by including technologies to aid the drivers to proactively reduce situations of risk or minimize the impact of accident if they happen.

Founded on advances in motor vehicle technologies and the type of accident avoidance mechanism, safety of motor vehicles can be defined into two main groups: passive and active safety-mechanisms (

Table 3.)

Table 3: Examples of Motor vehicle Safety Mechanisms

Safety	Passive	Technology	Seatbelts
			Airbags (SRS)
		Regulation	Speed Limits
			Driver's License
			Alcohol Test
	Active	Technology	Anti-lock Brakes (ABS)
			Electronic Stability Programs (ESP)
			Collision Avoidance Systems
		Regulation	N A

Passive safety can be described as a system or set of systems that work together to minimize the impact of an accident in drivers. Airbag systems (SRS) are examples of passive safety as they diminished the effect of accidents on drivers. In the area of motor vehicle regulation, governments and transportation agencies create rules and statues to regulate the right to operate motor vehicles, as well as to penalize drivers that do not comply with those mandates.

Active safety can be describe a system or set of systems that make driving safer and prevent accidents from occurring. Anti-lock brakes (ABS) are examples of active

safety devices as they assist drivers to break more efficient and maintain control of vehicles.

2.5. Improving motor vehicle safety through technology

During the first century of motor vehicles, when vehicles were viewed as a mechanical device, safety was developed with the predominant focus on offering the best available crash protection to occupants based on the use of passive safety mechanisms. Although there have been vast improvements in passive safety over the past few decades, fatality and serious injury rates have remained high (U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, 2005.) One reason for this is that increasing traffic densities and total miles driven per year tend to offset the passive safety advances (National Safety Council (NSC), Injury Facts, 2006.)

To measure passive safety performance, a number of consumer tests have been established, such as the Insurance Institute of Highway Safety (IIHS) tests and the United States New Car Assessment Program (US NCAP.) Motor vehicle drivers pay attention to these ratings when buying a vehicle and vehicle safety performance considerably exceeds current legal requirements (Summers, S., Prasad, A., 2006.) The paradox, though, is that despite the best efforts of drivers, industry and government, the public is still not adequately protected from motor vehicle accidents resulting on injuries and fatalities.

While the government is targeting to reduce injury and fatality rates by 20 percent by 2008 via regulatory mechanisms to improve passive safety in motor vehicles (Department of Transportation (DOT,) 2003,) these targets may be difficult to attain through passive safety measures alone. To achieve objectives of this magnitude, a comprehensive safety system that integrates modern active mechanisms with existing passive mechanisms would be needed.

However, merely integrating active safety mechanisms into the motor vehicle is insufficient. A comprehensive system that is able to provide feedback on driving behavior and environment is needed to bridge the lack of interaction and understanding between the driver and the safety mechanism. This facilitates the optimization of the benefits from active safety mechanisms.

In general, research studies have found that safety can be improved when feedback is provided (Komaki, J., et. al., 1978.) In relation to motor vehicle safety, studies on feedback systems conducted in the transportation sector have found interesting results. For instance, a research report employing passenger-observed feedback helped drivers improve their safety behavior and showed that individual feedback is an effective tool for positive behavior modification (Wouters, I.J., Bos, J.M., 2000.)

Current advances in motor vehicle electronics and communications will permit to incorporate feedback systems in motor vehicles based on the performance of vehicles and behavior of drivers. If proven effective, technologies of this type would have the potential of collecting real-time information about the behavior of drivers to provide feedback and

improve driving safety. Similar concepts have been explored by researchers in commercial transport operations with encouraging results. A research study on feedback systems with drivers of commercial-vehicles suggested that the introduction of in-vehicle technologies oriented to monitor drivers may increase safety in transport operations and may be effective in reducing traffic accidents (Hutton, K. A., Sibley, C. G., Harper, D. N., Hunt, M., 2001.)

Chapter 3. Technology attempts for motor vehicle safety

3.1. Event recording mechanisms

To address regulation on safety and emission requirements in the United States, event recording mechanisms were made available in modern motor vehicles for the purpose of monitoring and collecting critical information from these systems (Leen, G., Heffernan, D., 2002.) In recent years there has been a proliferation of event data recorders, primarily since to the introduction of supplementary air bags and, in particular, because of the need to monitor and control the deployment of these systems.

Many modern air bag control systems have adopted electronic sensing systems where a vehicle mounted accelerometer is used to monitor the crash pulse. A microprocessor analyzes the vehicle's acceleration-time history and, based on pre-programmed decision logic, determines when air bag systems should be deployed. Using some of the computer memory present in such systems, manufacturers have been able to store certain data relating to collision events by the use of event recording mechanisms. Analysis of these data has provided a means to refine the algorithms used for deployment logic.

The use of event recording mechanisms for the collection of data on flight controls and parameters associated with the aircraft operation is often known in the aviation industry. A less recognized fact is that most modern vehicles includes event recording mechanisms for gathering diagnostic and troubleshooting information associated with airbags (SRS,) anti-lock brakes (ABS,) emissions control (Jones, W.D., 2004.) Data from these recording mechanisms can be retrieved using a variety of proprietary and commercial readers available in the market.

3.1.1. Motor vehicle Event Data Recorders (MVEDR)

Event recording mechanisms implemented in passenger motor vehicles are described as motor vehicle event data recorders or MVEDR. Automakers in the United States are currently installing Motor MVEDR in a growing numbers of passenger cars and light-duty trucks. Current MVEDRs provide an ideal baseline for developing a variety of application leveraging on the data elements provided by these data recorders.

In the market of motor vehicle manufacturers, Ford Motor Company and General-Motors (GM) are the only companies that have publicly released information about the MVEDRs available in their vehicles; whereas GM is the only one of them that has brought to the market an application (OnStar™) based on the capabilities from these data recorders (Appendix A.) Other vehicle manufacturers have kept this information as proprietary and have not release information about their MVEDR nor have created application based on these data recorders.

3.1.1.1. General Motors (GM) Sensing and Diagnostic Module (SDM)

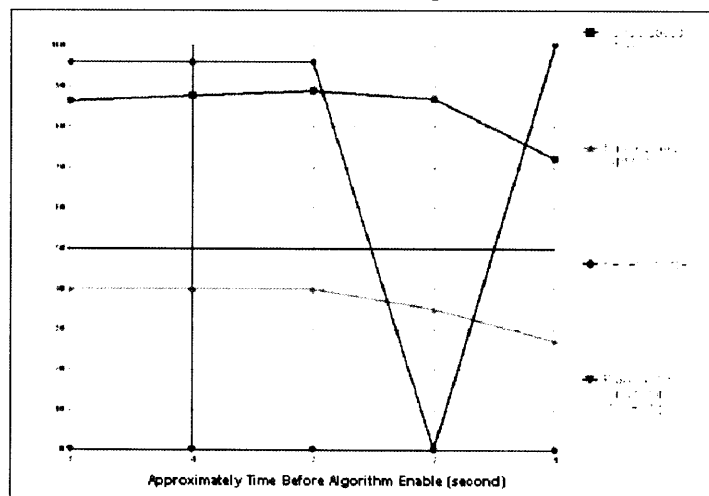
MVEDRs in GM vehicles have the capability to store a description of both the crash and the pre-crash phase of a traffic collision (Correia et al, 2001.) The MVEDR in GM vehicles is referred to as the Sensing and Diagnostic Module (SDM). Event data parameters in SDMs include longitudinal change in velocity vs. time during the impact, airbag trigger times, and seat belt status. Later versions of the GM MVEDRs also store pre-crash data including a record of vehicle speed, engine throttle position, engine revolutions per minute, and brake status for five seconds preceding the impact. Since their introduction in the early 1990's, GM has continuously improved their MVEDR design.

The cumulative time history in the change in velocity of the vehicle that occurs during the impact is recorded by the SDM. When pre-crash data are available, this information consists of the vehicle's speed (mph), engine speed (rpm), throttle position (%), and the status of the brake light switch (on or off) for a period of five seconds prior to the event that triggered the recording. In addition, the SDM indicates the status of the driver's seat belt buckle switch (buckled or unbuckled) at the time of the event.

Data relating to vehicle speed, engine speed, percentage throttle and brake switch status are stored in a buffer that is capable of storing five values of each data element. Values are recorded at one-second intervals with the most recent values overriding the oldest values (see Appendix A for details.)

As shown in Figure 2 (Lenard, J., et.al., 2004,) newer versions of the GM EDR can store up to five seconds of pre-crash data. Data elements include vehicle speed, engine throttle position, engine revolutions per minute, and brake status versus time for the five seconds preceding the time the airbag control module believes that a crash has begun.

Figure 2: Example of GM (SDM) pre-crash information



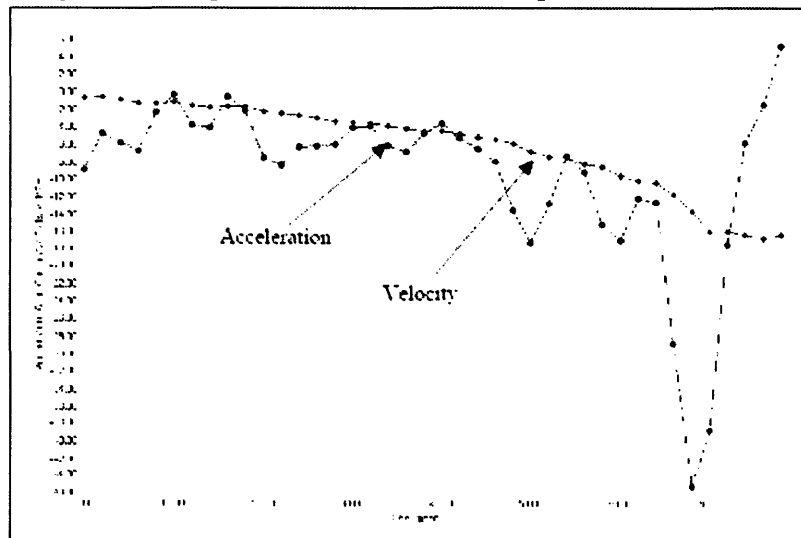
The data elements shown in Figure 2 provide a record of the actions taken by the driver just prior to the crash. The first four parameters, vehicle speed, engine speed, brake

status and throttle position are recorded at approximately five one-second intervals before impact, so this graph chart shows release of the throttle, application of the brakes and a reduction of engine speed in the five seconds preceding impact..

3.1.1.2. Ford Motor Company Restrain Control Module (RCM)

The Ford MVEDR is called the Restraint Control Module (RCM). The emphasis of the Ford MVEDR is on monitoring the performance of occupant restraint systems including multistage frontal airbag deployment, and side impact airbags. The design on the Ford RCM features considerably finer resolution than the GM SDM. However, because a faster sampling rate consumes more of the airbag module's limited memory, the Ford RCM does not record for as long as the GM SDM, and may cause it to store only a single event.

Figure 3: Example of Ford MVEDR (RCM) pre-crash information



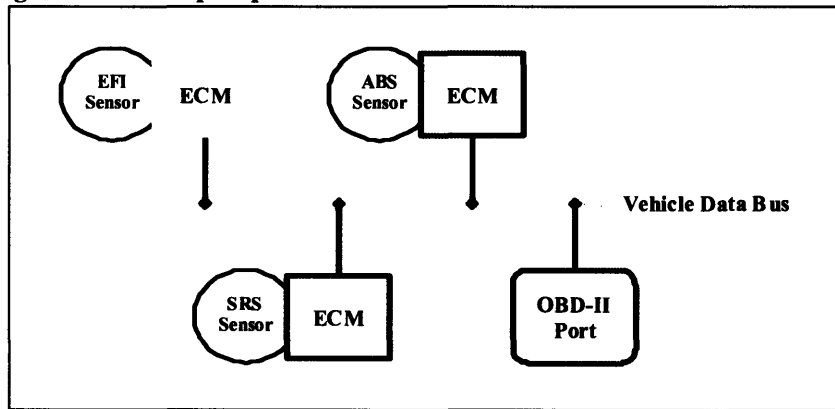
As shown in Figure 3, the RCM in Ford can store both a longitudinal and a lateral crash pulse (see Appendix A for details.) The crash pulse is stored as acceleration versus time one sample every 2 milliseconds. Up to 40 acceleration measurements along each axis can be stored for a total duration of 78 milliseconds (Lenard, J., et.al., 2004.)

3.1.2. Motor vehicle Event Parameters from the On-Board Diagnostic (OBD) Port

Service diagnostic information available through the On Board Diagnostics (OBD) ports of vehicles provides a source of potential MVEDR data elements. On Board Diagnostic (OBD) ports are incorporated into the on-board computers of new vehicles to monitor different components and systems. The second generation of OBD requirements, which is known as OBD-II, has been fully in effect since the 1996 model year. Since that year, the OBD-II port is a requirement by the Environmental Protection Agency (EPA) on all passenger cars and light trucks in the United States. Specifications for the OBD-II port have been standardized by the Society of Automotive Engineers (SAE) (SAE, 2002.)

Although the original intent of the OBD-II port was to allow access to engine and emissions diagnostic data, the OBD-II port is increasingly used as an access point to other sensors via control modules (ECM) on the vehicle data bus. As shown in Figure 4, the OBD II port provides diagnostic access to many of the vehicle on-board sensors monitored by these ECMs. Examples include the engine fuel management (EFI) module, antilock braking (ABS) module, and airbag systems (SRS) module.

Figure 4: OBD-II port provides access to on-board vehicle sensors via ECMs



Due to the different functionalities and characteristics among vehicles, the number of data elements available on OBD-II port varies accordingly. However, as a minimum requirement on the OBD-II specification (SAE, 2002,) the data elements described in Figure 5 are available in vehicles including the OBD-II.

Figure 5: Data Elements available from the OBD-II port.

Data Element Description
Vehicle Speed
Accelerator Pedal Position
Brake Pedal Position
Brake Switch Status
Throttle Position Position
Engine Speed (RPM)
Transmission Status
Fuel System Status
Power Sensors Status
Temperature Sensors Status
Oxygen Sensors Status

3.1.2.1. Electronic devices for measuring and recording driving exposure: Progressive Insurance TripSensor™

A problem with conventional insurance determination systems is that much of the data gathered from the applicant is not verifiable, and even existing public records contain only minimal information, much of which has little relevance towards an assessment of the likelihood of a claim subsequently occurring. In other words, current rating systems are primarily based on past realized losses. In addition, not all of the data

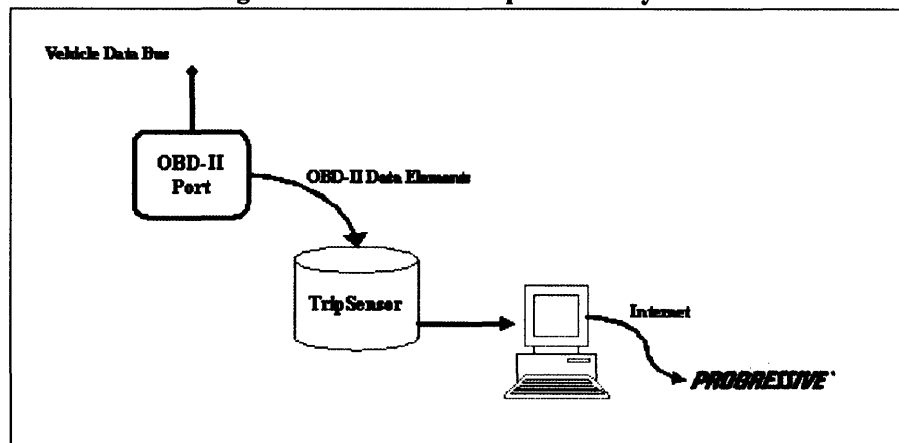
obtained through conventional systems necessarily reliably predicts the manner or safety of future operation of the vehicle.

