CHAPTER 1

INTRODUCTION

1.1 GLOBAL SYSTEM FOR MOBILE COMMUNICATION

During the early 1980s, analog cellular telephone systems experienced rapid growth in Europe, particularly in Scandinavia and the United Kingdom, but also in France and Germany. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only the mobile equipment limited to operation within national boundaries, which in a united Europe were increasingly unimportant, but there was also an extremely limited market for each type of equipment, so economies of scale and the subsequent savings could not be realized. The Europeans realized this early on, and in 1982 the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Groupe Special Mobile (GSM) which later called as Global System for Mobile Communication to study and develop a pan-European public land mobile system. The proposed system had to meet certain criteria:

- Good subjective speech quality
- Low terminal and service cost
- Support for international roaming
- Ability to support handheld terminals
- Support for range of new services and facilities
• Spectral efficiency
• ISDN compatibility

Although standardized in Europe, GSM is not only a European standard rather it is for worldwide. GSM is designed to provide a comprehensive range of services and features to the users which are not available on analogue cellular networks and in many cases exceeding much in advance of the old public switched telephone network (PSTN). In addition to digital transmission, GSM incorporates many advanced services and features like worldwide roaming in other GSM networks. At the time of creating this report, GSM service had surpassed the 6 billion subscribers mark with global penetration reaches around 87% and it is currently available across more than 219 countries and territories worldwide (ITU World Telecommunication 2011).

GSM differs from first generation wireless systems, in that it uses digital technology and time division multiple access transmission methods. GSM is a circuit-switched system that divides each 200 kHz channel into eight 25 kHz time-slots. The GSM mobile telephony service is based on a series of contiguous radio cells, which provide complete coverage of the service area and allow the subscriber operation anywhere within it. Prior to this cellular concept, radiophones were limited to just one transmitter covering the whole service area. Cellular telephony differs from the radiophone service because instead of one large transmitter, many small ones are used to cover the same area. The basic problem is to handle the situation where a person using the phone in one cell moves out of range of that cell. In the radiophone service there was no solution and the call was lost, which is why the service area was so large. In cellular telephony, handing the call over to the next cell solves the problem. This process is totally automatic and requires no specific intervention by the user, but it is a complex technical function requiring significant processing power to achieve a quick reaction.
The functional architecture of a GSM system (Croft 2003) can be broadly divided into the Mobile Station, the Base Station Subsystem, and the Network Subsystem. Each subsystem is comprised of functional entities that communicate through the various interfaces using specified protocols. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as air interface or radio link. The Base Station Subsystem communicates with the Mobile service Switching Center across the A interface. The subscriber carries the mobile station; the base station subsystem controls the radio link with the Mobile Station. The network subsystem, which is the main part of which the Mobile services Switching Center, performs the switching of calls between the mobile and other fixed or mobile network users, as well as management of mobile services, such as authentication. The Figure 1.1 shows the GSM architecture (Croft 2003).

Figure 1.1 Global Systems for Mobile Communication Architecture
1.1.1 Mobile Station

The Mobile Station (MS) provides access to the GSM network. The MS consists of Mobile Equipment (ME) and a Subscriber Identity Module (SIM). The mobile equipment is uniquely identified by what is referred to as the International Mobile Equipment Identity (IMEI). The SIM card stores the sensitive information such as a unique identifier called the International Mobile Subscriber Identity (IMSI) and a secret key for authentication called Ki. The IMSI consists of three parts (Garg 1999), namely:

**Mobile Country Code (MCC)** - 3 digits decimal, whose function is to identify the domiciliary country of a mobile terminal/user.

**Mobile Network Code (MNC)** - 2 digits decimal, whose function is to identify the home network, within the country associated with the MCC.

**Mobile Subscriber Identification Number (MSIN)** - 10 digits decimal, whose function is to uniquely identify a mobile terminal/user within its home network.

Where, MSIN is unique for a MCC/MNC combination. All this information may be protected on the MS by personal identity number (PIN). In 3GPP (3rd Generation Partnership Project) terminology, MSISDN (Mobile Subscriber Integrated Services Digital Network Number) refers to the telephone number of a mobile subscriber and has a direct relationship with the IMSI number on the serving GSM network.

1.1.2 Base Station Subsystem

The Base Station Subsystem (BSS) consists of the Base Transceiver Station (BTS) and the Base Station Controller (BSC). The Base Station Controller manages the radio resources for one or more BTS. The BSC is
responsible for handling traffic and signaling between a MS and the Network Switching Subsystem. The BSS carries out the coding of speech channels, allocation of radio channels to MS, paging, quality management of transmission and reception Over the Air (OTA) interface among other tasks related to the radio network.

1.1.3 Network Switching Subsystem

The Switching Subsystem is the main component of the GSM mobile network. Its main responsibilities include: GSM switching, mobility management, interconnection to other networks and system control. The central component of the Network Subsystem is the Mobile Switching Center (MSC) which performs the telephony switching functions of the system and controls calls to and from other telephone and data systems. It also performs functions such as toll ticketing, network interfacing, common channel signaling, and others. The MSC provides the connection to the public fixed network (PSTN) and signaling between functional entities using the ITU-T Signaling System Number 7. This is more commonly known as the SS7 network (Lin 1996). The MSC thus has an interface to one or more BSCs and to external networks.

Several databases are available for control and network management. It is important that these databases are scalable, have high capacity and low delay. The following databases are usually considered to be part of the MSC (Croft 2003):

- Home Location Register (HLR)
- Visitor Location Register (VLR)
- Authentication Centre (AuC)
- Equipment Identity Register (EIR)
Home Location Register (HLR) — The HLR is a database used for storage and management of subscriptions. The HLR is considered as the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status. When an individual buys a subscription from one of the PCS operators, he or she is registered in the HLR of that operator.

Visitor Location Register (VLR) — The VLR is a database that contains temporary information about subscribers that are needed by the MSC in order to service visiting subscribers. The VLR is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. Later, if the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time.

Authentication center (AUC) — The AuC is a function to authenticate each SIM card that attempts to connect to the GSM core network (typically when the phone is powered on). It provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call. Once the authentication is successful, the HLR is allowed to manage the SIM. If the authentication fails, then no services are possible from the particular combination of SIM card and mobile phone operator attempted.

