# Drowsiness Prevention System

Design Project III


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4th Semester | Master of Design (ID)

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# DROWSINESS PREVENTION SYSTEM FOR DRIVERS

INDUSTRIAL DESIGN PROJECT – III

## MDP – 474

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# Drowsiness Prevention System

## Design Project III (IDP-603)

under the guidance of
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# Approval Sheet

This project titled "Drowsiness Prevention System" is prepared and submitted by Anirban Maiti in partial fulfilment of the requirement for the degree of 'Masters in Design' in Industrial Design. It has been examined and is recommend for approval and acceptance.

Guide:

Co-guide:

Internal Examiner:

External Examiner:

Chairman:

# Declaration

The work done as a part of the written submission under this report "Drowsiness Prevention System" as project three for post graduate program in Industrial Design Centre, IIT Bombay, India under the guidance of Prof. Dr.-Ing. Ralph Bruder(IAD TU Darmstadt), Lukas Bier(Senior Research Associates IAD TU Darmstadt), Prof. G. G. Ray, Prof. Vijay Bapat and Prof. Sugandh Malhotra.

I hereby declare all the content of this project is an original work with appropriate reference information or links provided wherever due.

Any violation of the above will be cause for disciplinary action by the institute.

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# Acknowledgement

I am heartily thankful to my project guides Prof. Dr.-Ing. Ralph Bruder(IAD TU Darmstadt), Lukas Bier(Senior Research Associates IAD TU Darmstadt), Prof. G. G. Ray, Prof. Vijay Bapat and Prof. Sugandh Malhotra for teaching me work ethics and setting an example of discipline at workspace, for encouraging me at every level to take decisions for my project and believing in me when I chose one option over the other.

I am also obliged to the staffs at studios who were always ready to back up with knowledge and guidance while working in workshops making ideations, mockups and prototypes.

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# Introduction

Image Source - http://ossekeag.ca/well-rested-drowsy-driving/

## About the project

Many drivers know this scary situation that on long highway drives the attention drops instantly. Due to many reasons the driver get tired and cant resist himself/herself from sleeping on wheel. From those sleep related fatigue issues can be monitored easily and there is huge opportunity to save thousands of life from the highway accidents especially at the night time.

In India, drowsiness if one the major reason behind accidents like driving in drunk condition. So, it is a important field to work on and come up with non-intrusive solution with less cognitive load.


Image 1.1 - Percentage of Car Accidents due to drowsiness
Source: https://www.soclean.com/sleep-talk/2014/11/10/new-aaa-report-reveals-alarming-new-statistics-drowsy-driving/

## Background Study

During long driving in highways, monotony occurs very often. After a short period of yawning follows the dangerous “microsleep”, which lead to drowsiness and then to further accidents *(Amini et al. 2016)*[1].

Based on studies it is assumed that around 21% of all accidents are caused by drowsiness, for Germany it is 25% and in the case of Indian Truck accidents, it is 57%. Hence it is one of the most dangerous and leading causes for deadly accidents which leads to huge amount of economical and infrastructural loss.

# Motivation for the project

It is a global problem, irrespective to economical and cultural background. The development and outcome of the project can create a great impact on the large scale over the society. It also deals with safety issues of the drivers.

# Purposes of the Project

A huge percentage of the overall accidents are caused by drowsiness. The main purpose of this project is to diminish this cause of accidents which is quite possible. This project also deals with different cultural background and affordability and user interaction with the car itself.

# Objectives of the Project

There are basic three issues to focus:
(i) Make driving experience interesting to reduce monotony
(ii) Monitoring drowsiness of different stages
(iii) Making driver awake in the most efficient way

and everything should be done without distracting the driver from driving itself.

# Methodology

As this type of development project is very hard to test on actual scenario, the only option is to make a simulator inside the laboratory and to develop an artificial ambience which is as much as closer possible to the real time scenario.
Even there are lots of processes which are very much possible in simulator but not at actual real life condition. So based on different processes we have to find out most effective non-intrusive process to monitor drivers' condition in monotonous situations.
Later we can test different concept with different users to get feedback and further progress in actual but with limited cognitive load to get an idea of feasibility.