The limited amount of accumulated relevant data and its minimal evidential value towards computation of a fair cost of insurance has generated a long-felt need for an improved system for more reliably and accurately accumulating data having a highly relevant evidential value towards predicting the actual manner of a vehicle's future operation and its driver.

To cope with the uncertainty on the information gathered from conventional insurance determination systems, Progressive Insurance developed data acquisition and processing system (TripSensor™) for monitoring motor vehicle operational characteristics for purposes of providing a more accurate determination of a cost of insurance for the vehicle.

TripSensor™ is comprised on an electronic device that plugs into the OBDII port of passenger motor vehicle and light trucks for recording date and time stamped data elements from different sensor in the vehicle. The data elements collected by this device are sequentially recorded at regular intervals from the vehicle OBD-II port to create a time marked set of individual data elements (Figure 6.)

Figure 6: Overview of TripSensor™ system



By the use of proprietary computer software, data collected by the TripSensor™ device can be downloaded into a personal computer to display information on how the vehicle was driven, including trip start and end times, vehicle speeds, rates of acceleration and braking. This data can be then processed to obtain a summary, plot or table format, that can be send via the Internet to Progressive Insurance for obtaining discounts in the insurance premium of the vehicle.

3.2. Road-warning mechanisms

Technological advances in the car industry and the high level of computerization of cars have enabled the development of a variety of road-warning mechanism to improve safety in motor vehicles. These mechanisms are designed to increase driver

confidence and help prevent motor vehicle accidents. The implementation of these systems has helped to improve driving by compensating response and distraction from drivers.

Road-warning mechanisms have been developed for a wide variety of safety applications. Some of them are designed to help in accident prevention and others are designed to provide support in the event of an accident. A number of these mechanisms have been already introduced in high-end motor vehicles in the United States. Table 4 describes the type and function of some of the most popular road-warning mechanisms available in the market.

Table 4: Examples of modern road-warning mechanisms

Type	Function
Route Guidance Systems (RGS)	<i>Provides drivers with visual and spoken navigation recommendations.</i>
Speed Adaptation Systems (SAS)	<i>System alerting the driver when speed limits are exceeded.</i>
Lane Keeping Systems (LKS)	<i>Warns drivers when the vehicle begins to move out of its lane.</i>
Collision Avoidance Systems (CAS)	<i>Adjusts speed in order to maintain a proper distance between vehicles in the same lane.</i>

Following, a definition of the various road-warning mechanisms described in Table 4 will be provided, as well as an overview on potential contributions these mechanisms will have in the area of motor vehicle safety.

3.2.1. Route Guidance Systems (RGS)

Route guidance systems (RGS) range from simple navigation systems based on digital maps to dynamic route guidance systems based on actual traffic information. Several autonomous systems are available on the market and the driver interface ranges from a map with the location of the car and the destination to a display with an arrow showing the driving or turning direction.

As one of the main driving tasks in an unfamiliar area is to find the way to the destination, a route guidance system can reduce the stress on the driver and release mental capacity to better observe and react in traffic. In theory, the system will also reduce exposure as the amount of unnecessary driving is reduced. The route guidance facility may on the other hand create new trips because drivers feel comfortable going to unknown destinations (Gstalter, H., Fastenmeier, 2003.)

The full potential of route guidance systems could arise if user criteria are included, if local risk information is included, and if preference for safe roads is built into the system. These factors must be built in if safety benefits should be substantial. It is also important that the route guidance system is of a certain quality: this means that the database is detailed enough to cover the whole trip to any destination. In urban areas it is crucial that the system includes all one-way streets and turning bans to avoid confusing

and dangerous driving situations. Maps must be up-to-date and the location system of the vehicle must be accurate in order to avoid confusing or dangerous driving situations.

3.2.2. Speed Adaptation Systems (SAS)

Speed adaptation includes both infrastructure systems as variable speed limits and vehicle-based systems as intelligent speed adaptation (ISA.)

Variable speed limits that can be varied according to weather, road surface and light condition can give substantial safety benefits as the drivers typically underestimate the danger and overestimate the suitable speed in these conditions. There are probably also indirect effects as the acceptance for and the compliance to the speed limits may improve if the limits are experienced as more reasonable.

Safety benefits will arise from ISA as excessive speeds could be reduced based on this mechanism. If properly implemented, these systems are expected to have a great positive influence on the individual drivers that use ISA, but also to influence other vehicles by slowing down the overall speed in urban areas.

Based on the potential effect of reducing speed to comply with speed limits, intelligent speed adaptation (ISA) is one of the most promising safety systems. The full potential of this mechanism could arise with a compulsory and intervening system used on all roads and taking advantage of the possibility to vary speed limits more than today dynamically and geographically in response to the driving conditions.

3.2.3. Lane Keeping System (LKS)

Lane keeping is supported by three functions: lane-keeping-assistant, lane-departure-warning and lane-change-assistant.

Lane-keeping-assistant provides support through additional and perceptible force in the steering wheel. Lane-departure-warning gives warnings to the driver in order to avoid leaving the lane unintentionally. Lane-change-assistant gives information/warning to the driver about relevant obstacles when driver intends to change the lane.

Lane-keeping-assistant and lane-departure-warning assist the driver in keeping the direction and contributes to the prevention of collisions where the driver. Lane-keeping assistant-implies that the car is automatically steered parallel to the drivers steering movements, while lane-departure-warning warns the driver by for example vibrations in the steering wheel.

Application based on Lane Keeping System (LKS) have the potential of contributing to safer lane changes by warning and preventing lane changes when vehicles reside in parallel lanes close enough to constitute a collision risk.

3.2.4. Collision Avoidance Systems (CAS)

Collision avoidance covers a number of systems such as adaptive cruise control (ACC), and brake assistance mechanisms.

ACC maintains a constant safe distance to the vehicle in front, automatically reduces speed if the vehicle in front slows down, and automatically increases speed if the vehicle in front picks up speed. In the event that the vehicle in front makes a lane change or speeds away, the own vehicle accelerates till it reaches a preset cruising speed of the conventional cruise control

In emergency braking situation some drivers do not activate the vehicle brake with the highest possible force to make full use of the anti-lock break system (ABS.) If the special conditions of emergency braking situations are detected from some brake activation parameters the brake assist system activates the vehicle brake with the highest possible force.

The safety benefit of adaptive cruise control (ACC) arises mainly from a reduction of the number of rear-end collisions. The total effect of ACC is very uncertain. Cruise control systems reduce driver stress but can also cause safety problems in critical situations, if not properly designed.

Adaptive Brake Lights are designed to reduce the risk of bumper-to-bumper collisions by enlarging the brake light area when the driver forcefully applies the brakes.

3.3. Context-aware mechanisms

Nowadays, the majority of driving safety mechanisms only attempt to assist people without improving awareness on driver behavior. For instance, road guidance systems (RGS) make us not have to look for directions, collision avoidance systems (CAS) alert drivers of potential collisions, and speed adaptation systems (SAS) aid drivers to maintain their vehicles within speed limits. Devices such as those are some examples of the assistive direction many motor vehicle manufacturers are following for their vehicles. In contrast, context aware motor vehicle technologies have the potential of exceeding the benefits of these safety approaches with the use of feedback and assistance mechanisms based on the performance and behavior of drivers (Huang, Y.H., et. al, 2005.)

3.3.1. Context aware ubiquitous computing in the car

Nowadays, the advanced levels of computerization available in motor vehicles allow us to monitor several aspects of vehicle performance with few modifications. Vehicle-technologies such as MVEDRs and road warning mechanisms are already available allowing drivers to log information related to motor vehicle based on pre-defined events such as changes in speed and braking/acceleration patterns (Gabauer, D.J., Gabler, H.C., 2005,) as well as to aid them to improve control and navigation in their vehicles.

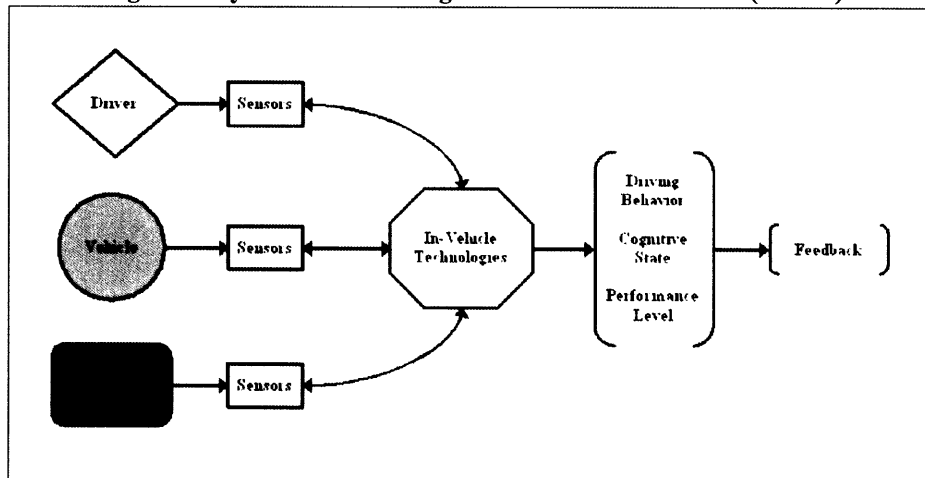
Rather than just being a logging tool or assistance in control and navigation, a next-generation of in-vehicles technologies could make use of external and on-board sensors to collect information about drivers and monitor their driving performance and cognitive levels. With the assistance of processing algorithms, information from these sensors can then be used to create personalized models to predict driving behavior and present feedback to drivers.

3.3.2. Research platform: AgeLab’s Driver Aware Car (ADAC)

Researchers from the AgeLab at the MIT Center of Transportation and Logistics (CTL) have envisioned a future implementation of a motor vehicle platform based on the use of context aware ubiquitous computing in the car. This vehicle platform would be based on the integration of persuasive systems (Fogg, B.J., 2002.) that present drivers with context-sensitive feedback mechanisms to remind them of appropriate driving techniques and promote positive behavior changes of their driving habits.

To accomplish a holistic view about the driver, the ADAC will monitor and collect information from the driver, vehicle, and environment via in-vehicle technologies from data coming from on-board and external sensors (Figure 7.) Based on this information, ADAC would able to identify common driving behaviors, cognitive states, and the performance levels, providing appropriate feedback accordingly. The implementation of the ADAC concept model will combine computerized mechanisms with context aware in-vehicle technologies to offer drivers real-time feedback on their driving performance. Real-time feedback mechanisms in the ADAC will be deployed by the use of non-obtrusive interaction methods to allow the system to present information without interfering with the driver’s task at hand.

Figure 7: System model for AgeLab’s Driver Aware Car (ADAC)



Source: Coughlin, 2004

3.3.2.1. Conceptual model

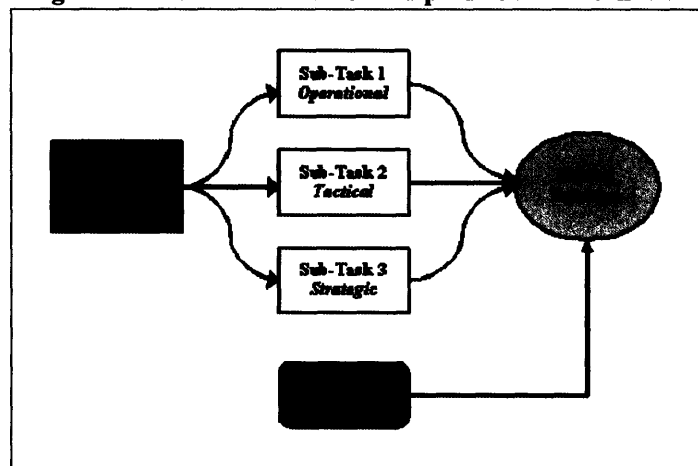
The ADAC conceptual model is envisioned as a research platform for studies on the feasibility of including context-aware in-vehicle technologies for the collection of data about drivers to provide real-time monitoring and feedback about their driving

behavior. In addition to its role of monitoring and post-process feedback, this conceptual model will also serve in determining if driving behavior could be changed through the use of feedback-mechanisms from data collected by context-aware in-vehicle technologies.

To deliver the research platform envisioned by the ADAC conceptual model, an integrated method that stimulates and predicts real-world driver behavior must be incorporated as its most fundamental mechanism. This method will deliver a framework to allow the dissection of driving processes into multiple processes or sub-tasks. For its effectiveness in real-world driving-situations, metrics of safe and stable navigation should be also included as default within this framework.

The process of driving can be described as an ever-changing set of basic sub-tasks that must be integrated and interleaved (Figure 8.) Studies on driver behavior models have found that the processes of driving can be described by three main processes or sub-tasks: 1) operational sub-task that involve manipulating control inputs for stable driving, 2) tactical sub-task that govern safe interactions with the environment and other vehicles, and 3) strategic sub-task for higher-level reasoning and planning (Michon, J. A., 1985.) The conceptual model implemented for the ADAC is intended to address these basic tasks for the purpose of achieving a truly integrated driver model that stimulates and predicts real-world driver behavior.

Figure 8: Method to stimulate and predict driver behavior



Due to its object-oriented characteristics, the method to stimulate and predict driver behavior described in this section can be expressed using algorithms based on logical primitives implemented by computer systems (Gaglio, S., et. al., 2006.) As advances in electronics permit the increasing computerization of motor vehicles, methods of this kind have the potential to use the processing capabilities available in these vehicles, as well as the resources provided by sensors and other in-vehicle technologies.