Equipment Identity Register (EIR) — The EIR is a database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations. The AUC and EIR are implemented as stand-alone nodes or a combined AUC/EIR node.

1.2 DRIVER DISTRACTION

According to Young et al (2003) driving a motor vehicle is a complex task that requires the interaction and coordination of various
cognitive, physical, sensory and psychomotor skills, and a considerable
degree of concentration and attention on the part of the driver. In reality,
however, drivers continually divide their attention between competing driving
and non-driving tasks. The study carried by Young et al (2007) found, drivers
are easily distracted by an object, event or activity to such an extent that they are
no longer able to allocate sufficient attention to the driving task. When this
happens driving performance is compromised and road safety issues arise.

Driver distraction has been given in various forms of definitions
based on clarifying the danger of being distracted while driving. According
to Ranney et al (2000) driver distraction may be characterized as, “Any
activity that takes a driver’s attention away from the task of driving for
example, from rolling down a window to using a cell phone can contribute to
a crash”. While, Stutts et al (2003) defined distraction as, “When a driver is
delayed in recognition of information needed to safely accomplish the driving
task because of some event, activity, object or person (both inside and outside
the vehicle) compelled or tended to induce the driver’s shifting attention away
from the driving task”. And recently the distraction defined by Regan et al
(2009) states that, “Diversion of attention away from activities which are
critical for safe driving towards a competing activity.” is called as distraction.

The trend is that the amount of distracting equipment in the
vehicles is increasing as it gets more available and easier to use, at the same
time, complexity of these equipment also increases. As a result of this, drivers
are more and more exposed to inattentive driving. Nowadays there are mobile
phones, car audio equipment, navigation systems, TV-screens, DVD-players and
cruise controls only to name a few. All these things “steal” attention from the
primary task (driving) which can expose the driver to a dangerous situation.

According to the U.S. National Highway Traffic Safety
Administration (NHTSA), 20-25% of crashes or 1.4 million crashes per year
involve some type of driver distraction (Sundeen 2002). A survey carried out by McEvoy et al (2007) consisting of 1,367 drivers involved in a collision found, over 30% of drivers experienced at least one distraction at the time of collision, with distraction contributing to 13.6% of all collisions. It was reported by Garder (2006) that, distraction was a primary factor in 28% of head-on crashes on rural, two-lane collector or arterial roads. Similarly, the 100-Car Naturalistic Driving Study carried by NHTSA (2006) videotaped the drivers of 100 vehicles for more than one year. Analysis of the data showed, that reaching for an object (reaching a cell phone) increased risk of a crash or near crash by 9 times, looking at an external object (look down for dialing a number in cell phone) by 3.7 times, reading by 3 times, applying makeup by 3 times, dialing a handheld device by almost 3 times, and talking or listening on a handheld device by 1.3 times.

1.2.1 Types of Driver Distraction

In order to analyze different types and levels of driver distraction, quite a number of observational studies have been conducted by Baron and Green (2006). In general, Young et al (2003), Green (1999) classified driver distraction into four types: physical distraction, visual, cognitive and auditory distraction. Any distracting activity involves one, or more, of these. The act of operating a hand-held mobile phone, for example, may involve all four types of distraction: physical distraction (dialing), visual distraction (looking at the display), auditory distraction (holding a conversation with the other person) and cognitive distraction (focusing on the topic of conversation).

Physical Distraction

Physical distraction occurs when a driver takes one or both hands off the wheel while driving to manipulate an object, instead of focusing on the tasks required for safe driving. In other words, physical distractions are the
physical things that get in the way of communication. Examples of such things include the telephone, a pick-up truck door, an uncomfortable meeting place, and noise.

**Visual Distraction**

According to Janitzek et al (2010) study, visual distraction occurs when a driver’s visual field is block, or if their visual attention is on something other than the road and this impairs their observation of the road environment. In other words, visual distraction is defined as any type of distraction that takes the driver’s eyes off the road.

**Cognitive Distraction**

Cognitive distraction occurs when a driver thinks about something not related to the driving task at the point they are unable to safely navigate the road environment. It is noted by Shannon (2009) that, when mental (cognitive) tasks are performed concurrently, the performance of both tasks is often worse than if they were performed separately, because attention has to be divided, or switched, between the tasks and the tasks must compete for the same cognitive processes i.e., driver’s brain processes information received from any source, not driving related, during the driving task. This takes the mind off of the dangerous task of operating a motor vehicle.

**Auditory Distraction**

Auditory distraction occurs when a driver either momentarily or continuously focuses their attention on sounds rather than the road environment. For example, when a driver is using a hand-held or hands-free mobile phone while driving, she or he must devote part of their attention to operating the phone and maintaining the telephone conversation, (Auditory
distraction) and part to operating the vehicle, and responding to the constantly changing road and traffic conditions. The demands of the phone conversation must compete with the demands of driving the vehicle safely.

As per the study reported by Donmez et al (2006), Zhang et al (2006), Donmez et al (2007) all these four types of distraction caused while interacting with in-vehicle technology during driving have significant impair on the driver’s ability to maintain speed, preparedness to react to unexpected hazards (e.g. to slow down when a pedestrian suddenly crosses the road in front of the vehicle), lateral position on the road and reaction time. It was also impaired a driver’s visual search patterns and decision-making processes and would increase the risk of been involved in a collision. The off-road glances associated with using in-vehicle devices leads to large and frequent lane deviations, uneven steering control and slow response to lead vehicle braking.

Further, the study carried out by Regan et al (2009) found that, human brain is limited, and not able to do several tasks at the same time. Especially, when tasks are similar, highly demand and when required continuous attention, performance will inevitably suffer. Even when performed a simple secondary task, performance of both driving and the secondary task are affected. As per the study carried by Just et al (2008), when language comprehensions are performed concurrently with driving, it draws mental resources away from the driving and produces deterioration in driving performance, even when it does not require holding or dialing a phone.

The Carnegie study carried by Wallin (2010) found, certain areas of the brain suffer a reduction in activity of up to 37% when using a cell phone while driving. Through brain imaging, experimental study was carried out by Just et al (2008), which demonstrated the importance of cognitive distraction. According to this study, secondary auditory tasks (similar to hands-free cell
phone conversations) negatively impact spatial and visual processing which are necessary for maintaining driving performance. Researchers like Strayer et al (2003), Stutts et al (2005) have also discovered that, the more attention that is directed to a secondary task, the more the driving performance suffers, both in regard to awareness of one’s current situation and vehicle control measures.