To illustrate the algorithm implementing the method to stimulate and predict driver behavior, an example describing a driving process is shown in Table 5:

Table 5: Algorithm / Method to simulate and predict driver behavior

- **Task:** *“taking a curve in the road”*
 - **Step 1: Collect information on the driving process through sensors of in-vehicle technologies**
 - *Driver*
 - *Vehicle*
 - *Environment*
 - **Step 2: Dissection of the driving process into sub-tasks**
 - Sub-Task 1: Operational
 - *IF current objective is to steer and all perceptual variables for steering have been noticed; THEN check if driver is steering according to these variables; ELSE provide appropriate feedback.*
 - Sub-Task 2: Tactical
 - *IF current objective is to identify a perceptual point for steering and there is a curve present; THEN check the attention of the driver to this perceptual point and calculate the position and distance from this point; ELSE provide appropriate feedback..*
 - Sub-Task 3: Strategic
 - *IF current objective have been completed successfully; THEN update database and personal profile of the driver based on this event and navigation baseline; ELSE provide appropriate feedback.*
 - **Step 3: Definition of driver behavior**
 - *Collect the state of sub-tasks from previous steps into memory*
 - *Compare memory information with navigation guidelines.*
 - *Assemble a function describing the event describing the process of driving.*
 - *Compilation and outcome.*
 - *“Monitoring a driver taking a curve in the road within safe and stable navigation parameters.”*
-

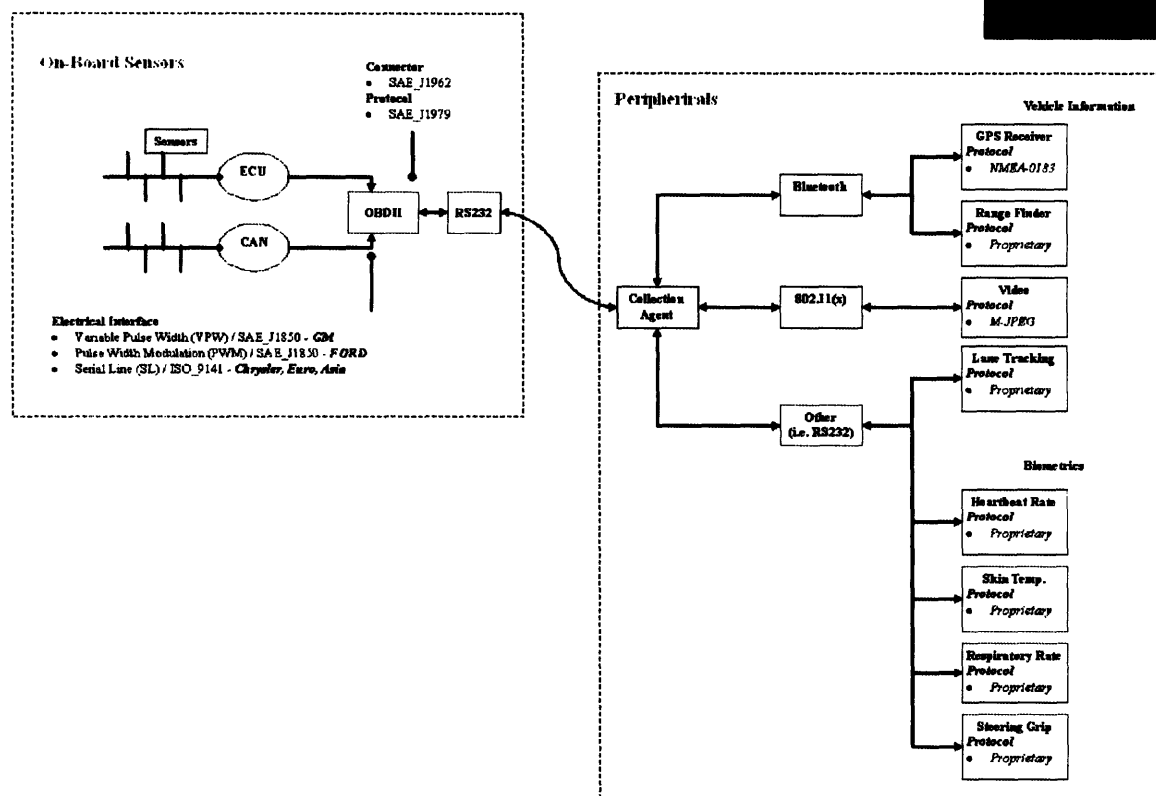
This example shows how the driving process of *“taking a curve in the road”* is described as a function of logical primitives. For instance, step 1 denotes the logical primitive of fetching information about the driver, vehicle, and environment via in-vehicle technologies. Step 2, denotes the logical primitives of dissecting operational, tactical, and strategic sub-tasks by the use of conditional statements. Step 3 denotes the logical primitives of processing information from previous steps, comparing information with predefined guidelines to re-produce the process of driving.

3.3.2.2. Technology model

The architecture for the AgeLab's Driver Aware Car (ADAC) should consist of an array of sensors connected to in-vehicle technologies for the collection of data related the driver, vehicle, and environment. The architecture interface should be programmable and flexible to allow future integration with applications dealing with the manipulation/analysis of data.

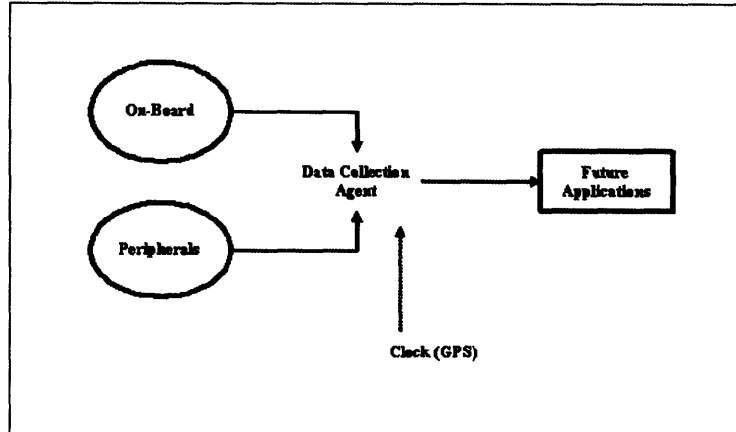
A Block diagram showing the top-level architecture of the instrumented vehicle is showed in Figure 9 Within the top-level architecture, there are two sub-architecture domains: 1) on-board sensors, and 2) other peripherals.

Figure 9: Driver Aware Car (ADAC) - Top Level Architecture



Based on this type of architecture, the top-level design should support the integration and synchronization of sensor -data available at each domain. This synchronization will be based on time-information from the Global-Positioning-System (GPS) unit. Figure 10 shows a block diagram for this synchronization.

Figure 10: Context-Aware Car (ADAC) - Architecture Interface



The on-board module contains sensors embedded into the vehicle. These sensors are part of a network connected to the vehicle Electronic Control Module (ECM) and/or Controlled Area Network (CAN). These networks are physically/logically accessible based on the OBDII specification (SAE-J1979, E/E Diagnostic Test Modes.)

3.3.2.2.1. On-Board Sensors

The number and type of sensors available in a vehicle vary according to its manufacturer and model. For this reason, it is difficult to define a list that will convey the information for all existing vehicles. However, for our particular research interests, the following list of on-board sensors has been identified

Table 6: On-Board Sensors List*

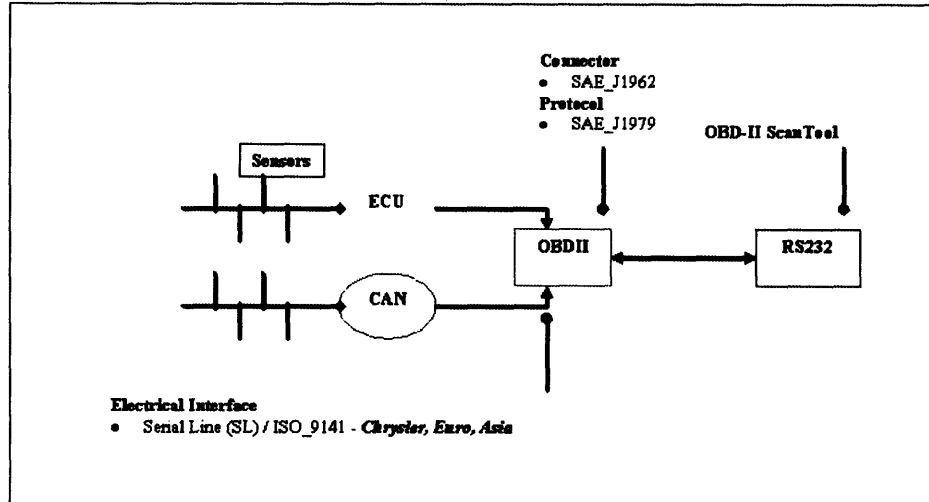
Sensor	Interface	Protocol	Source
Throttle Position Sensors	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Brake Pedal Position Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Vehicle Speed Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Vehicle Acceleration Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Steering Angle Sensors	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Parking Brake Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Transmission Gear Position Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Fuel Tank Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Temperature (Outside) Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Door Ajar Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Door Lock Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Ignition Switch Position Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Windsheel Status Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Entertainment Control Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Humidity (Outside) Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
HVAC Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Turn Signals Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Interior Lighting Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Headlamps Status Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Hazard Signal Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle
Engine Load Sensor	OBDII (SAE J1962)	OBDII (SAE J1979) / CAN (SAE J1939)	Vehicle

*Based on On-Board-Diagnostic (OBDII) - Enhanced interface for Ford (E101) 1994-2006

*Depending on the CAN implementation, sensors on the CAN may be accessible by SAE_J1979

The data in Table 6 shows a list of sensors and related information. Regardless of their protocol (OBDII or CAN), sensors are accessible via the OBDII connector interface. A generic block diagram of the on-board sensors and their corresponding interface is shown in Figure 11

Figure 11: Block Diagram of On-Board Sensors



To gather information from the on-board sensors the OBDII interface connector (SAE_J1962) is connected to a collection agent (i.e. computer system) via a serial (EIA232) connection.

3.3.2.2. Peripheral Devices

In addition to the sensors listed in Table 6, data from devices that are not part of the standard vehicle on-board interface will also be collected. Some examples relevant for this project are biometrics, video and off-vehicle information.

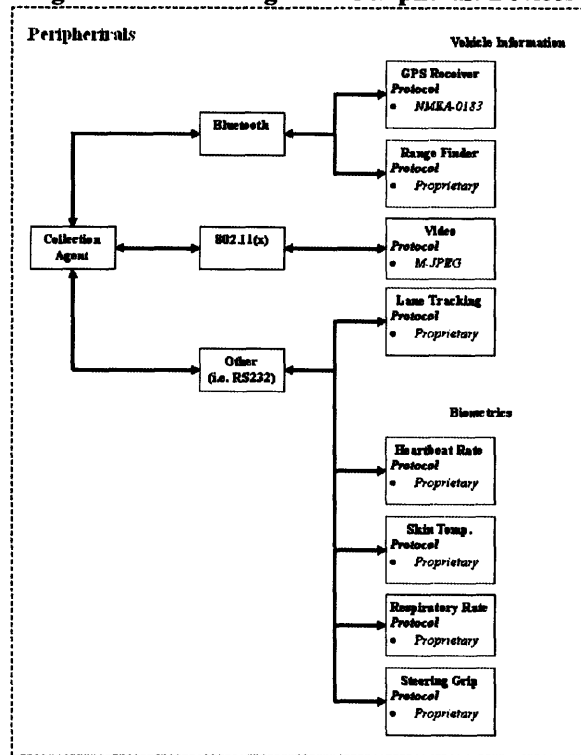
Within this domain, devices are connected to the data collection agent via the corresponding interface at each device. A list of devices and their corresponding interface and protocol specifications are listed on Table 7.

Table 7: List of Peripheral Devices

Vehicle Information			Biometrics		
Device	Interface	Protocol	Device	Interface	Protocol
GPS Receiver	Bluetooth	NMEA-0183	Heartbeat Rate	Proprietary	Proprietary
Range Finder	Bluetooth	Proprietary	Skin Temperature	Proprietary	Proprietary
Lane Tracking	Proprietary	Proprietary	Respiration Rate	Proprietary	Proprietary
Video	802.11(x)	M-JPEG	Steering Wheel Grip	Proprietary	Proprietary

Data is retrieved by the collection agent (i.e. computer system) in a synchronous fashion based on time-information from the GPS receiver (see Figure 10). The high-level architecture for this domain is shown in Figure 12.

Figure 12: Block Diagram – Peripherals Devices



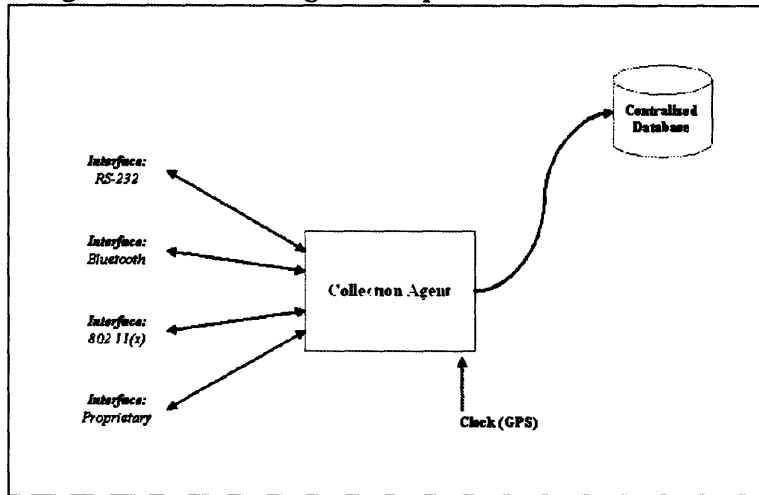
3.3.2.2.3. Data Collection Agent

The application responsible of collecting data from the different devices will reside in the data collection agent (Figure 12). This application is software based and will perform data collection functions based on:

- Global clock signal (GPS Time Information – see Figure 10), and
- Translation from lower level communication protocols.

The interface utilized by each device in the peripherals domain is listed in Table 7. It is the function of the collection-agent to provide the required translation mechanism to allow the collection of data from each of these devices. To accomplish this task, the collection-agent should have access to the connection interface at each of the devices. In addition, to obtain a normal distribution among data, the collection agent should be aware of the acquisition rate supported by each device. The data collected should be synchronized to the clock signal available from the GPS receiver and then saved in a centralized database accessible by the collection agent. A block diagram for this architecture is shown in Figure 13.

Figure 13: Collection Agent - Peripheral Devices Architecture



3.3.2.2.4. Data-retrieval Agent

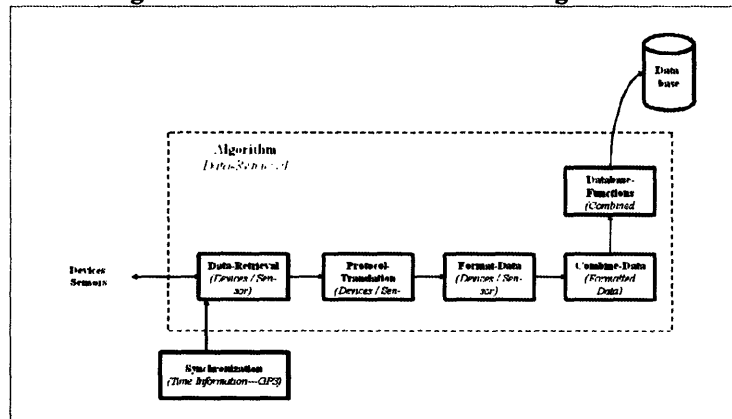
A data-retrieval Agent is based on an algorithm that should reside as the core element in the Collection-Agent. This algorithm should take advantage of the different “tools” or “functions” available from each of the devices/sensors from the on-board and peripheral devices.

The data-retrieval algorithm should:

- Synchronize the collection of data from each device/sensor to time-information available from the GPS receiver.
- Allow protocol translation that will arrange a predetermined string of data common to all devices.
- Combine data from each device/sensor in a single event based on the relative time-information from the GPS receiver
- Provide database forward/storage functions, having the time-information as the primary key for each record (event).

A block diagram denoting the functions of the algorithm is shown in Figure 14.

Figure 14: Modules – Data Retrieval Algorithm



In addition to the retrieval of data, our project will have an additional step that will provide an algorithm for analysis of data based on state-of-the-art Artificial Intelligence (AI) functions. Results from this step will provide means for the identification of patterns and feedback mechanisms.

Chapter 4. Literature on personal trade-offs in context-aware ubiquitous computing in the car

A review of current literature on the topics of context-aware ubiquitous computing in the car, privacy issues, and public policy provided a firm foundation for the research in this thesis. This section presents a discussion of the results of our literature review taking a look at the role of public policy and regulation in the discussion of ubiquitous computing

4.1. Ubiquitous computing and its threat to privacy

The conflict of ubiquitous computing and personal privacy is not new. In the past, countermeasures have been developed in an attempt to protect privacy while adopting new technologies to society. For instance, Hahn et. al. discussed examples of such countermeasures at the inception of the Internet. He goes onto discuss the fundamentals of information privacy protection, summarized in "Fair Information Practices", as defined by the Federal Trade Commission which is mostly based on self regulatory and industry practice (Hann, et. al., 2002.) When ubiquitous computing became a reality, control of data issues became a hot topic. Questions regarding the rightful owner of data, permission control, and the control of data flow were high priority for policy makers. Regarding ubiquitous computing, one expert explained that privacy is largely an issue of control, and that there are at least two ways of interpreting this notion of "being in control." One method presents a sense of control that is "legally, contractually, or normatively endowed." A second interpretation presents control as the regular, everyday, participatory management of personal information disclosure (Lederer S., 2003.)

Many researchers and practitioners have discussed privacy issues relating to the application of new technologies such as the internet and ubiquitous computing. For instance, Langheinrich employs an approach of "privacy boundaries" that aim to describe various reasons where some degree of personal information flow is distinguished as threatening and the way in which ubiquitous computing could make the problem large and more complex (Langheinrich M., 2002.) Applications based on ubiquitous computing, although still a relatively new technologies, have garnered much attention in the public policy arena (Kang, J., et. al., 2005.) Policy and privacy concerns regarding ubiquitous computing have also been a hot topic in many recent forums (Endres, C., 2005.) In the case of ubiquitous computing in the car, policy makers will play a key role for the adoption of this technology into mainstream motor vehicle market in the United States.

4.2. Privacy implications of ubiquitous computing in the car

There are privacy issues which are unique to the implementation of ubiquitous technologies in the car. Applications of ubiquitous technologies comparable to the AgeLab's Driver Aware Car (ADAC) are sensor-rich environments, thus in addition to static data such as vehicle identification information; a significant amount of data generated in the vehicle is dynamic and personalized to the driver. In applications like the ADAC, there are a large number of electronic control units (ECUs) which constantly

monitor the drivers, the vehicle, and their environment. The data generated by these control units are available for external monitoring by way of the car bus and other collection mechanisms. Examples of dynamic data may include information such as for vehicle performance, driver behavior, and cognitive state. This information is related to position data obtained from GPS sensors to provide a context-aware description of the operation of the vehicle, as well as the actions and the state of the driver.

Privacy has been seen a controversial issue for application and systems based on ubiquitous computing. On the one hand, the convergence and increasing widespread deployment of sensors, wireless networking, and devices of all form factors are providing tremendous opportunities for technological designs, allowing the creation of systems that can improve safety, efficiency, and convenience (i.e. AgeLab's Driver Aware Car (ADAC).) On the other hand, there are numerous sources that indicate a general discomfort over the potential for abuse, fear over a potential lack of control, and desire for privacy-sensitive applications and systems using ubiquitous computing (Garfinkel, S, 2001; Brin, D., 1998.) These concerns suggest that privacy may be a barrier to the long-term success of ubiquitous computing particularly in the car.

The fundamental problem, however, is that ubiquitous computing also introduce many new privacy risks, often at a rate faster than legal mechanisms and social norms can adapt. Ubiquitous computing technologies change the privacy landscape by dramatically lowering the cost of collection, making it easy to gather and share a wide range of real-time data about individuals and their behavior.

4.3. Challenges in building privacy-sensitive ubiquitous computing applications

From a technical perspective, one of the main challenges in building privacy-sensitive ubiquitous computing applications may be in the fact that privacy is not a purely technical issue, but also involves aspects of legislation, and social norms (Beckwith, R., 2003.) Moreover, privacy is a flexible concept in practice, based on perceptions of risk and benefit from different stakeholders. For example, many people routinely use a credit card to buy goods and services on the Internet because they believe that the convenience of online purchases outweighs the potential cost of such transaction data being misused.

However, the problem of building privacy-sensitive ubiquitous computing applications could be address by providing a more solid technical foundation for building applications, as well as better user interface guidelines to help end-users manage privacy, giving these users greater control and feedback over their personal information. This approach can be applied to applications such as ADAC to provide drivers with the ability to control manage the mount of privacy for sharing their personal information.

From an application development perspective, though, there are still challenges in the evaluation of privacy measures in ubiquitous computing systems. First, it is hard to analyze end-user needs for privacy in application of ubiquitous computing. While there is a great deal of speculation, there is not a great deal of meaningful information that can be used to inform the design of such systems. Second, it is difficult to design effective user

interfaces for privacy in ubiquitous computing systems. It is not clear what kinds of user interfaces work well and what kinds do not. Third, it is difficult to build privacy-sensitive ubiquitous computing applications. It is not clear what abstractions and mechanisms are useful for application developers in managing ubiquitous computing privacy. Furthermore, it takes a high level of technical expertise to design and develop ubiquitous computing systems in general, even without addressing the privacy needs (Bartram L., Czerwinsky M., 2002; Carter, S., Mankoff, J., 2004.)

4.4. Data ownership of information collected via ubiquitous computing applications in the car.

Applications of ubiquitous technologies comparable to the AgeLab's Driver Aware Car (ADAC) have the potential to collect real-time information to recreate the state and behavior of drivers while driving their motor vehicles. This information can be then use to increase driving safety and provide more comfort to drivers.

It can also be arguable that in addition to drivers themselves, this information can also be use for similar endeavors from other parties such as vehicle manufacturers, consumer groups, health-care providers, government, law enforcement, insurance companies, judicial entities, and researchers. Thus, these groups have also the possibility of using this information to create services or products for that will increase safety and promote the wellbeing of society.

Despite all the benefits that sharing information from ubiquitous computing applications in the car might provide, however, this topic has not been without controversy (Matthew L., Wald, 2002.) Privacy concerns related to data ownership seem to be an important issue in the agenda of those advocating privacy and consumer protection rights (Minch, R.P., 2004.) Oftentimes, the concern is less about the data ubiquitous computing applications in the car can presently gather, but instead what future applications or technologies might be capable of recording (Narciso D., 2002.) Presumably on advances of electronics, these applications could be design to monitor and collect considerably more data and have the capability to share it more pervasively. Proponents of ubiquitous computing applications in the car could argue that each of these innovations might improve highway safety. Such improvements, however, would come at an increase of data sharing and data ownership issues. Faced with such potential invasion upon personal privacy and data ownership, the public may be doubtless be more willing to permit the collection of certain types of data by the use ubiquitous computing applications in the car.

4.5. Privacy and public policy in context-aware ubiquitous computing

Privacy issues are thick barrier for the utilization of context-aware ubiquitous computing both generically as well as in the case of motor vehicle technologies such as ADAC. White gives his opinion that if there is public anxiety, some kind of regulation is unavoidable (White, J.C., 2003.) He also describes the alternative of the regulation based on the degree of freedom, such as "Law", "Mandatory Self-Regulation", "Voluntary Self-

Regulation" and "Laissez Faire". White goes on to recommend self-regulation because this will preserve the freedom of the companies, and allow the most flexibility for the new technology to evolve. One counterargument is that self-regulation should be mandatory. However, it is difficult to enforce the self-regulation to companies thus it needs serious penalties for companies that fail to follow established protocols.

Regarding the formation of the policy frameworks for context-aware ubiquitous computing and similar technologies, many researchers and consumer group propose notions. Kumar specifies six aspects for policy formation review and four concerns that also have to be addressed for the correct formulation of policies related to applications based on ubiquitous computing (Kumar, R., 2003.) He mainly mentions the necessity of conducting a stakeholder's analysis, consideration on management of data, and appropriate process of policy formation. Lederer explains that most privacy laws around the world are based on some variation on the fair information practices and makes out five characters of such practices (Lederer S., 2003.) White also recommends four models: comprehensive law, sectoral law, self-regulation, and technology that all location privacy laws should contain which allow for flexibility of privacy protection in order to take after-the-fact policies for the purpose of solving potential problems (White, J.C., 2003.) These researches imply the consideration points of research for policies that facilitate the implementation of ubiquitous technologies; (1) identification of stakeholders, (2) consideration of treatment of data ownership, (3) acceptance of technology adopters, and 4) accuracy of data collected by monitoring technologies.

Chapter 5. Systematic Approach to Stakeholder Analysis

A systems approach of thinking was utilized to determine the nature of the data needed for producing appropriate findings and recommendations. First, a stakeholder's analysis was constructed. Using that analysis, a variety of academic, commercial, and governmental sources as a representation of the various stakeholders were analyzed to understand: a) the prime interest of the stake holders over context-aware ubiquitous computing in the car, and b) the effect of this the application of this on the different stakeholders. Second, a series of focus-groups were designed and administered to potential users of context-aware ubiquitous computing in the car to understand their opinion on a) privacy, b) data-ownership, c) regulation, and d) adoption of technology.

5.1. Statement of research questions

For this thesis, ubiquitous in-vehicles technologies based on context-aware models were researched as a concept-mechanism for the collection of information about driver behavior to provide real-time feedback to enhance motor vehicle safety. This concept-mechanism is recommended as a framework for future developments of in-vehicle technologies.

It is common for applications of this nature to face a plethora of policy barriers, including privacy, data-ownership, and regulation. Therefore, to understand these barriers, exploratory research based on qualitative methods is included addressing the following research questions:

- Can context-aware ubiquitous technologies in the car collect data about drivers to provide real-time monitoring and post-process feedback about their driving behavior?
- Can driving behavior be changed by post-processing feedback from data collected by context-aware ubiquitous technologies in the car?
- What policy implications in a) privacy, b) data ownership, and c) regulation will be raised by the use of context-aware ubiquitous technologies in the car for the collection and sharing of real-time information of motor vehicle drivers?

5.2. Stakeholders analysis

A stakeholder's analysis was conducted to determine the groups that are affected by the potential use of context-aware ubiquitous computing in the car. For findings and implications to be relevant, a consensus which satisfies the primary interests of all stakeholders should be obtained. After identifying the various groups, a probing analysis was conducted on effects that context-aware ubiquitous technologies could have on these stakeholders.

5.2.1. Identification of interest and effects on stakeholders

On the industry side, the focus was on the motor vehicles manufacturers. In the healthcare industry, attention was directed to healthcare providers. Governmental

agencies, like the National Highway Traffic Safety Administration (NHTSA,) were also incorporated into the stockholder’s analysis. Insurance companies were also included in the analysis. Law enforcement, including local and state police were also considered in the analysis. Lastly, potential adopters and consumer interest groups were also considered. The actual stakeholder analysis is shown in the chart on the following page.

Table 8: Overview of Stakeholders Analysis

Stakeholders	Prime Interests	Effects of Context-Aware Ubiquitous Technologies in the Car on the Various Stakeholders
Motor-Vehicle Drivers	<ul style="list-style-type: none"> • Privacy • Safety • Comfort 	<ul style="list-style-type: none"> • Provides vehicle and highway safety • Improves driving performance • Relinquish certain level of privacy
Family of Motor-Vehicle Drivers	<ul style="list-style-type: none"> • Safety • Costs 	<ul style="list-style-type: none"> • Allows monitoring of drivers
Motor-Vehicle Manufacturers	<ul style="list-style-type: none"> • Increase motor-vehicle sales • Regulatory compliance 	<ul style="list-style-type: none"> • Improve design of vehicles. • Use technology to meet safety regulations.
Consumer Groups	<ul style="list-style-type: none"> • Protection of consumers 	<ul style="list-style-type: none"> • Concerned about Privacy • Fear possible abuse of individual rights by government and companies
Healthcare Providers	<ul style="list-style-type: none"> • Patient's health 	<ul style="list-style-type: none"> • Reduces number emergency room visits. • Reduce hospital workload
Insurance Companies	<ul style="list-style-type: none"> • Lower insurance payout • Accurate premium rating of clients 	<ul style="list-style-type: none"> • Reduces number emergency room visits. • Reduce hospital workload
Government (NHSTA, DOT)	<ul style="list-style-type: none"> • Need to balance between companies and consumers concerns over technology 	<ul style="list-style-type: none"> • Need to proactively produce new policy measures for monitoring technologies in the car.
Law Enforcement	<ul style="list-style-type: none"> • Accurate and impartial information on drivers and vehicles 	<ul style="list-style-type: none"> • Determination of factors associated with drivers, motor-vehicles, and accidents.

5.3. Qualitative analysis

Qualitative analyses were conducted through a series of semi-structured focus group interviews to understand how individuals and groups view and understand the idea of context-aware ubiquitous technologies in the car and construct meaning out of their personal experiences. For this analysis, a total of four focus-groups were put together

with the objective of collecting information that will aid to answer the research questions posed in this thesis.

5.3.1. Participants

Subjects for this study participated in a total of four focus-group meetings over a two-day period in the summer of 2006. The grounded-theory method of Strauss and Corbin, including a carefully observation of the research questions of this thesis and the role that each subject would have in the focus groups, was use to develop a screening criteria for the participation of subjects in these meetings (Strauss, A.L., Corbin, J., 1990.) The initial sampling criteria included: 1) balanced gender mix; 2) ownership of a motor vehicle; and 3) usage of a personal computer 5 or more days per week as evidence of familiarity with modern technologies.

As the protocols were analyzed, theoretical sampling criteria were expanded after the second protocol, based on criteria relevant to the evolving theory. After the second protocol, the initial sample was expanded to include: 4) those who drive at least 10,000 miles per year and on at least 5 days per week as a measurement of vehicle usage; 5) One age split of participants between the ages of 21 and 30 and participants age 50 or older; 6) drivers that are financially responsible for their car insurance. After the third protocol, the criteria were expanded to include: 7) the amount of traffic violations or accidents as a metric to identify their driving behavior; and 8) drivers of age 50 or older who have children age 15 to 22 living at home. For the present study, saturation occurred following the analysis of the third protocols. The final sample consisted of four focus groups and 46 participants.

All participants were drivers living and licensed in the state of Massachusetts. Drivers were recruited by established by Performance Plus, a market research field services in the Boston area. Performance Plus began recruitment with their own proprietary databases that include listings of people who had expressed interest in participating in market research. From these initial listings, recruitment followed a sampling approach, with contacted people referring others who might be interested and eligible to participate.

Based on the described recruitment procedures, screening staff from Performance Plus called identified telephone numbers to recruit participants. The staff requested to speak with the person on the list, to which they explained the purpose and nature of the study, and inquired a sequence of questions based on a pre-set questionnaire (Appendix B). If the person was eligible for study participation, the staff explained the purpose and nature of the study and extended and invitation to participate in the study.

Recruitment goals for rating sessions were set at 12 people per session, with a recruiting criteria based on the specifications detailed in the screener questionnaire (Appendix B.) The study protocols and instruments were approved by the Committee on the Use of Human Subjects (COUHES) from the Massachusetts Institute of Technology (MIT.)

5.3.2. Focus groups

The strength of focus group research is to increase qualitative insights into specific topics, attitudes and behaviors (Wilson, V., 1997.) Focus groups are a form of group interview that capitalizes on communication between research participants in order to generate data. Although group interviews are often used convenient way to collect data from several people simultaneously, focus groups explicitly use group interaction as part of the method. This means that instead of the researcher asking each person to respond to a question in turn, people are encouraged to talk to one another: asking questions, exchanging anecdotes and commenting on each others' experiences and points of view (Kitzinger J., 1994.)

Focus groups are a good tool for exploring “why people think or feel the way they do” (Krueger, R.A., 1994.) They provide researchers with the opportunity to delve into the internal dynamics of people’s actions and choices in a group setting, uncovering information that could not be easily obtained from a survey (Morgan, D.L., 1998.) Focus groups have limitations, most notably concerns over the influence of the group on individuals’ opinions and the ability to generalize to the population (Morgan, D.L., 1997.) However, they are ideal for projects such as this that seek to define people’s attitudes and feelings about driving and the changes they have made with age. In addition, focus group methods provide an ideal baseline (i.e., being able to explore and confirm) for further quantitative research, by shaping the development of surveys/ questionnaires (Edmunds, H.,1999.)

5.3.3. Data analysis procedure

Data were collected through four semi-structured focus-group interviews in the summer of 2006. The focus-groups were coordinated by Performance Plus; a market research field services in the Boston area. Participants were recruited based on proprietary databases that included listings of people who had expressed interest in participating in market research. For the interviews, groups were assembled in four groups based on: 1) balanced gender mix; 2) age split of participants between the ages of 21 and 30 and participants age 50 or older; 3) the amount of traffic violations or accidents as a metric to identify their driving behavior. Participants were encouraged to share their personal opinions and to give examples from their own lives to increase understanding of the meaning of motor vehicle safety in their lives.