1.2.2 Sources of Driver Distraction

There are various forms of driver distraction with varying impacts on driver impairment which includes usage of mobile phones, text messaging, in-vehicle Internet facilities, sound systems, eating, drinking, smoking and interacting with other occupants. As the number of in-vehicle technology are increasing, some of them have the potential to distract—which is a crucial problem leading to inattention/distraction which shoots up to 78% of crashes on roads.

To examine which is more dominating on individual source of driver distraction, this research has been carried out by collecting the outcomes from various studies. Research carried out by Strayer et al (2003), Strayer et al (2006) compares the drivers who use cell phones with non cell phone users and found, drivers talking on cell phones miss twice as many traffic signals, are more likely to swerve into the next lane (46%), tailgate (23%), have close calls (18%) and run red lights (10%).

There are also research carried out by Rakauskas et al (2008), Strayer et al (2006) which compares the use of a cell phone while driving with intoxication at the legal limit of (80mg/100ml, or 0.08) and found that, drivers engaged in the conversations or completing in-vehicle tasks were more impaired than drivers who were not involved in any distraction task. Indeed, using a cell phone were generally more impairing than causing accidents in
intoxication at the legal limit of (80mg/100ml, or 0.08) with the driver’s reaction times to hazards were on average 30 percent slower when conversing on a hand-held mobile phone than while driving under the influence of alcohol, and 50 percent slower than under normal driving conditions. The study carried out in the United Kingdom by Nobel and Riswadkar (2009) found, using a cell phone while driving has a greater adverse impact on reaction time and stopping distances than driving under the influence of alcohol as shown in Figure 1.2.

![Figure 1.2 Mobile Phone Impair Driving distraction](image)

**Figure 1.2 Mobile Phone Impair Driving distraction**

As per the evidence obtained from Burns et al (2002) there is loss of speed control while using a mobile phone. While, the study carried by Wallin et al (2010) shows, the action of listening to a phone call alone is a notable distraction, which is strong enough to make the driver to resemble the driving pattern of a legally drunk driver.
A detailed analysis on braking time, driving speed and distance covered when the driver talking on phone while driving with alcoholic condition driver was carried out by Strayer et al (2003) were represented in Figures 1.3-1.5. Figure 1.3 presents the braking profiles. In the baseline condition, participants began braking within 1 second of the pace car deceleration. Similar braking profiles were obtained for both the cell phone and alcohol conditions. However, compared to baseline, when participants were legally intoxicated they tended to brake with greater force, whereas participant’s reactions were slower when they were conversing on a cell phone.

![Figure 1.3 Brake Profile](image)

**Figure 1.3 Brake Profile**

Figure 1.4 presents the driving speed profiles. In the baseline condition, participants began decelerating within 1 second of the onset of the pace car’s brake lights; reaching minimum speed 2 seconds after the pace car began to decelerate, where upon participants began a gradual return to pre-braking driving speed. When participants were legally intoxicated, they drove slower, but the shape of the speed profile did not differ from baseline. By contrast, when participants were conversing on a cell phone it took them longer to recover their speed following braking.
Figure 1.4 Speed Profile

Figure 1.5 presents the following distance profiles. In the baseline condition, participants followed approximately 28.5 meters behind the pace car and as the pace car decelerated, the following distance decreased, and reaching nadir approximately 2 seconds after the onset of the pace car’s brake lights. When participants were legally intoxicated, they followed closer to the pace car, whereas participants increased their following distance when they were conversing on a cell phone.

Figure 1.5 Distance Profile
The study concluded that drivers conversing on a cell phone were involved in more rear-end collisions, and their initial reaction to vehicles braking in front of them was slowed by 8.4%, relative to baseline. In addition, compared to baseline, it took participants who were talking on the cell phone 14.8% longer to recover the speed that was lost during braking. Drivers using a cell phone attempted to compensate for their increased reaction time by driving 3.1% slower than baseline and increasing their following distance by 4.4%. By contrast, when participants were legally intoxicated, neither accident rates, nor reaction time to vehicles braking in front of the participant, nor recovery of lost speed following braking differed significantly from baseline.

There are studies carried out which compares driver engaged in a phone conversation with listening to radio. According to the study conducted by Noble (2009) from the University of Utah, drivers engaged in phone conversations had significantly slower response times to traffic signals than those listening to the radio. While the research carried out by Consiglio et al (2003) compared the reaction time with other in-vehicle distraction tasks like listening to music, and tuning of the radio and found reaction time does not increase as high when compared to the use of a cell phone. By contrast, the research performed by Strayer et al (2001) found, performance was not even disrupted by listening to radio broadcasts or listening to a book on tape. The study carried by Reed-Jones et al (2008) conclude, phone task resulted in higher distraction, when radio adjustments was compared with dialing a handheld cell phone. As per the finding of Strayer and Johnston (2001) the probability of missing simulated traffic signal is doubled when the participants engaged in cell phone conversations was compared with listening to the radio.
There are also studies carried out by Consiglio et al (2003), Strayer and Johnston (2001) which compare the effect of using a mobile phone and listening to music in vehicles and found that the distraction while listening to music was far less than using a mobile phone. However, the recent study carried by Ayça et al (2012) shows drivers who listened to music performed as well as the drivers who did not listen to music, indicating that music did not impair their driving performance. Self-reports study carried by North and Hargreaves (2004) conclude drivers had indicated that they do not generally perceive music as a distracting auditory stimulus on the road. Similarly, the study carried out by Hatfield and Chamberlain (2008) found, cellular telephone conversation decreased response time, yet music had no effect or negative impact on response time while driving. The research carried by Dick et al (2011) found, vehicle speed was not affected by listening to music, but reduced in the telephone conversation conditions. A clinical trial performed by Horberry et al (2006) show, both the operating of entertainment system and conversing using a hands-free phone impaired driving performance. The experiments carried by Drews et al (2008), Strayer and Johnston (2001) using driving simulators shows, people engaged in cell phone conversations show poorer driving performance than people focused only on driving. Although drivers had encounter a number of distractions, cell phones appear to be particularly predominant: Cell phone users perform more poorly than people listening to music, listening to books on tape, or conversing with a passenger.

Researches carried out by Dragutinovic and Twisk (2005), McEvoy et al (2007), Drews et al (2008) compares the driver’s cell phone conversation with driver-passenger conversation and these studies concludes, in case of a passenger conversation, the passengers are much aware of the driving situation and can sometimes even helps in draw attention to dangerous situations. While, in the case of a mobile phone conversation, the other person is generally not even aware that his/her conversation partner is driving. The
study done by Consiglio et al (2003) compares passenger conversation with hand-held or hand-free conversation and found it increased brake reaction times when driver makes conversation with cell phone. It is sometimes argued that cellular phones are no worse than other potential distractions. It is described by Klauer et al (2006) that passenger in the adjacent seat decreased accident rates whereas a cell phone conversation increased accident rates. The work carried by Charlton (2009) found, reaction times of the drivers conversing on cell phones increased, and the drivers are more likely to crash compared with drivers talking to passengers. The other study carried out by Drews et al (2008) is to compare the cell phone conversation and driver-passenger conversation with no distractions and found the cell phone use negatively impacted lane keeping, while the study performed by Jibo (2010) shows, cell phone conversation increased following distance and impaired navigation; on the other hand, passenger conversation had little effect on all 3 measures. From the drivers viewpoint, on driver-passenger conversation the study carried out by McEvoy et al (2006) found, nearly 70% of respondents felt that talking with a passenger is not a distracting activity. The research demonstrated by Frank et al (2004) found, the number of driving errors is higher for those having a cell phone conversation when compare to driver-passenger conversation.

The work performed by Young et al (2008) conclude, driving performance measures were relatively unaffected by eating and drinking, however, perceived driver workload was significantly higher, and there were more incidents result in accidents, when compared to driving normally. As per the findings of Neyens and Boyle (2008) mobile phone conversation associated with increased injury severity, whereas the effects of smoking, eating or drinking were not significant. Similarly, the study carried out in 2007 by Neyens and Boyle (2007) shows, mobile phone use while driving was a serious distracter that typically resulted in crashes, and defined dialing a
cell phone as a complex secondary tasks, which increased the likelihood of crashes/near crashes by three times, producing an odds ratio (OR) of 3.10 (confidence interval (CI):1.72, 5.47). Moderately complex tasks, such as inserting/retrieving CDs or eating, increased the crash likelihood by 2.1 (CI: 1.62, 2.72). The risk of in-vehicle distraction was carried by Klauer et al (2006) based on task complexity, which defined as the number of glances away from the road and the number of button presses: the bigger these numbers the more complex the task. In general, glances totaling more than two seconds for any purpose increased near-crash/crash risk to double that of normal baseline driving and found use of cell phone required more glance away from the primary task when compared to smoking, eating or makeup. The study executed by Stutts et al (2003) compared cell phone conversation with other distracting activities while driving such as grooming, reaching or leaning for an object, reading and writing, and found these are relatively common and least distraction type.

From these studies, it is concluded that cell phone conversation while driving provide more risk to the driver when compared to other in-vehicle distraction, and it is the top most in-vehicle distraction which increases the risk of accidents, reaction time to apply brakes, sudden variations in speed, and missing crucial information like traffic signals, neighboring vehicles etc.,

1.3 CELL PHONE DISTRACTION

As the number of driver’s use of cell phones while driving increases, the interest in linking the hand-held cell phone use while driving with road safety also increases. The more recent mobile phones, the so-called smart phones, have even more features that will distract the driver, such as an address book, E-mail, a diary, navigation and Internet. No research has yet been conducted into the effects of the use of these specific features, which
may pose even greater cause of driver distraction. Evidence of the widespread use of these technologies while driving, and associated safety consequences, come from recent surveys, observational studies, research experiments, and crash analyses (AAA Foundation for Traffic Safety 2008), Madden and Lehnart (2009), Pickrell and Ye (2009).

Mobile phones potentially distract driver in several ways:

**Physically:** Instead of focusing on the physical tasks required by driving (e.g. steering, gear changing), drivers had to use one or both of their hands to manipulate the phone.

**Visually:** Mobile phones could visually distract drivers in two ways:

- Firstly, drivers had to move their eyes from the road and focus on the mobile phone in order to be able to use it.
- Secondly, while talking on a mobile phone, even if driver’s eyes are focused on the road, they 'look but do not see'.

For example, while using a hand-held mobile phone, drivers must remove one hand from the steering wheel to hold and operate the phone (Physical Distraction). They must also take their eyes off the road (Visual Distraction), at least momentarily, to pick up and put down the phone and to dial numbers. Although the physical distraction is far greater with hand-held phones, there is still some physical activity with hands-free systems. Even though they do not need to be held during the call, the driver must still divert their eyes from the road to locate the phone and (usually) press at least one button. The higher the frequency of glances off the road, the bigger the threat to be involved in a danger situation while driving. The study executed by Zhang et al (2006), Klauer et al (2006) pointed out that, visual distraction of more than two seconds is considered to be a critical time of visual absence.
**Auditory:** The focus of driver’s attention moves from the road environment to the sounds of the mobile phone and the conversation. This particularly applies when the sound quality is poor.

**Cognitive:** According to Dragutinovic and Twisk (2005), Shannon (2009) studies which described cognitive distraction as, instead of focusing their attention and thoughts on driving, drivers divert their attention and focus on the topic of the phone conversation.

All four aspects are important to safe driving practices, and a failure at any level can increase risk and raise liability concerns. A large number of studies has been carried out by Strayer et al (2003), Strayer and Johnston (2001), Consiglio et al (2003), Rakauskas et al (2004), Hancock et al (2003), Just et al (2008), Caird et al (2008) have shown that using a mobile phone (a cognitive task) while driving degrades driving performance.

The research demonstrated by Östlund et al (2006) show, when using a cell phone while driving, driver will have impact on driving behavior such as lane deviation, speed, change in steering, missing signal etc., especially steering wheel plays an pivotal role in accidents which changes mostly increased for both visual and cognitive distractions in comparison with normal (non-distracted) driving, but in different ways: a visual secondary task leads to increased steering wheel movements in a wide range of amplitudes (i.e., 2-6 degrees) whereas cognitive tasks cause corrective movements with small amplitudes (less than 1degree). A vehicle position in the lane could be used as an indicator for measuring driver performance. Lateral position changes relative to the centerline have been reported in the majority of experiments addressing visual distraction. In general, lateral control degrades with increasing level of visual distraction, but it becomes more precise under cognitive distraction. This can imply that the involvement in the visual task
can lead to a more degraded driving performance compared with cognitive distraction.