The focus groups were taped and analyzed by the author of this thesis. Data collection and analysis were conducted concurrently. The nature of the initial interview questions was transformed and shaped during the research process, moving from very general to very focus. The focus groups ran an average of about two hours and were facilitated by Dr. Laura K. M. Donorfio, Assistant Professor of the University of Connecticut from the Center for Developmental Disabilities and MIT AgeLab research affiliate via a pre-set set of questions in the form of a moderator’s guide related to the research questions in this thesis (Appendix B.) In addition to covering questions about the meaning of driving safety, feedback on driving behavior, and technologies in the car for safety, the focus groups discussed a number of other topics related to feedback from

technologies in the car, privacy concerns, sharing of personal information collected from technologies in the car, and monitoring technologies in the home.

One of the most significant components of grounded theory is the development of major themes that come from the “data” or the phenomenon under study (Donorfio, L.M., 1996.) The major themes are characterized by one or more of the following: Their relevance to the research question, the importance the theme had for the participants, the frequency of them being mentioned and the consistency of them being mentioned by participants of the different focus groups. The next section of this thesis will discuss the major themes that were generated, developed, and elaborated from the focus groups.

The major themes identified from the qualitative analysis range from issues that identify and influence safe driving, over the feedback drivers receive about their driving performance, to ubiquitous technologies in the car that can help in safe driving. Further, the benefits and drawbacks of technology giving feedback on driving performance were discussed as well as how feedback by technology on driving performance should be given. And finally, issues related to privacy and data sharing were discussed to provide comments on how data collected from ubiquitous technologies in the car can be use for the benefit of the drivers is summarized.

5.4. Findings

5.4.1. Characteristics of safe and good drivers

When asked “what are the characteristics of someone who is a good driver?” respondents mentioned many safe behaviors and good driving habits (i.e., no tail-gating, wear seat-belts, obey traffic laws) as well as certain personality traits (i.e., patience, awareness, able to act/react).

Table 9: Characteristics of Good Drivers

Behaviors	Personality Traits
No tail-gating	Patience
Wear seat belts	Awareness
Obey traffic laws	Able to act/react

Similarly, unsafe behaviors (e.g., speeding) and unsafe personality traits (e.g., aggressive) were mentioned. Surprisingly, when the respondents were asked “what are the characteristics of someone who is a safe driver?” they described similar characteristics as the ones for good drivers; although, in most instances respondents agreed that good drives and safe drivers are not the same.

Table 10: Characteristics of Bad Drivers

Behaviors	Personality Traits
Speeding	Aggressive
Unnecessary Lane Changing	Road rage
Do not obey traffic laws	Distraction

There was a consensus that in order to be a good driver one should be a safe driver. There was a significant difference among how the groups defined good and safe drivers. Drivers in the age group of 21 to 30 years believed that good and safe drivers are those who exhibit greater skills on handling the vehicle. In contrast, the drivers in the age group of 50 and above years were more focused on the attitude towards obeying the laws of the road.

Table 11: Main Definition of Good and Safe Drivers

Young Drivers (21 to 30 years)	Older Drivers (50 + years)
Skills Handling the Vehicle	Attitude towards obeying the law

In addition to driving habits and personality traits, the respondents also mentioned the use of car technologies such as air-bags, anti-lock brakes, and safety-belts as metrics for the characterization of good and safe drivers.

5.4.2. Receptivity about getting feedback on driving performance

The focus-groups discussions demonstrated that the participants were open to the idea of receiving feedback on their driving behavior. Furthermore, nearly every one mentioned that they have received some type of feedback about their driving behavior from significant others, parents, and children, but not from other relatives or friends. According to the participants, for the most part feedback was given regarding the speeding, lane-changing, breaking, and proximity to other vehicles.

In the focus-group discussions it was a frequent topic that drivers are willing to receive comments on their driving behavior only if this is specific, constructive, and respectful. Feedback is also welcome if it is positive and accompanied without signs of attitude. Feedback is wanted from persons the drivers respect and perceive as knowledgeable about their driving. Feedback was felt to be less desirable if it was related to events that they are well aware about or they serve only as a critique. As a participant from the young/good driver group shared:

“... I guess I don’t even bother driving with my mother anymore... it is a constant critique...”

In addition, the participants also that negative feedback was perceived as not helpful. And, receiving negative feedback for doing something “wrong” but not being told how to do it “right,” was mentioned as not being helpful feedback.

5.4.3. Experience with technology to enhance and improve driving

When asked, “what are some of the features in your car that makes you feel safe and enhance your driving?” the participants responded with a list of different features available in current cars such as: radio, air-conditioning, airbags, cruise-control, power-windows, and indicators on the dashboard. After the initial discussion on this subject, an

exercise based on a questionnaire was give to them (Appendix C). The questionnaire included a list of features that can aid drivers with their driving skills and behavior and other to increase safety in their vehicles. The list included some technologies that are already available in the market and some others that are still in development and will be integrated in future motor vehicle platforms.

Interestingly enough, after the participants went through the exercise, the center of the conversation changed from talking about standard technologies currently available in motor vehicles today to include technologies that will be available in the future. For instance, among the most frequently mentioned technologies were systems for anti-lock brakes, airbags, collision-avoidance, vision-enhancement, proximity sensing, lane deviation warning, and navigation (Table 12.)

Table 12: Technologies to Enhance Safety and Driving Behavior

Anti-Lock Brakes
Airbags
Collision Avoidance
Vision Enhancement
Proximity Sensing
Lane deviation warning
Navigation Assistance

Most of the participants found that these technologies could enhance safety and provide assistance for better driving. As one of the participants from the older/bad driver group shared:

“... for me having these technologies(in the car) would help me to avoid getting into an accident by telling me what else is on the road...”

Participants in the younger groups were more interested in technology that will enhance the performance of their vehicles, as supposed to the participants in the older groups that were eager to have technology to improve their driving behavior and ease their view on the conditions of the road.

Table 13: Interests of Participants about Technologies in the Car

Young Drivers (21 to 30 years)	Older Drivers (50 + years)
<ul style="list-style-type: none"> • Enhance the performance of the vehicle 	<ul style="list-style-type: none"> • Enhance Driving behavior • Assist on viewing road conditions

Additionally to their emotional reactions to the usage of monitoring technologies in the car, and which indicated a strong sense of risk, participants also articulated specific concerns about using the service by relating it to particular system functionality and reliability. Some of the participants were concerned about incidents where technologies of this kind may malfunction or behave different than expected. Both groups also agreed that the introduction of more technology in the car could potentially be more distracting which will detract from the safety implications of the technologies.

5.4.4. Benefits and drawbacks of technology as means of giving feedback on driving behavior

When asked, both younger and older drivers could see perceived benefits of these feedback systems. Participants were asked what the perceived benefits of feedback systems would provide. Participants believed that their driving performance would increase by the use of these systems. Safety enhancements were also a perceived benefit from these technologies. Participants believe that receiving constructive criticism on their driving habits would improve safety.

Table 14: Perceived Impact of Monitoring Technologies in the Car

	Young Drivers (21 to 30 years)	Older Drivers (50 + years)
Good Drivers	<ul style="list-style-type: none"> • Helpful for other people 	<ul style="list-style-type: none"> • Like to be in control
Bad Drivers	<ul style="list-style-type: none"> • Helpful for them/family 	<ul style="list-style-type: none"> • Fear of being misused by other parties

While participants could see clear benefits of feedback systems, they still saw a significant number of drawbacks. Participants in the young/good group expressed that implementing these systems would be useful to people other than themselves. In contrast participants in the older/good group mentioned that this type of technology would be helpful not just for them but also to other members of their family such as young children and parents.

Participants in the younger/bad groups expressed that too much reliance on technologies to provide feedback will decrease the amount of control one has over their vehicle thus impairing their driving. As one of the participants in the young/bad driver group shared:

“...it is helpful to have these technologies but I am little concern about people getting into their cars not worrying about driving thinking that the car will do everything for them...”

Participants also expressed concerns about this technology being too invasive and preventing them from experiencing the drive. As one of the participants in the younger/bad driver group noted:

“...driving is about an experience... if too technology laden, removes people from the experience...”

Participants from the older/bad group states that this technologies have the potential to be useful but they may not be willing to implement them in their cars. Participants in this group expressed their concern about the consequences of sharing this data with other parties. Their major fears were related to having this information used against them.

Despite their interest in this type of technologies, participants were apprehensive about the associated costs. It was clear through the number of comments inquiring about the costs that this issue may be a barrier to acceptance. However, participants expressed if they can obtain value from having these technologies then they would be less concern with the increased costs.

There was a consensus of the general benefits and drawbacks of feedback technologies. However, there was a difference between the older and younger groups in a personal need of technology (Table 15.)

Table 15: Perceptions Where Technologies are Most Helpful

Young Drivers (21 to 30 years)	Older Drivers (50 + years)
<ul style="list-style-type: none"> • Older Drivers 	<ul style="list-style-type: none"> • Themselves
<ul style="list-style-type: none"> • Drivers with Medical Conditions 	<ul style="list-style-type: none"> • Younger Children (16 to 21 years)

The older groups suggested that although drawbacks exist, technology provides the opportunity for supplementing or improving their driving skills and enhancing safety. The older groups perceived that they would personally benefit from these technologies. In addition, the older groups of participants mentioned that they would like to have this type of technology to increase the safety and behavior of the young children. As one participant older/good driver group pointed out,

“...if I can improve [driving behavior] in any way [via feedback technologies] I would like to know...”

The younger groups were more resistant to the idea of implementing these technologies in their own cars. Based on the different responses from people in these groups, while they find these technologies useful, they believe that older populations or those with driving impairments need these technologies the most. As a participant in the young/good driver group noted,

“... if you have a condition were you shouldn't be and need to drive then it is good to have it [feedback technologies] ...”

5.4.5. Preferences of feedback delivery through technologies in the car

The participants discussed how they would like to receive feedback on their driving behavior from technologies in the car. Trends that suggested simplicity and personalization emerged consistently through the groups. In addition participants were very specific about the types of information they would like to receive from this systems, not only about them but also about the vehicle and its environment.

One point of discussion was being able to customize the technology to meet their needs and requirements. Participants discussed different modalities of feedback and

agreed that feedback should be received in a simple way and should not intervene with their primary endeavor of driving. Warnings should be provided via audible cues so to avoid changing their attention from the road. Whereas feedback on their driving behavior could be given in other ways for which a variety of preferences among the participants existed. Older participants expressed that they would like to receive feedback via audible cues in the form of an artificial voice; whereas younger participants preferred to receive visual cues from a device similar to a computer screen. Overall, participants stated that they would feel more comfortable if they are given the ability to specify how feedback information is presented to them.

Timing of feedback was another issue that produced a variety of different opinions. Although it was consistent that warnings (i.e. distances from other vehicles) should be given immediately, there was no consistent opinion about the right time and frequency for reviews of driving behavior. An additional personal preference that participants suggested was the option to turn the feedback system on or off.

Participants in the older groups expressed that they would preferred it to be delivered whenever they requested it; whereas participants in the younger groups preferred the information delivered to them by the system at the end of the trip or on a weekly or monthly schedule. These responses suggested that a feedback system should be adaptable to the preferences of the individual driver.

Based on the responses from participants in the different groups, there are three types of feedback categories they would like to receive from technologies in the car: 1) related to the car, 2) related to the driver, 3) related to the driving environment.

Table 16: Feedback Domains

Feedback Domain		
Driver	Car	Environment
<i>Driving Behavior</i>	<i>Mechanical Conditions</i>	<i>Road Conditions</i>
• Awareness	• Maintenance	• Visibility
• Physiological	• Safety Systems	• Navigation
• Stress	• Gas / Tires / Oil	• Traffic

In regards to information related to the car, participants wanted to see the performance and mechanical conditions of the vehicle (engine, tires, electrical system, anti-lock brakes, and airbags,) as well as recommendation on how to improve the gas mileage and overall maintenance.

Related to information from the driver, participants agreed they would like to receive feedback from their driving behavior as long as it is not obvious to them. Participants agreed to be monitored on their physiological state only if they have a medical condition such diabetes and heart disease. One of the participants in the older/bad driver group emphasized this idea by saying:

“I don’t need a machine to tell me I am stress... I already know that... I want the machine to tell me what to do about it.”

For feedback related to the driving environment, participants would like receive information on the conditions of the road, blind spots, navigation, and proximity to other vehicles. Other information important to the participants included ways to received traffic alerts, weather in real time.

Table 17: Relevant Feedback Categories among Groups

	Young Drivers (21 to 30 years)	Older Drivers (50 + years)
Good Drivers	Car	Car / Driver / Environment
Bad Drivers	Car	Car / Environment

5.4.6. Attitudes towards privacy, trust, data sharing/ownership

Participants discussed who should be given access to the data collected technologies in the car. Many participants were concerned about how the data could be shared and protected from different stakeholders such as consumer protection groups, healthcare providers, insurance companies, car manufacturers, government, and law enforcement groups to preserve personal privacy.

By analyzing the discussion from the focus-groups it was clear that the most controversial aspect of the system was its invasiveness, in that it collected and processed personal information with the potential of sharing it with others. With the exception of a few individuals, all participants identified invasion of their privacy as their main concern, especially when considering the scenario when the information collected about them can be stored and shared.

In addition to the protection of their privacy, participants were also concerned about how much trust they could actually put on the system in regards to keeping their personal information safe. The vast majority of participants would resist providing their data unless they could be confident that data would be used fairly and that they can obtain benefits from sharing it.

Most of the participants were worried that the data collected from monitoring system like this could be misused by some stakeholders, mostly insurance companies, law enforcement, and the government. For instance, one of the participants in the older/bad driver group expressed that:

“... eventually everything could end up with the insurance companies and everything [rates] will go sky high...”

Others expressed mistrust in the government and were concern that a system such as this could provide excessive access to their personal information. As one participant in the older/good driver shared:

“... I don't want to get “Big Brother” involved... I don't want to start receiving traffic tickets in the mail.”

From all the groups, participants in the younger/bad drivers and older/bad driver groups are willing to share their personal information with most of the stakeholders. These groups view medical doctors and car companies as equally trusting sources with whom to share their information. More than three-quarters of the participants in the younger/bad drivers group and about half of the participants in the older/bad drivers group are eager to share their information with these doctors and car companies (Table 18 and Table 19.)

Table 18: Willingness to Share Personal Information - Younger / Bad Driver Groups

Younger (21-30 years) : Bad Drivers Group (n=12)		
	Willing to Share Information (percentage)	Not Willing to Share Information (percentage)
Consumer Groups	67%	33%
Medical Doctor	83%	17%
Medical Insurance Company	33%	67%
Car Companies	92%	8%
Law Enforcement Agencies	25%	75%
Government	33%	67%
Auto Insurance Company	0%	100%
Other People	58%	42%

Table 19: Willingness to Share Personal Information - Older / Bad Driver Groups

Older (50+ years) : Bad Drivers Group (n=11)		
	Willing to Share Information (percentage)	Not Willing to Share Information (percentage)
Consumer Groups	27%	73%
Medical Doctor	55%	45%
Medical Insurance Company	0%	100%
Car Companies	45%	55%
Law Enforcement Agencies	0%	100%
Government	0%	100%
Auto Insurance Company	0%	100%
Other People	0%	100%

Participants in the younger/older bad drivers groups are willing to share their personal information because they believe that medical doctors and car-companies will offer sufficient incentives to encourage such information sharing, without compromising their privacy and security. For example, participants from these groups expressed that sharing information with medical doctors may result in better health monitoring. With

respect to car companies, participants believed that this information can be use to increase vehicle safety and car performance.