The study carried by Harbluk et al (2002) classified distraction based on eye glance. As per the study, frequent and/or long off-road glances indicate visual distraction and concentrated glances toward the road center indicate cognitive distraction. Distracted drivers check the mirrors and the speedometer much less frequently while performing secondary cognitive and verbal tasks relative to no task conditions, and spend more time looking to the center of the road. This gaze concentration was reflected in reduced horizontal and vertical variability of gaze positioning as well as longer duration of on-road glances. The work performed by Lora (2010) provide differentiation of these two types of distraction based on differences in visual behavior and driving behavior as shown in Table 1.1.

Table 1.1 Distraction Types

<table>
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<tr>
<td><strong>Visual Behavior</strong></td>
<td>Frequent and long off-road glances</td>
<td>Visual attention allocated to the road center</td>
</tr>
<tr>
<td><strong>Vehicle Control</strong></td>
<td>Abrupt steering movements with large (2-6 degrees) amplitude, large steering entropy</td>
<td>Corrective movements with small (less than 1 degree) amplitude, small steering entropy</td>
</tr>
<tr>
<td><strong>Vehicle State</strong></td>
<td>Large and frequent lane deviations speed decrease and headway increase</td>
<td>Unchanged or small lane variation speed does not changed significantly</td>
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</table>
The study carried out by Redelmeier and Tibshirani (1997) show, talking on a phone was associated with a 4-fold increase in the risk of a property-damage-only crash and the study performed by McEvoy et al (2005) observed a 4-fold increase in the risk of a crash serious enough to injure the driver. Another research carried by Klauer et al (2006) involving 100 vehicles monitored for about a year are outfitted with cameras and other technology and found the cell phone use is a common source of driver distraction. The odds of an at-fault near-crash or crash were 2.8 times as high when dialing a hand-held device than when hand-held phones were not used. When talking on a hand-held phone, the odds ratio was 1.3 times as high.

The risk of crash based on eye glance analysis given by Box (2009) show, the tasks with the highest risks have the longest duration of eyes off road time. The study includes light vehicle drivers and truck drivers indicate that using a cell phone can substantially increase the risk of safety-critical events such as crashes or near-crashes. An overview of different tasks and their effect on accident hazard is provided in Table 1.2.

Table 1.2 Cell Phone Task Vs Risk Crash

<table>
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<tr>
<th>CELL PHONE TASK</th>
<th>Risk of Crash or Near Crash Event</th>
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<tr>
<td><strong>Light Vehicle/cars</strong></td>
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<tr>
<td>Dialing a Cell Phone</td>
<td>2.8 times as high as non-distracted driving</td>
</tr>
<tr>
<td>Talking and Listening to Cell Phone</td>
<td>1.3 times as high as non-distracted driving</td>
</tr>
<tr>
<td>Reaching for a Cell Phone</td>
<td>1.4 times as high as non-distracted driving</td>
</tr>
<tr>
<td><strong>Heavy Vehicle/Trucks</strong></td>
<td></td>
</tr>
<tr>
<td>Dialing a Cell Phone</td>
<td>5.9 times as high as non-distracted driving</td>
</tr>
<tr>
<td>Talking and Listening to Cell Phone</td>
<td>1.0 times as high as non-distracted driving</td>
</tr>
<tr>
<td>Reaching for a Cell Phone</td>
<td>6.7 times as high as non-distracted driving</td>
</tr>
</tbody>
</table>

A study done in a simulated environment by Schattler et al (2006) observed twice as many crashes when subjects used cell phones while driving
compares to the control condition. A clinical trial carried out by Hancock et al (2003) requires subjects to respond to a cell phone, at the same time they had to make a stopping decision. The study found that, the drivers had a slower response to the light change, braked more intensely and exhibited a 15% increase in non response to the stop signs light. This study is in agreement with the findings of Beede and Kass (2006) which shown, driving performance was impacted significantly in terms of traffic violations, driving maintenance (standard deviation of lane position, for example), attention lapses and response time when drivers were talking on a hands-free phone.

1.4 HAND-HELD VS HAND-FREE CELL PHONES

In spite of the risk associate with use of cell phones while driving are well known. Many drivers have a common understanding that a hands-free (HF) cell phone is a safer option than a handheld (HH) cell phone for talking while driving. The study reported by McCartt et al (2006) show, there is growing evidence that using a mobile phone (either hands-free or handheld) while driving is an unsafe driving practice in both urban and rural environments. While, the work carried by Horrey and Wickens (2004) found, hands-free cell phone may eliminate the physical distraction involved in manual handling of a cell phone and also beneficial in situations which requires high amount of manual steering input. However, hands-free model will not ameliorate the more significant cognitive interference caused by the cell phone conversation. Similarly, studies carried by Strayer et al (2006), White et al (2004) found that using a hands-free mobile phone is not significantly safer than using a hand-held mobile phone while driving. The research carried by Strayer et al (2006) examined the effects of the phone type (HH and HF) during different periods of a call (pre-call, during a call, and post-call) as within-subject factors on driving performance and conclude the number of collisions and speed did not differ as a function of the phone type.
The works performed by Ishigami and Klein (2009), Klauer et al (2006) shows, talking on phone, regardless of phone type, has a negative impact on performance especially in detecting and identifying objects. This study is in agreement with Hendrick and Switzer (2007) which support the idea that, talking on cell phones, regardless if it is hands-free or hand-held, reduces speed of information processing while driving. Likewise, the study done by McEvoy et al (2005) found, as more and more new vehicles are equipped with Bluetooth technology, facilitating voice activation and therefore, totally hands-free phone use. Though this may lead to fewer hand held phones used while driving in the future, this may not remove the risk. Importantly, if this new technology actually increases mobile phone use in cars, it could contribute to even more crashes. At least in the short term, it seems likely that mobile phone use in cars will continue to grow, despite the growing evidence of the risk it creates.