In contrast, participants from the older/good drivers and younger/good drivers are less willing to share their personal information with medical doctors and car companies (Table 20 and Table 21.)

Table 20: Willingness to Share Personal Information - Younger / Good Driver Groups

Younger (21-30 years) : Good Drivers Group (n=11)		
	Willing to Share Information (percentage)	Not Willing to Share Information (percentage)
Consumer Groups	0%	100%
Medical Doctor	45%	55%
Medical Insurance Company	18%	82%
Car Companies	27%	73%
Law Enforcement Agencies	9%	91%
Government	0%	100%
Auto Insurance Company	36%	64%
Other People	0%	100%

Table 21: Willingness to Share Personal Information - Older / Good Driver Groups

Older (50+ years) : Good Drivers Group (n=12)		
	Willing to Share Information (percentage)	Not Willing to Share Information (percentage)
Consumer Groups	17%	83%
Medical Doctor	25%	75%
Medical Insurance Company	8%	92%
Car Companies	33%	67%
Law Enforcement Agencies	8%	92%
Government	8%	92%
Auto Insurance Company	17%	83%
Other People	8%	92%

Results from Table 18 to Table 21 reflect the participants' general unwillingness to disclose or share their personal information and driving behavior with commercial and governmental stakeholders. This is not surprising, given the reiterated concerns about privacy, lack of trust, and security issues. However, a deviation from these concerns was observed the idea of tangible rewards such as monetary incentives for information sharing was proposed (Table 22.) Younger drivers expressed significant interest and enthusiasm for such incentives, especially participants in the young/bad drivers groups who were willing to share their data for less monetary incentives that the young/good drivers group. Conversely, older drivers remained hesitant and somewhat skeptical about

the practicality of such incentives, which they believe had to be of significant magnitude for them to be agreeable to information sharing.

Table 22: Perceived Incentives to Share Personal Information

	Young Drivers (21 to 30 years)	Older Drivers (50 + years)
Good Drivers	Compensation	Privacy
Bad Drivers	Compensation	Privacy

5.5. Discussion

Motor vehicles are the primary source of transportation for Americans. While they provide independence and make our high-speed modern life possible, careless mistakes and aggressive driving leads to countless serious accidents every year. Modern technologies have the capability to help prevent many of these accidents. However, currently these technologies are segregated components and do not function as an integrated system to protect individuals in accidents.

The research in this thesis takes the first steps at developing and integrating technological systems for increasing driver safety. By combining technologies that already exists such as airbags, anti-lock brakes, on-board diagnostics, navigation assistants, and electronic stability programs with a series of sensors we have turn the standard car which has a single focus into a device that is aware of its driver and the environment and can respond to both as needed.

While an integrated motor vehicle has the capability to save lives, it can only do so by continuously collecting information on the driver. This is because the system works based on pattern recognition, and the pattern its studying are those of the driver behavior. Although this makes the system very accurate it also makes it very invasive. In modern day society people are very protective of personal information. Therefore, regulations need to be developed that allow the ubiquitous technologies to collect information without sacrificing driver privacy.

In order to determine what aspects of ubiquitous technologies in the car raise the most concerns among drivers, a series of focus-groups were conducted. The focus-groups revealed that individuals were open to the idea of receiving feedback on their driving behavior. Furthermore, most people have already received some form of driving feedback and therefore a system that collected it automatically is not that foreign of a concept.

The focus-groups further showed that not only were drivers familiar with the safety mechanisms that exist in their cars but are looking forward to technologies that are in development to improve driver safety. Thus, rather than fearing technologies in their car, most drivers embraced the idea. However, one common concern was the possibility of an overly automated car to malfunction and leave the driver with no control.

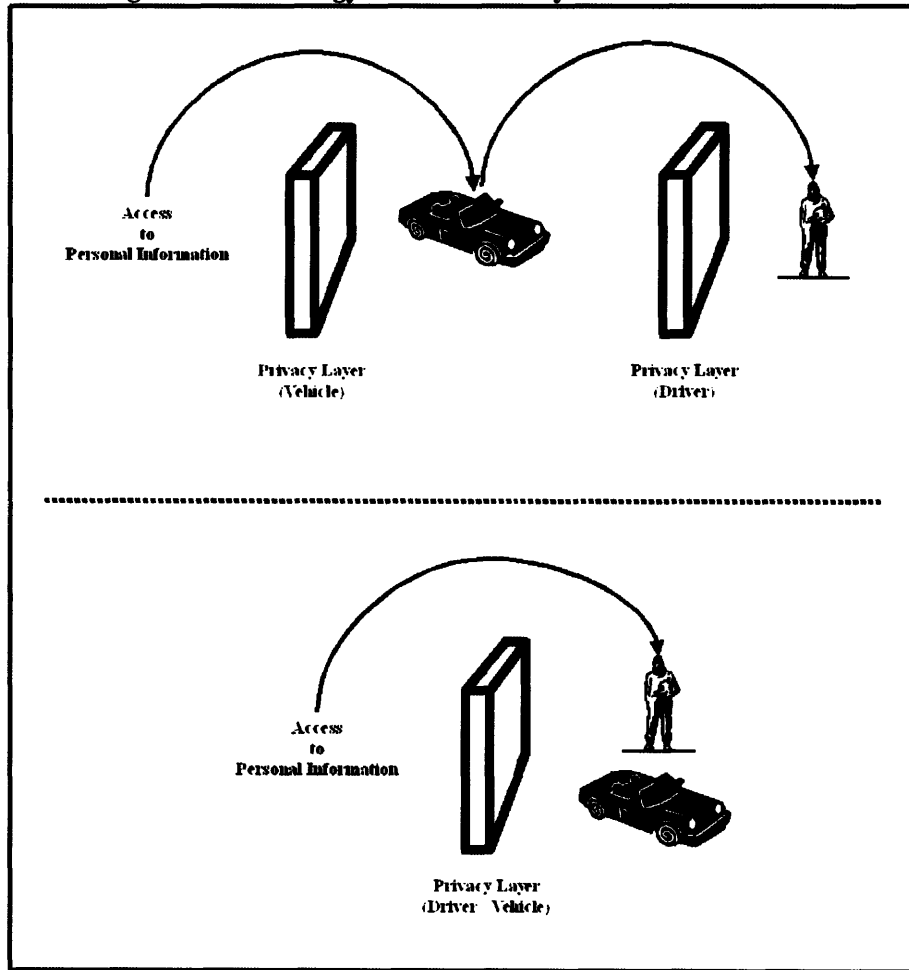
Analyzing the comments made by focus-groups participants made it clear that the most controversial aspect of the system was its invasiveness, because the system has the potential to share the information in collected with anyone. Participants were more unwilling to share information about their driver behavior with insurance companies and the government because they did not see any benefits to this exchange of information. Likewise, most individual were willing to share their personal data with medical professionals and car manufacturers because they believe that these stakeholders will use this information in a manner that would be beneficial for the consumers. Ultimately, the focus groups revealed that individuals are only willing to sacrifice their privacy when they get something in return.

5.6. Implications

The objectives of the focus-groups were fulfilled successfully and the results obtained provide valuable information that hold significant implications. Technology in the car today has the potential

The core technologies needed to collect driving data and provide post-processing feedback exist today. Integrating these technologies into a comprehensive system can create a paradigm shift in regulation, monitoring, and feedback, transferring control of information into the hands of drivers and users. This system simplifies access to personal information by removing privacy layers that have traditionally existed before (Figure 15.)

Figure 15: Technology Enabled Pathway to Information Access



From the findings of the focus-groups, these technologies will be accepted by drivers if they satisfy a set of restrictions and requirements. These restrictions can be identified from a detailed analysis of focus-groups responses, and they consequently give rise to major policy implications.

The implications of this research can be grouped into two main groups:

- Implications for technology design and integration,
- Implications for policy design.

5.6.1. Implications for technology innovation

A well designed system would be affordable, acceptable, and accessible. Drivers are concern with value from money, and will be receptive to increase costs if the technologies can enhance safety and driving performance. Acceptability of feedback is dependent on the ability of the system to provide positive and constructive advice without creating unnecessary frustration for the driver. In addition, the system should not compromise a drivers' overall control of the car. The mechanism, frequency, and availability of driver feedback should be adjustable by the driver as in when he wishes.

5.6.2. Implications for public policy

Addressing the implications for technology design alone is insufficient for context aware in vehicle technologies to become widely accepted and adopted by society. There is a need to consider broader policy implications that affect a wider range of stakeholders. These policy implications are concerned with privacy, data ownership, and trust.

The respect for personal freedom and privacy is a hallmark of American culture. This is reflected in the Fourth Amendment of the U.S. Constitution, which states that: “The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated...” To further protect the rights of automobile owners, a comprehensive set of legislation has been passed since the beginning of the 20th century. These legislations include:

- Federal Trade Commission Act (1914)
- Fair Credit Reporting Act (1970)
- Privacy Act (1974)
- Freedom of Information Act (1974)
- Family Educational Rights and Privacy Act (1974)
- Foreign Intelligence Surveillance Act (1978)
- Right to Financial Privacy Act (1978)
- Privacy Protection Act (1980)
- Cable Communications Policy Act (1984)
- Electronic Communications Privacy Act (1986)
- Video Privacy Protection Act (1988)
- Employee Polygraph Protection Act (1988)
- Telephone Consumer Protection Act (1991)
- Driver's Privacy Protection Act (1994)
- Health Insurance Portability and Accountability Act (1996)
- Telecommunications Act (1996)
- Children's Online Privacy Protection Act (1998)
- Financial Modernization Services Act (1999)
- USA Patriot Act (2001)

Source: *Privacy / Data Protection Project, University of Miami, Miller School of Medicine*

Three of the most relevant legislations are the Freedom of Information Act (5 U.S.C. sec. 552,) the Privacy Act of 1974 (5 U.S.C. sec. 552a,) and the Driver's Privacy Protection Act (Table 23.)

Table 23: Legal Mechanisms for the Protection of Privacy and Personal Information

Legal Mechanisms		
Freedom of Information Act	5 U.S.C. sec. 552	<i>Prohibits disclosure of personal information received by the agency that, if disclosed, would constitute a clearly unwarranted invasion of personal privacy (sec. 552(b)(6).)</i> <ul style="list-style-type: none"> •
Privacy Act of 1974	5 U.S.C. sec. 552a	<i>Provide citizens the right to see records about oneself, subject to the Privacy Act's exemptions</i> <ul style="list-style-type: none"> •
		<i>Provide citizens the right to amend that record if it is inaccurate, irrelevant, untimely, or incomplete</i> <ul style="list-style-type: none"> •
		<i>Provide citizens the right to sue the government for violations of the statute including permitting others to see one's records unless specifically permitted by the Act.</i> <ul style="list-style-type: none"> •
Driver's Privacy Protection Act of 1984	Public Law 103-322, amended by Public Law 106-69	<i>Release of information collected by a state department of motor vehicles for its official functions requires the express consent of the individual.</i> <ul style="list-style-type: none"> •

Data-ownership can be well protected by the Privacy Act of 1974 which was created to balance the government's need to maintain information about individuals to be protected against unwarranted invasions of privacy. The Act grants individuals increased rights of access to agency records maintained on themselves and also the right to seek amendments of these records.

A driver's privacy can be well protected by all three legal mechanisms in Table 23 above. The Freedom of Information Act prevents unreasonable search and seizures, as well as unwarranted disclosure of personal information by government agencies. The Privacy Act of 1974 provides drivers with a legal tool to challenge any violations of their personal privacy. The Driver's Privacy Protection Act prevents the release of information without a driver's consent.

With this framework in mind, the next step would to determine how to encourage drivers to allow access to their driving information. Any initiatives introduced must be overseen by a trustworthy regulatory body, which may be in the form of an exiting government agency or newly created institution. This entity should act as a platform accessible by the private sector, governmental authority, and drivers. As a source of information, watchdog, and enforcer, it would ensure the protection of driver's interests while capture important benefits for society.

Having said that, designing and implementing a robust regulatory framework will require more quantitative research, in the form of large sample surveys that can provide details on regulatory demands user's point of view. This will complement the findings from the qualitative exploratory research such as the one conducted for this thesis.

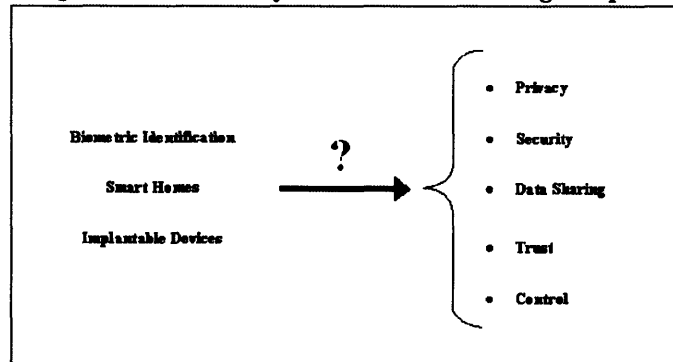
Chapter 6. Future research and applications beyond the car

The exploratory research accomplished in this thesis is of significance relevance to several other technology domains undergoing rapid development today. Examples include biometric identification, smart homes, and implantable devices. As concerns over national and corporate security become heightened, companies and governments are starting to look to biometric identification technologies for systems that can promise higher levels of security. However, these systems raise a plethora of privacy concerns that bear similarity to in vehicle technologies in the automobile such as those studied in this thesis. These concerns may be even more difficult to address, because the collection of personal information about users using biometric identification systems may take place without the individual's knowledge.

The usefulness of ubiquitous technologies in the home is also becoming a reality. As the success of smart home studies and pilot projects become more apparent, these technologies will start to move into the regular consumer market. While they hold great promise to simplify our lives by predicting our needs before they occur, their implementation also raise serious privacy and security concerns. Data concerning the users and their environments are constantly being collected, and the data needs to be securely stored and its integrity preserved. Data access is an issue of primary concern since these systems collect extremely detailed information of the users. Users are likely to want data access to be strictly controlled and limited to a select few. Furthermore, the success of these systems is integrally tied to the level of trust consumers have for the technology service providers. The issues of trust relevant to in vehicle technologies as revealed in this thesis provides useful stepping stones for researchers to examine the deeper issues of trust surrounding smart home technologies.

The area of implantable devices provides yet another unique set of challenges because these technologies or devices are carried by users everywhere they go. Unlike in vehicle or smart home technologies, it is almost impossible to turn implantable devices off once they are embedded. Furthermore, after the user agrees to get an implantable device, they relinquish control to the manufacturer of the device. This raises serious concerns about privacy, security, and trust because of the asymmetric access and availability of information that arise from such scenarios. The user provides all the data but does not have control over it. As such, trust between the user and the technology provider is of utmost importance. The design and implementation of policy in this area has to be carefully crafted to address the information asymmetries between the user and the provider.

Table 24: Public Questions and Policy Concerns Surrounding Ubiquitous Technologies



In summary, Table 24 illustrates the different areas of policy concerns in the various applications of ubiquitous technologies discussed above. Biometric identification primarily raises concerns related to privacy and security. Smart homes technologies are likely to raise policy concerns regarding privacy, security, data sharing, and trust. For applications related to implantable devices, in addition to privacy, security, data sharing, and trust, policy concerns are also raised on the area of control as to what parties have jurisdiction accessing these types of devices.