There are few more studies carried out by Strayer and Johnston (2001), Törnros and Bolling (2005), Törnros and Bolling (2006) which measures the driver’s reaction time (RT) from their manual responses and none of which found an HF phone advantage. These responses included pressing a micro switch attached to the finger or pressing a button located in the thumb position on top of the joystick. The study performed by Matthews et al (2003) examined the effect of phone type (HH, HF with an external speaker, and HF with an earpiece) on the driver’s subjective workload and intelligibility of words in a field study. They showed that the subject’s intelligibility of words was poorer for the HF with an external speaker than for the HH or the HF phones with an earpiece. In addition, the subject’s frustration (one of the components of workload) was greater for the HF phone with an external speaker than for the HH phone or the HF phone with an earpiece. Thus, the participants felt frustrated when they could not hear well which would always increase the possibilities of crashes.
The relationship between type of handset used with frequency of calling while driving have also been analyzed by White et al (2010) which found, hand-held mobile phone users were more likely to report never using their mobile phone while driving for answering a call (22%) and making a call (37%) than hands-free users (7% and 14%, respectively). The study carried by Matthews et al (2003), McEvoy et al (2005) shows, the potential of hands-free mobile phone use while driving is no safer than using a hand-held mobile phone. However, suggests that the implementation of strategies to increase awareness of the risks of this behavior for all drivers may be warranted.

### 1.5 EFFECTS ON DRIVER PERFORMANCE WHILE USING CELL PHONE

Different types and levels of driver distraction will influence driver’s behavior and performance while having a phone conversation. This effects of driving behavior is measured by Cooper and Zheng (2002) in various ways, including reduced sensitivity to road conditions, increased mental workload, poor lane maintenance, impaired gap judgment slower responses to events and stimuli and the effect on driving performance depends on several interrelated factors: the nature of the activity, the ability and experience of the user, the complexity of the driving task and the design, location, and activities with in-vehicle technologies.

The work carried by Harbluk et al (2002) is to determine whether the complexity of a conversation when using the mobile phones affects the drivers response time to stimuli. This result suggests that the driver’s ability to perceive and respond to hazardous situations in the driving environment is significantly impaired when conversing on the mobile phones, particularly when the conversation is complex in nature. In addition, Cooper and Zheng (2002) explains the impact of mobile phone-based distraction on driver’s
decision-making ability and, in particular, their ability to make safe cross-traffic turning decisions are analyzed and found both listening and responding to verbal messages (as occurs during a phone conversation) while driving, reduces a driver’s ability to adequately consider and process all the information necessary for safe decision-making and, in turn, can adversely impact road safety. Further, Strayer et al (2003) found the conversing on a mobile phone while driving lead to an increase in reaction times to a lead braking vehicle, with this increase in reaction times becoming more pronounced as the density of the traffic increased.

A review carried by McCartt et al (2006) of more than 125 cell phone studies including experimental ones found, impairment in simulated or test-track driving performance is measured among users of the hand-held and hands-free cell phones and confirmed that cell phone conversations while driving are associated with impaired reaction time and showed no differences in risk between hands-free and handheld phones. Statistical analyses that aggregate the results of Caird et al (2008), Horrey and Wickens (2004) shows similar findings i.e., the phone conversation tasks typically slowed reaction times and increased lane deviations and steering wheel movements regardless of phone type.

A good empirical example is a study conducted by Hurwitz and Wheatley (2001) in a simulator which show, reaction time to an unexpected event was on the order of 300 ms slower while the driver was engaged in a distraction task like cell phone than when he or she was not. While, the studies carried by Caird et al (2008), Beede and kass (2006) shows, talking on a cell phone increases reaction time to an unexpected obstacle and also increases headway.

The detailed analysis carried out by Hancock et al (2003) show, drivers talking on the phone shows their reactions were 18% slower and also
took 17% longer to recover the speed that was lost following braking. While, the study reported by Strayer and Drews (2004) found, there was a 2-fold increase in the number of rear end collisions when conversing on a cell phone during driving. In support of this finding, a 2004 survey carried by Seo and Torabi (2004) revealed that the most frequently cited reason for crashes or rear end crashes involves mobile phones use while driving, particularly TMWD (talking on a mobile phone while driving) rather than attempting to answer or dial.

To study the effect of using cell phone while driving, Alm and Nilsson (1995) uses two of the most commonly used longitudinal control measures, vehicle speed and the following distance. The study revealed both the vehicle speed and the following distance has been affected. A study on the effects of naturalistic cell phone conversations on driving performance was found by Rakauskas et al (2004). According to this study, the cell phone use causes drivers to have higher variation in accelerator pedal position, drive more slowly with more variation in speed, and report a higher level of workload. While, the detailed research carried by Strayer et al (2003) show, in addition to providing attention to surrounding traffic, pedestrians, potholes, warning signs, traffic lights, the speedometer, and everything else a driver monitored will be impaired while talking on a cell phone.

The study executed by Young et al (2003) based on steering wheel movements reports, visually distracted drivers steer their car in a different way than attentive drivers do. While, the study described by Regan et al (2009) show, under normal condition, when not performing secondary tasks, drivers usually do a number of small corrective steering wheel movements to keep the lateral position. When they perform a visually or manually demanding secondary task, drivers often make a number of large and abrupt steering wheel movements to correct heading errors.
The work reported Regan et al (2009) show, reaction time is regarded as an essential driving performance indicator, increases in reaction time can decisively raise the accident risk in unexpected and hazardous driving situations, particularly when the use of devices are complex like cell phones. The study performed by Jannette and Mark (2009) found, both manual and speech control in secondary IVIS interaction tasks led to significant increases in reaction times. Table 1.3 shows the summary on effects on driver performance while using cell phone.