Bibliography

- Allan, R., Onstar System Puts Telematics On The Map, *Electronics Design*, volume 31, 2003.
- Brown, I. D., Driver fatigue. *Human Factors*, volume 36, number 2, 2004.
- Bergasa, L.M., Nuevo, J., Sotelo, M.A., Barea, R., Lopez, M.E., Real-time system for monitoring driver vigilance, *Intelligent Transportation Systems, IEEE Transactions on* , volume 7, number1, 2006.
- Borriello, G., Chalmers, M., LaMarca, A., Nixon, P., Delivering real-world ubiquitous location systems, *Communications of the ACM*, volume 48, number 3, 2005.
- Beckwith, R., Designing for ubiquity: the perception of privacy, *Pervasive Computing, IEEE*, volume 2, number 2, 2003.
- Bartram L., Czerwinsky M., Design and evaluation of notification interfaces for ubiquitous computing, *UbiComp Workshop*, 2002.
- Coughlin, J., Working Group Notes on Driver Wellness and Driver Aware Car, June 2004.
- Chittaro, L., De Marco, L., Driver Distraction Caused by Mobile Devices: Studying and Reducing Safety Risks, *Proceeding 1st Int'l Workshop Mobile Technologies and Health: Benefits and Risks*, 2004.
- Chiang, D.P., Brooks, A.M., Weir, D.H., On the highway measures of driver glance behavior with an example automobile navigation system, *Applied Ergonomics*, volume 35, number 3, 2004.
- Correia, J.T., Iliadis, K.A., McCarron, E.S., Smole, M.A., Utilizing Data from Automotive Event Data Recorders, *Proceedings of the Canadian Multidisciplinary Road Safety Conference XII*, June 2001.
- Carter, S., Mankoff, J., Czerwinsky M., Challenges for UbiComp Evaluation, *Technical Report CSD-04-1331, UC Berkeley*, 2004.
- Chidester A., Hinch J., Mercer T.C., Schultz K.S., Recording Automotive Crash Event Data; *Proceedings of the International Symposium on Transportation Recorders*, 1999.
- Donorfio, L.M., *Filial responsibility: widowed mothers and their caregiving daughters, a qualitative grounded theory approach*, University of Connecticut, 1996.
- Department of Transportation (DOT), *Strategic Plan 2003-2008, Safer, Simpler, Smarter Transportation Solutions*, 2003.
- David K., Earle E., *USA Today, Car dashboards look more and more like jet cockpits*, May 30, 2002.
- Endres, C., A survey of software infrastructures and frameworks for ubiquitous computing, *Mobile Information Systems*, volume 1, number 1, 2005.
- Edmunds, H., *The focus group research handbook*, NTC Business Books Lincolnwood, 1999.
- Fuller, R., *Accid Anal Prev, Towards a general theory of driver behavior*, volume 37, number 3, 2005.
- Fogg, B.J., *Persuasive Technology: Using Computers to Change What We Think and Do*, Morgan Kaufmann, 2002.

- Gabauer, D.J., Gabler, H.C., Evaluation of Acceleration Severity Index Threshold Values Utilizing Event Data Recorder Technology, Proceedings of the TRB 84th Annual Meeting, Paper 05-2220, January 2005.
- Gaglio, S., Gatani, L., Lo Re, G., Urso, A., A Logical Architecture for Active Network Management, Journal of Network and Systems Management, volume 14, number 1, 2006.
- Gstalter, H., Fastenmeier, W., Safety Impacts of In-Car Navigation Systems, Der Fahrer im 21. Jahrhundert, 2003.
- Godavarty S., Broyles S., Parten S., Interfacing to the on-board diagnostic system, IEEE vehicle technologies conference, 2000.
- Garfinkel, S., Database Nation: The Death of Privacy in the 21st Century, O'Reilly & Associates, 2001.
- Hutton, K.A., Sibley, C.G., Harper, D.N., Hunt, M., Modifying driver behavior with passenger feedback, Transportation Research Part F: Traffic Psychology and Behaviour, volume 4, number 4, 2001.
- Healey, J., Picard, R., SmartCar: detecting driver stress, 15th International Conference on Pattern Recognition, volume 4, pages.218-221, 2000.
- Huang, Y.H., Roetting, M., McDevitt, J.R., Melton, D., and Courtney, T.K., In-Vehicle Safety Feedback, Professional Safety - The American Society of Safety Engineers, 2005.
- Hann, I.H., Hui, K., Lee, T.S., Png, I.P., The Benefits and Costs of Online Privacy
- Jiang, X., Siren: Context-aware Computing for Firefighting, International Conference on Pervasive Computing, 2004.
- Jones, W.D., Black boxes get green light [car crash data recorders], Spectrum, IEEE, volume 41, number 12, 2004.
- Kluger, A.N., Denisi, A., The Effects of Feedback Interventions on Performance: A Historical Review, A Meta-Analysis, and A Preliminary Feedback Intervention Theory, Psychological bulletin, volume 119, number 2, American Psychological Association 1996.
- Krueger, R.A., Focus groups, Sage Publications Thousand Oaks, 1994.
- Kang, J., Cuff, D., Pervasive Computing: Embedding the Public Sphere, Washington and Lee Law Review, volume 62, 2005.
- Kumar, R., Interaction of RFID Technology and Public Policy, RFID Privacy Workshop, 2003.
- Komaki, J., Barwick, K. D., Scott, L. R., A behavioral approach to occupational safety: Pinpointing and reinforcing safe performance in a food manufacturing plant, Journal of Applied Psychology, volume 63, number 4, 1978.
- Kitzinger J., The methodology of focus groups: the importance of interactions between research participants, Sociology of Health and Illness, volume 16, 1994.
- Leen, G., Heffernan, D., Expanding automotive electronic systems, Computer, volume 35, number 1, year 2002.
- Legislation, 23rd International Conference on Information Systems, 2002.

- Lederer S., *Designing Disclosure: Interactive Personal Privacy at the Dawn of Ubiquitous Computing*, Unpublished Master of Science, University of California, Berkeley, Computer Science Division, Berkeley, CA, 2003.
- Langheinrich M., *Privacy Invasions in Ubiquitous Computing*, Ubicomp Privacy Workshop, 2002.
- Liebemann, E.K., Meder, K., Schuh, J., Nenninger, G., *Safety and Performance Enhancement: The Bosch Electronic Stability Control (ESP)*, SAE Convergence, 2004.
- Leen, G., Heffernan, D., *Expanding automotive electronic systems*, Computer, volume 35, number 1, 2002.
- Lenard, J., Morris, A., Thomas, P., *Use of smart technologies to collect and retain crash information*, Loughborough University, 2004.
- Minino A.M., Heron M.P., Smith B.L., *Deaths: Preliminary Data for 2004*, National vital Statistics Report, vol 154, no19, National Center for Health Statistics, 2006.
- Matthews, G., & Sparkes, T. *The role of general attentional resources in simulated driving performance*, Vision in Vehicles, 1996.
- Moriarty, P., Honnery, D., *Safety impacts of vehicular information technology*, International Journal of Vehicle Design, volume 31, number 2, 2003.
- Mohrman, A.M., Resnick, S.M., *Designing performance appraisal systems: aligning appraisals and organizational realities*, Jossey-Bass Publishers, 1989.
- Minch, R.P., *Privacy issues in location-aware mobile devices*, journal System Sciences, Proceedings of the 37th Annual Hawaii International Conference on, 2004.
- Matthew L., Wald, *The Debate over Event Data Recorders*, New York Times, (Sunday, Dec. 29, 2002.)
- Michon, J. A., *A critical view of driver behavior models: What do we know, what should we do?*, Human Behavior and Traffic Safety, 1985.
- Morgan, D.L., *Planning focus groups: Focus groups*, Sage Publications, 1998.
- Morgan, D.L., *Focus Groups As Qualitative Research*, Sage Publications, 1997.
- Mccartt, A.T., Hellinga, L.A., Bratiman, K.A., *Cell Phones and Driving: Review of Research*, Traffic Injury Prevention, volume 7, number 2, 2006.
- National Safety Council, *Injury Facts® 2005–2006 Edition*, 2006.
- National Sleep Foundation, *Sleep Strategies for Shift Workers*, Washington, DC, 2005.
- National Highway Traffic Administration, *Event Data Recorders - Notice of Proposed Rulemaking*, Federal Register, Vol. 69, No. 113, 2004.
- Narciso D., *Sensors Tell How Teen Driver Crashed*, Columbus Dispatch, 2002.
- Safety Facts, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, 2004.
- Sabey, B. E., Taylor, H., *The known risks we run: the highway*, Transportation Road Research Laboratory, Supplementary Report SR 567, 1980.

Smart, R.G. and Cannon, E. and Howard, A. and Frise, P., Can we design cars to prevent road rage?, *International Journal of Vehicle Information and Communication Systems*, volume 1, number 1, 2005.

Summers, S., Prasad, A., NHTSA's Recent Compatibility Test Program, *Proceedings of the Nineteenth International Conference on Enhanced Safety of Vehicles*, volume 278, 2006.

Society of Automotive Engineers, SAE J1962 Surface Vehicle Standard, Diagnostic Connector, 2002.

Strauss, A.L., Corbin, J., *Basics of qualitative research: grounded theory procedures and techniques*, Sage Publications, 1990.

U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *Transportation Statistics Annual Report*, Washington, DC, 2005.

White, J.C., *People, Not Places: A Policy Framework for Analyzing Location Privacy Issues*, Masters Memo Prepared for the Electronic Privacy Information Center, 2003.

Wilson, V., Focus Groups: A Useful Qualitative Method for Educational Research?, *British Educational Research Journal*, volume 23, number 2, year 1997.

Wouters, I.J., Bos, J.M., Traffic accident reduction by monitoring driver behavior with in-car data recorders, *Accid Anal Prev*, volume 32, number 5, 2000.

Yaacov, A., Maltz, M., Shinar, D., Effects of an In-Vehicle Collision Avoidance Warning System on Short- and Long-Term Driving Performance, *BenHuman Factors*, volume 44, number 2, 2002.

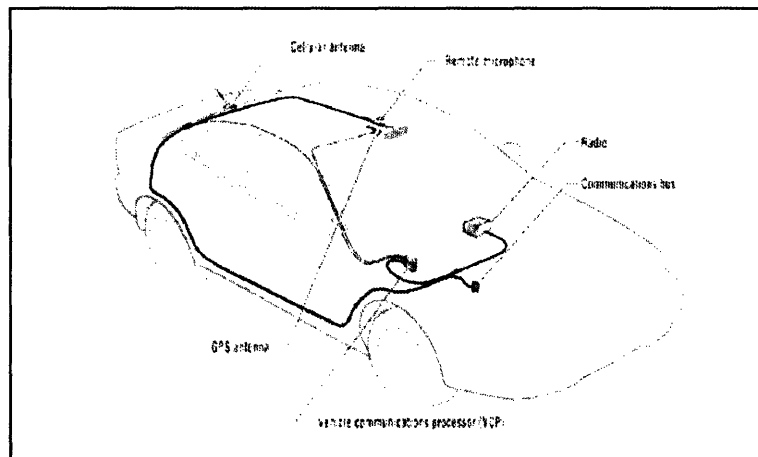
Zohar, D., Modifying supervisory practices to improve subunit safety: A leadership-based intervention model, *Journal of Applied Psychology*, volume 87, number 1, 2002.

Appendix A

How On-Star works? (Allan, R, 2003.)

OnStar employs a three-button system (white, blue and red) mounted either on the rear-view mirror or on the dashboard. Interactive hands-free communications takes place via a built-in cellular phone and the radio's speakers. The white-dot button is used for voice-activated cellular phone communications or connecting with the Virtual Advisor. The blue button connects the driver with a Call Center Advisor for help with a variety of services. The red button is used for emergencies. A driver's personal identification number (PIN) or a code number is used to initiate some security services such as door unlocks and stolen-vehicle location request. Within the vehicle a communications processor is located and tied to a bus, the car's radio, a remote GPS antenna, and a microphone located above the rearview mirror, along with a cellular antenna that's mounted on the rear window (Figure). It is believed that OnStar uses a CAN (Controller-Area-Network) bus to monitor engine's performance and emission controls as required by EPA OBD II.

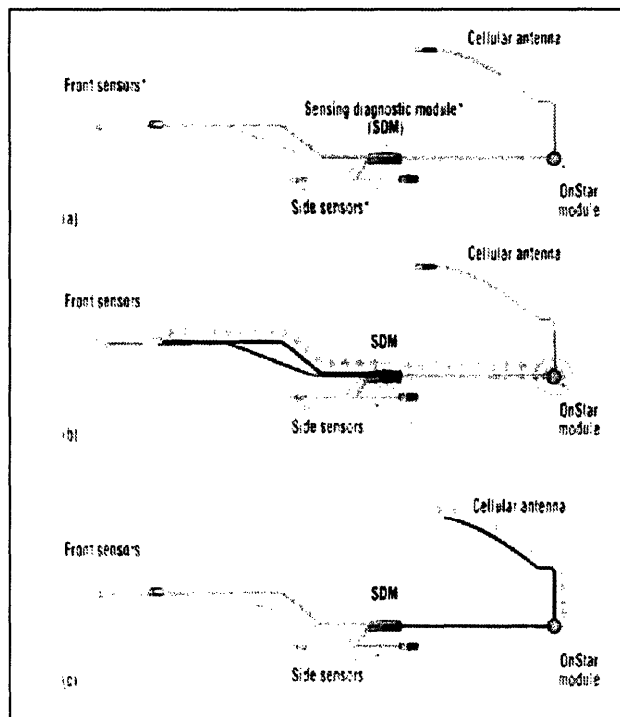
Figure: Main components of the OnStar interactive GPS tracking system on the vehicle side



Crash Notification System.

OnStar has introduced an advanced automatic crash notification (AACN) system on approximately 400,000 of its most popular 2004 vehicles, making it the first automaker to do so (Figure). The new system goes beyond the CAN system already in place on the airbags. By using a collection of strategically located sensors, AACN, through the OnStar system, automatically calls for help if the vehicle is involved in a moderate to severe front-, rear-, or side-impact, regardless of airbag deployment. It provides crashseverity information to the Call Center operator, who relays it to 911 dispatchers, helping dispatchers determine the type of emergency service required and how fast it's necessary.

Figure: OnStar advanced automatic notification system (AACN) system



In OnStar's advance automatic crash-notification (AACN) systems, front and side sensors along with the sensing capabilities of a sensing diagnostic module (SDM) plus accelerometer measure crash severity (a.) for moderate to severe crashes, determined by the SDM, crash data is transmitted from the sensors to the SDM regardless of airbag deployment (b). Within seconds, the DM transmits crash information to the OnStar Call Center, which is then forwarded to 911 dispatchers for emergency help (c).

**General Motors (GM) Sensing Diagnostics Module (SDM) Motor vehicle
Event Data Recorder (MVEDR)**

Figure: GM MVEDR Data Elements (Lenard, J., et.al., 2004.)