<table>
<thead>
<tr>
<th>Decision Making</th>
<th>Using a mobile phone while driving affect decision making and concentration which fail to maintain safe gap. When making a decision to turn across oncoming traffic, we may miss important information such as environmental and surrounding traffic conditions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time</td>
<td>Driver will react slower when using a mobile phone, particularly when they are in conversation which may leads to take longer respond for traffic signals or completely miss them.</td>
</tr>
<tr>
<td>Applying brake and Gap Maintenance</td>
<td>During cell phone conversation driver takes more time to apply brake and while applying they apply the break with more force and less control which results in shorter stopping distances of the car in front.</td>
</tr>
<tr>
<td>Lane Maintenance</td>
<td>Phone conversation tasks typically increased lane deviations and steering wheel movements, even on a straight road with little traffic.</td>
</tr>
<tr>
<td>Surrounding</td>
<td>When using a mobile phone, driver spends less time in checking the mirrors and monitoring the traffic around. This affects the ability to monitor and negotiate traffic safely.</td>
</tr>
</tbody>
</table>

Table 1.3 Effects on Driver Performance While Using the Cell Phone
1.6 **BAN ON CELL PHONE**

Driver’s use of cell phone increases the crash risk especially teens are at higher risk for crashes while using the cell phone, which has led to the introduction of many legal measures. One of the most commonly applied legal measures against the cell phone use in a vehicle is the prohibition of a hand-held use of phones. As of February 2012, the number of GSM cell phone subscribers have been surpassed the 6 billion people mark and is currently available across more than 219 countries and territories worldwide. This rapid growth in cell phone use has led to concerns regarding their impact on driver performance and road safety. The issue of distracted driving has gained the attention of the public and policy makers. As a safety concern, distracted driving is an international issue. Numerous legislative efforts are under way to restrict hand-held cell phone use while driving. Lawmakers had identified what they perceive to be a safety issue, and many either has enacted or proposed new legislation to ban the use of cell phones by motorists.

Enforcement of distracted driving laws can be particularly difficult. Even when the behaviors that constitute illegal distracted driving have been clearly defined by legislation, observing and measuring those behaviors can be a challenge (Ranney 2008). The study carried by McEvoy et al (2005) conclude, laws on limiting all the cell phone use while driving will be difficult to enforce and suggested a possible solution in the future to change mobile phones so they cannot be used when vehicles are in motion. A study carried out by Zandvliet (2009) in Netherlands show, the use of hand-held phones in the car has been increasing, rather than decreasing after the ban of using cell phone while driving. The study carried out by Foss et al (2009) found the effect of legislation on driving behavior turns out to be disappointing, especially in the case of young people.
The study carried out by James (James 2011) found, even when legislative body enacts a hand-held cell phone ban to reduce a known crash risk, the drivers initially reduces use of mobile phone while driving in fear of getting a traffic ticket. After few months, when no enforcement action is noticed or when enforcement is not strict then the use of cell phone while driving returns to pre-ban levels, and risk remains the same. Similarly, Hahn and Prieger (2006) found there is weak evidence for a reduction in accidents due to a cell phone-use ban (hand-held or hands-free) after controlling for selection bias and heterogeneous risk across drivers. In support of all these studies, a study carried by McCartt and Geary (2004) show, the hand-held cell phone user rate while driving in New York dropped from 2.3% (before the law was enacted) to 1.1% in the first few months immediately following the enactment of the law. However, this rate rebounded back up to 2.1% about a year later. These study is in agreement with Rajalin et al (2005), Hussain et al (2006) suggested that banning the use of hand-held mobile phones initially lowers the rate of hand-held mobile phone use while driving (by up to 50%), before figures subsequently rise back up to pre-legislation levels. The reasoning behind this subsequent rise and return to pre-legislation levels may be two-fold:

**Enforcement:** After a brief period of compliance, drivers are judging that the risk of getting caught is minimal, hence returning to using hand-held mobile phones while driving;

**Publicity:** After a reduction in the publicity about the risks of mobile phone use while driving, drivers may have forgetting or demoting these risks.

The study carried out by Nikolaev et al (2010) compared county-level accidents in New York pre-ban (1997-2001) and post-ban (2002-2007), and they are unable to distinguish between decreases in accidents due to the cell phone ban. While, the study performed by Burger et al (2011) found no
evidence of a state-wide decrease in accidents as a result of the ban. Though their results are specific to California, cell phone bans in other jurisdictions have similar enforcement and penalty.

After examined the merits of all the cell phone law regulations it was described by McCartt et al (2006) that, all new cars to be equipped with Bluetooth fully hands-free phones which may eliminate the physical distraction of handling phones, but the distraction from phone conversations would remain. Even, various experimental evidences strongly suggest that the telephonic conversations—even if conducted using fully hands-free voice-activation phones—are distracting.

Though the use of a hand-held cell phone (i.e., holding a phone to your ear while you talk) is much more easily observed than the use of a hands-free phone, even in countries with hand-held cell phone bans, in many cases it is not against the law to manually manipulate the phone to initiate or answer a hands-free call (i.e., drivers can pick up the phone and press buttons to dial a number, scroll through contacts, or to answer a call) – which, according to Klauer et al (2006) may be primary sources for distraction, as those tasks may takes the driver’s eyes off the road. Although more than 50 countries have made laws on banning cell phone, which is applicable only to handheld cell phones, various research shows “hands-free devices do not eliminate the risks of distracted driving, and may worsen them by suggesting that the behavior is safe.

According to the studies carried out by McEvoy, et al (2005), Redelmeier and Tibshirani (1997) there is no difference in the risk associated with using a hand-held versus a hands-free cell phone while driving. While, the study performed by Strayer et al (2004) found, a ban on the hand-held phone does not solve the cognitive problem associated with cell phone conversations. It has been proven that when drivers talk on the phone, their
cognitive function is diverted from the task of driving. They may see hazards, but either does not recognize the danger or cannot react to it in time to avoid a crash. When judging hand-held and hands-free cell phone operation side by side, there is no difference in the level of impairment. In short, it is the conversation that causes the impairment, not holding the phone. So the countries hand-held bans, as designed, will not have a large impact on crash rates.

Many countries have banned the use of a hand held (not hand free) cell phone by drivers while driving, while India is the most recent and one among few countries which bans both the hand-held and a hand-free phone without giving any relaxation. There are also few countries like the U.K which have ban the use of a hand-held, while in the case of hand-free, the drivers are held responsible only if he/she found distracted and not in control of the vehicle. In Australia, the total ban on hand-free mobile phone only for learners and novice drivers. The study carried by Kolko (2009) reported that, if the act on using a hand held cell phone is banned, then it will force the drivers to shift from one method to another i.e., the changing from hand-held to hands-free device. The study also found that, there is no difference in using either hand held or hand-free phone use.

Further, Strayer et al (2003) study found, legislative initiatives that restrict handheld devices but permit hands-free devices are not likely to eliminate the problems associated with using cell phones while driving, because these problems are attributed in large part to the distracting effects of the phone conversations themselves, effects that appears due to the direction of attention away from the external environment and toward an internal cognitive context associated with the phone conversation. The list of few countries legislation on the use of mobile phone while driving is shown in Appendix 1.
India is the most recent country which has imposed a ban on drivers from the use of both hand-held and hand-free cellular phones while driving along with fine, prior India had ban only the use of hand-held cell phone that too in selected states like Delhi, Andhra Pradesh, Chennai along with fine and there is no offense or ban on using hand-free cell phone. Due to increase in road accidents every year (India is accounted for nearly 10% of global road accidents) the government has come forward to ban both the type of phones. Though it’s considered to be good practice to reduce the road accidents, proper enforcement remains a vital problem as indicated by various studies. An alternate solution proposed by Robert et al (2000) which show, instead of banning the cell phone, the government should focus on gathering additional information to determine the extent of the problem and also consider providing information to the public on the relative risk of cellular phone use in vehicles. The study carried by the international association for the wireless telecommunication CTIA believes that education is a more effective approach to enhance driver’s awareness and responsibility rather than legislation narrowly aimed toward cell phone ban (CTIA 2008). On the other hand, there are also few studies carried out which shows the essential of cell phone while driving. The study carried by Lissy et al (2000) supports the use of cell phone and the study found, drivers feel safer if they can use their phone to let other people know they are delayed and for public health and safety consideration and it can further reduce emergency response time to automobile accidents.

Few studies have attempted to explore the economic implications of banning the use of mobile phones while driving. For example, the study carried by Hahn and Tetlock (1999) attempted to quantify the monetary benefits associated with a ban on mobile phones and the monetary costs associated with the loss of consumer convenience in being able to use the devices while driving. The study concluded that, a ban on the use of mobile phones may not be economically efficient. Similarly, Cohen and Graham
(2003) study concluded that, the estimated net benefit of a ban on mobile phone use while driving (in the US) was close to zero; that is, the value of preventing crashes caused by mobile phone use while driving was approximately equal to the value of the calls that would be eliminated by a ban.

Even with an introduction of laws prohibiting drivers from using cell phones including hand-free phone while on the road, enforcement remains a paramount problem. Without an effective method for ensuring drivers comply with these new laws, their ability to prevent automobile accidents remains uncertain.

1.7 MOTIVATION

Driver distraction is one of the leading causes of motor vehicle accidents. Distraction particularly when using cell phones is the most common and challenging. It is estimated that 1.34 lakhs people died in 2010, due to road crashes in India with an average of more than one death for 3.56 minute and one injury for every minute, accounted nearly 10% of global accidents.

The report ‘Road accidents in India’ prepared by the Transport Research Wing of the Ministry of Road transport and Highways, Government of India shows “driver fault” is the single most important factor which accounted for 81% of total accidents (Gururaj 2011). According to World Health Organization (WHO), road traffic crashes rank as the 9th leading cause of death and accounted for 2.2% of deaths globally. This number is expected to increase, and rank as the 5th leading cause by 2030 if no action is taken to address the current crisis reported by Puvanachandra et al (2012). Road traffic fatalities are forecast to rise from the current level of nearly 1.4 million deaths
annually to more than 1.9 million deaths per year by 2020. According to National Safety Council (NSC) of U.S., it is estimated that at least 28% of all traffic crashes or at least 1.6 million crashes each year involved drivers use of cell phones. The study carried by the Governors Highway Safety Association (GHSA), a nonprofit group that works to improve traffic safety, critically reviewed research of 350 scientific papers published since 2000 and concluded that driving distractions, primarily using cell phones and other electronic devices are associated with up to 25 percent of car crashes.

Having established this background it is important to draw attention to the idea that limited research work has been carried on to identify the percentage of cell phone distractions behind the crashes in India. This is of vital importance because the number of cell phone subscribers and motor vehicles in India has been far greater than other countries. In order to make efforts to change this scenario, there is a need to develop and implement strong mechanisms for prevention of mobile phone use while driving.

1.8 PROBLEM STATEMENT

This research is helpful in distinguishing whether the phone is used by the driver or passengers. According to Federal Accident Database (FARS), 38% of automobile trips include passengers who are considered to be safe in order to use their mobile phone to make or receive call/text. Any system or application developed so far needs human intervention i.e., driver needs to manually start the mobile application or need to engage himself in case of installation of specialized hardware like Bluetooth which require manual pairing before he start driving. This research further attempt to find a solution were manual starting of the application every time the driver enters the vehicle is unnecessary.
An additional problem which has been addressed is the status of the driver. In general, caller is not aware of the status of the person whom they are trying to call. For example, are they driving or not. So, notification should be sent to the caller via SMS that the driver is driving with approximate elapsed time. Current applications developed so far will let the information to the caller with regards to the driving status and not about the elapsed time. This research not only presents the driving status of the driver, but it also gives information to the caller on how long the driver would take to reach his/her destination.

According to the studies and surveys, it is observed that no mobile applications have been developed so far to deal with real emergency situations. It is important sometimes that the driver should be informed real emergency situations related to either work or family, which has been addressed as well in this research. At the same time, there is also possibility that driver may meet with an accident even while attending emergency call, in order to overcome this situation, research have been extended, and proposed an innovative solution which help in completely eliminate this risk. The added advantage of this research is addresses when the system is to start function. The research is also related with economic loss which occurred due to accidents and shown how far this system help in reducing these losses.

1.9 ORGANIZATION OF THESIS

This thesis is organized in six chapters. The first chapter discussed about architecture of GSM in general with distraction of using cell phone while driving and its effects on driving behavior and drivers. In the second chapter an extensive literature study is done in the area of hardware system, software or mobile application and the combination of both hardware and software technologies developed so far to prevent distractions which occur due to cell phone use while driving. In the third chapter, a case study is
performed to analyze the impact of mobile phone on road accidents in India. In the fourth, the proposed drivers or passenger detection system along with Cellphone Accident Preventer (C.A.P.) application development is presented with results. The fifth chapter discusses a real time implementation of the complete system along with how far this system help in reducing economic loss on cell phone accident. The final chapter concludes this work with direction of future work.