Parameter Type	Parameter	Data Type	Values
General	Prior Deployment?	Coded	Yes / No
	Airbag Warning Lamp Status	Coded	On / Off
	Ignition Cycles @ Event	Integer	
	Ignition Cycles @ Investigation	Integer	
	Brake Switch Gate @ Algorithm Enable	Coded	Applied / Not Applied
Restraints	Brake Switch Gate vs I/O Status	Coded	Valid / Invalid
	Seat Belt Status - Driver	Coded	Buckled / Unbuckled
	Frontal Airbag Suppressed - Passenger	Coded	Yes / No
	Frontal Airbag, Driver, Time from Algorithm Enable to 1st Stage Deployment (ms)	Floating Point	
	Frontal Airbag, Driver, Time from Algorithm Enable to 2nd Stage Deployment (ms)	Floating Point	
Event Counters	Frontal Airbag, Passenger, Time from Algorithm Enable to 1st Stage Deployment (ms)	Floating Point	
	Frontal Airbag, Passenger, Time from Algorithm Enable to 2nd Stage Deployment (ms)	Floating Point	
	Time between Non-Deployment and Deployment event (sec)	Floating Point	
	Frontal Airbag Deployment Level Event Counter	Integer	
	Event Recording Complete	Coded	Yes / No
Pre-Crash Data	Valid Events	Coded	Yes / No
	== 1 Events not recorded	Coded	Yes / No
	Time between Non-Deployment and Deployment Level event (sec)	Floating Point	
	Vehicle speed vs. time	Integer Array	
	Engine throttle % vs. time	Integer Array	
Driver Fuse	Engine speed (rpm) vs. time	Integer Array	
	Brake Status vs. time	Coded Array	On / Off
	Longitudinal Delta-V vs. time (mph)	Floating Point Array	
	Max Longitudinal Delta-V (mph)	Floating Point	
	Time of Algorithm Enable To Max Delta-V (ms)	Floating Point	

Ford Motor Company Restrain Control Module (RCM) Motor vehicle Event Data Recorder (MVEDR)

Figure: Ford MVEDR Data Elements (Lenard, J., et.al., 2004.)

Parameter Type	Parameter	Data Type	Data Values	
General	Data Validity Check	Codec	Valid/Invalid	
	EDR Model Version	Integer		
	Diagnostic Codes Active When Event Occurred	Integer		
Restraints	Side Airbag, Driver, Time from Safing Sensor Decision to Deployment (ms)	Integer		
	Side Airbag, Passenger, Time from Safing Sensor Decision to Deployment (ms)	Integer		
	Seat Belt Buckled, Driver	Coded	Yes/No	
	Seat Belt Buckled, Passenger	Coded	Yes/No	
	Seat Track in Forward Pos, Driver	Coded	Yes/No	
	Occupant Classification, Passenger	Coded	Adult/Child	
	Algorithm Runtime (ms)	Integer		
	Number of Invalid Recording Times	Integer		
	Pre-tensioner, Driver, Time from Algorithm Wakeup to Deployment (ms)	Integer		
	Frontal Airbag, Driver, Time from Algorithm Wakeup to 1st Stage Deployment (ms)	Integer		
	Frontal Airbag, Driver, Time from Algorithm Wakeup to 2nd Stage Deployment (ms)	Integer		
	Pre-tensioner, Passenger, Time from Algorithm Wakeup to Deployment (ms)	Integer		
Pre-Crash	Frontal Airbag, Pass., Time from Algorithm Wakeup to 1st Stage Deployment (ms)	Integer		
	Frontal Airbag, Pass., Time from Algorithm Wakeup to 2nd Stage Deployment (ms)	Integer		
	Longitudinal acceleration	Floating Point Array		
	Acceleration time stamp	Floating Point Array		
	Crash Pulse	Longitudinal acceleration	Floating Point Array	
		Lateral acceleration	Floating Point Array	
Acceleration time stamp		Floating Point Array		

Appendix B

Privacy and Monitoring Driver Focus Groups Respondents Specifications

- Recruit for a total of four groups: one young adult group of "good drivers," one older adult group of "good drivers," one young adult group of "poor drivers," and one older adult group of "poor drivers"
- Good drivers are defined as having had no citations or moving violations in the previous three years. Bad drivers are defined as having had three or more citations or moving violations in the previous three years.
- Gender: mix of men and women balanced within each group.
- In older adult groups, try to recruit mix of people who have children ages 15 to 22 living at home and those who do not.
- Participants should all have some degree of technological savviness, using a personal computer 5 or more days per week.
- One age split:
 - Participants between the ages of 21 and 30,
 - Participants age 50 or older.
- All participants must have a current driver's license and be responsible for paying for their own car/vehicle insurance
- On average drive at least 10,000 miles per year and on at least 5 days per week

Screening Questionnaire

FOUR GROUPS: Recruit 10-12 for each group (for an 8-10 person group)

ASK TO SPEAK TO PERSON ON LIST. IF NOT AVAILABLE, ARRANGE FOR CALL BACK.

CALL BACK DATE/TIME: _____

"Hello, I'm _____ from _____, a local, independent marketing research company. I am calling on behalf of MIT, The Massachusetts Institute of Technology"

Today, we are recruiting people to take part in a focus group discussion. If you qualify for one of our groups, we will give you a \$100 cash honorarium for taking part.

I assure you that I am not selling anything, nor will this call lead to any sales call. Let me ask you a few questions to see if you might qualify.

DO NOT ASK BUT RECORD GENDER

Female []

Male []

Which of the following groups includes your age?

Under 21 [] THANK & TERMINATE

21-30 []

31-49 [] THANK & TERMINATE

50 or older []

Do you have a current, valid state driver's license?

Yes []

NO [] THANK & TERMINATE

How many miles would you say on average you drive per year?

Less than 10,000 [] THANK & TERMINATE

10,000 or more []

On average, how many days per week would you say you drive your car?

0 to 4 [] THANK & TERMINATE

5 or more []

Do you or does your spouse own or lease your own car?

Yes []

NO [] THANK & TERMINATE

Are you aware of how much your car insurance costs are annually?

Yes []

NO [] THANK & TERMINATE

Are you or is your spouse responsible for paying for the car insurance on the vehicle you drive most often?

Yes []

NO [] THANK & TERMINATE

In the past three years, how many accidents or other moving violations - NOT including parking tickets - have you had which resulted in you receiving a ticket?

- 0 []
- 1 [] THANK & TERMINATE
- 2 [] THANK & TERMINATE
- 3 or more []

How often do you use a personal computer?

- More than twice a day []
- Once or twice a day [] THANK & TERMINATE
- Almost every day [] THANK & TERMINATE
- A few times a week [] THANK & TERMINATE
- A few times a month [] THANK & TERMINATE
- A few times a year [] THANK & TERMINATE
- Less than once a year [] THANK & TERMINATE

How many children between the ages of 15 and 21 do you have who are living at home?

- 0 []
- 1 []
- 2 []
- 3 or more []

IF PASS ALL ABOVE, RECRUIT AT THIS POINT FOR FOCUS GROUP.

IF NOT RECRUITED, THANK & TERMINATE.

INVITATION

The reason I have been asking you these questions is because I would like to invite you to a group discussion about new technologies in the car that might be used to provide information about people's driving behaviors.

Absolutely no sales or promotions are involved. We just want to hear your opinions. All opinions are kept confidential.

People who take part in these discussions usually enjoy themselves, and we think you will, too.

Because your opinions are important to us, we would like to give you \$100.00 for taking part.

The discussion will take about 2 hours and fifteen minutes and will be on (INSERT DAY AND DATE) at (INSERT TIME).

Will you help us with our research project?

YES CONFIRM DAY, DATE AND TIME OF DISCUSSION. GIVE COMPLETE DIRECTIONS TO FACILITY. ADVISE RESPONDENT TO ARRIVE 10 MINUTES BEFORE IT IS SCHEDULED TO BEGIN.

NO THANK RESPONDENT. TERMINATE AND TALLY.

Thank you very much for your help!

Implications of Monitoring Technologies in the Car Focus Group Discussion Guide

10 minutes

Introduction

Good Afternoon/Evening. Welcome and thanks for participating in today's group.

Moderator introduction

My name is Laura Donorfio and I am here doing research at the request of the Massachusetts Institute of Technology or as some of you may know it, MIT. My role here as a researcher is to get us through a list of specific questions, stay on track, and get us unstuck if we get stuck.

How many of you have participated in a **Focus Group** before? A focus group is a research tool used to hear, first hand, what you have to say. Instead of me interviewing each of you individually, I want you to think of it as a group interview. Research shows that group interviews are excellent at generating ideas.

"Ground rules":

- Balanced participation, hear from all of you
- Not seeking consensus, no wrong answers, all input (open & honest) is valuable
- This session is being videotaped / remain confidential--you don't have to worry about turning up in any commercials, one person at a time audible for tape)
- There are others viewing the focus group as well; they want to hear your feedback firsthand and may have some suggestions for questions they want me to ask you
- Pick up monetary gift for being here on the way out
- Informal / Enjoyable 2 hours discussion; we'll take a short break in the middle

Why You Were Chosen?

All of you were recruited to participate in today's focus group because you are people who drive regularly and are comfortable using technology. We have gathered you here to talk about some new technologies that record information about people's driving behaviors in cars, and what you think about these.

Participant Introductions:

Before we begin our conversation, I want to learn a bit more about you...In about 30 seconds, Name, where you live, hobby/free time activity.

Opening questions

20 minutes

- What are the characteristics of someone who is a good driver?
- Do you think that you are a good driver? Why or why not?
- Is a good driver the same thing as a safe driver?
- What makes someone a safe driver?
- Do you think that you are a safe driver? Why or why not?

- Do you get feedback or comments very often from other people who ride with you?
- What do people say to you?
- Do you listen to some people but not to others? How do you decide who you listen to?
- Is this feedback helpful to you?
- Probe: do you make any changes to your driving based on these comments?

Transition

- Would you be interested in receiving **more** feedback on how you're driving - how your driving performance is? Why or why not?
- Are there some situations in which you would rather get feedback?
- Are there some situations in which you would never want to get feedback?

Key Questions

40 minutes

Suppose there were technologies that could be built into your car that could give you feedback about your driving. These would be something like...DESCRIBE WHAT SYSTEM MIGHT LOOK/BE LIKE.

- Would you be willing to have such technologies built into your car?
- Would you be interested in receiving feedback on your driving performance from technologies built into your car?
- What types of feedback would you like to receive about your driving? Which do you think would be most valuable?
- Do you think that having such a system in your car might change the way that you drive? What kinds of changes do you think you would make?
- What kinds of benefits do you think you might get from having such a system?
- What would be some of the drawbacks to or disadvantages of having such a system?
- What do you think about a system that you could turn on or off to collect data from different users or at different times?

For older groups only (?):

- Aside from yourself, how would you feel about having such technology in cars or other vehicles driven by other people in your household, such as your children?
- Would you be interested in getting feedback on their driving performance, or having the car give them feedback on their driving?
- What kinds of benefits would you see to this system?
- What disadvantages do you see?

5 minutes break

Stretch Time: I am going to check with my team to see if there are any additional questions at this point. Please stretch and feel free to get refreshments...

35 minutes

If your car were to collect data and provide you with feedback on your driving performance, then these data might also be something that could be accessed by other people or organizations.

- Who do you think should have control or be able to access or look at the information your car would collect about your driving performance and behaviors?
- What kinds of worries - if any - would you have about who might be able to look at this information?
- How confident do you feel that you would be able to limit access to these data?

Would you be willing to share the information about your driving performance with:

- Consumer groups such as ????
- Your health care providers - your doctor, your medical insurance company?
- Car companies - such as Honda, GM, etc.
- Law enforcement agencies - such as the police or the registry of motor vehicles
- Government - such as the Department of Transportation
Your auto insurance company
- Why or why not for each of the above.
- For car companies - do you worry that car companies might use the data against you or others in some way in a product warranty dispute?

- Do you think that sharing such information would reduce your individual and personal privacy? Why or why not?
- What do you worry would happen if some other person or organization had access to your driving data? Would you have any concerns about your personal safety? What about privacy?

Suppose some of these organizations would be willing to compensate you in some way for having access to your information - for example, suppose your auto insurance company would be willing to give you a discount in exchange for being able to access your data -

- Would you then be more willing to let them have access to information about your driving?
- How much of a discount do you think they would have to give you for you to be willing to share this information? 10%? \$100? More?

Some private companies are looking into developing these kinds of technologies.

- What kind of advice would you give them about what the feedback to the driver should look like? Do you want a visual cue - Cingular bars, orb, flashing light - or an auditory cue? (NOTE: WE MIGHT WANT TO HAVE EXAMPLES OF THE DIFFERENT FEEDBACK TYPES TO SHOW PEOPLE WHAT WE MEAN)

- Do you think that government agencies like the National Highway Traffic Safety Administration should participate in some of the development of these technologies? Why or why not?
- Should these technologies be standardized across different kinds of cars and auto companies? Should they be required by the federal government to be installed in all vehicles?

10 minutes

One last check with team for questions.....

Summary - short summary of key thoughts from group

- Does this reflect what we talked about today?
- Are there any other questions you have, or any other comments that you want to add?
- Are there any other questions that you think we should have asked about?
- Final Question:
- If you could get feedback from your car on any one aspect of your driving, what would it be?

Close: Thank & terminate.

Appendix C

Exercise #1

Feature	Function	Vehicle I drive most often has this feature	I use this feature in my vehicle
Vehicle and Cargo Tracking System	<i>Allows cars to be tracked by police after being stolen.</i>		
Information System	<i>Visual Interface to manage devices such as cell phones, CD/DVD player, Radio, A/C, Navigation systems, etc.</i>		
Emergency System	<i>Contacts medical help automatically or with a push of a button. Similar to On-Star systems.</i>		
Navigation System	<i>Provides drivers with location information using maps and audible instructions.</i>		
Collision Avoidance / Warning system	<i>Detects the distance between vehicles in the same lane and warns the driver if vehicles are too close to each other based on the speed of both vehicles.</i>		
Vision Enhancement / Night Vision System	<i>External lighting systems to increase the visibility of drivers at night.</i>		
Cruise Control	<i>Maintain the speed of the vehicle based on a pre-defined value from the driver.</i>		
Side Sensing (proximity) Devices	<i>Detects other vehicles in adjacent lanes of the road.</i>		
Rollover Detection and Prevention System	<i>Measures roll rates and uses the braking system to prevent roll-overs.</i>		
Lane Tracking / Departure Warning System	<i>Warns drivers when the vehicle begins to move out of its lane.</i>		
Autonomous Cruise Control	<i>Adjust the speed of the vehicle without the intervention of drivers to maintain a proper distance between vehicles in the same lane.</i>		
Heading Control	<i>Senses deviations of the vehicle from the road.</i>		
Electronic Stability Program	<i>Uses various sensors to intervene when the car senses a possible loss of control.</i>		
Anti-Lock Brake System	<i>Prevents the brakes from locking and losing traction while braking. This shortens stopping distances in almost all cases.</i>		
Driver Alertness Monitor	<i>Uses cameras and sensors in the vehicle to sense driving-attention, stress-levels, road-rage, etc.</i>		
Breathalyzer	<i>Device for estimating blood alcohol content (BAC) from a breath sample</i>		
Physiological Measures Monitor	<i>Measures the pulse rate, skin temperature, muscle contractions, and respiratory rate.</i>		

Exercise # 2

Person / Group	Willing To Share Information	Not Willing To Share Information
Consumer Groups that <ul style="list-style-type: none"> • Advocate to Protect Consumer Rights To Privacy <i>Privacy Rights Clearinghouse (PRC), Center for Democracy and Technology (CDT).</i>		
<ul style="list-style-type: none"> • Medical Doctor 		
<ul style="list-style-type: none"> • Medical Insurance Company 		
<ul style="list-style-type: none"> • Car Companies <i>Honda, GM, etc.</i> 		
<ul style="list-style-type: none"> • Law Enforcement Agencies <i>Police or Motor Vehicles</i> 		
<ul style="list-style-type: none"> • Government 		
<ul style="list-style-type: none"> • Department of Transportation 		
<ul style="list-style-type: none"> • Auto Insurance Company 		
<ul style="list-style-type: none"> • Other People <i>Such as Other Drivers or Pedestrians on the Road</i> 		