# 02

## About Drowsiness

http://www.bombaytimes.com/photo/56200120.cms

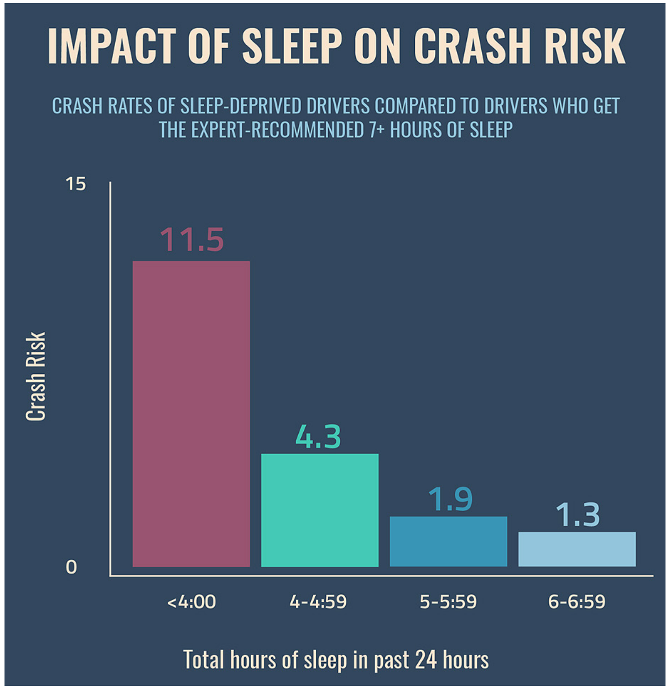


Image 2.1 - Impact of Sleep in Crash Risk
Source: https://www.aaa.com/drowsy driving

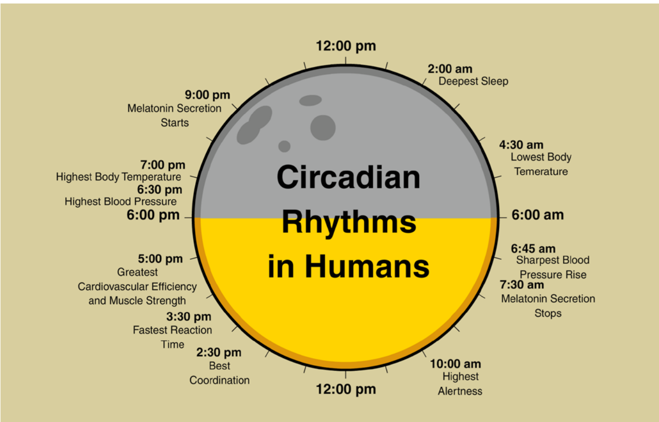


Image 2.2 - Circadian Rhythms in Human Body
Source: http://aboutislam.net/science/faith-science/circadian-rhythm-fasting/

# Fatigue

In the everyday language, as well as in science there is disagreement about the uniform description of fatigue. The terms of tiredness, fatigue and sleepiness are used often interchangeably in everyday parlance.

Schmidtke (1965)has drawn several characteristics to the definition of fatigue. Therefore, fatigue is the result of a previous load and stress and causes a reversible reduction of the performance and functionality of a people [2].

Drowsiness is basically extreme tiredness resulting from mental or physical exertion depends on Work load, work stress and work performance and leads to these results one after another -
(i) Fatigue (work related)
(ii) Tiredness (physical condition)
(iii) Sleepiness (effect that causes accidents)

# Types of Fatigue

There are mainly two types of fatigue in the area of occupational health issues. Those are -
(i) TR Fatigue (Task Related) (for Work Load, Work Stress, Work Performance)
(ii) SR Fatigue (Sleep Related) (for Circadian Rhythm)

SR Fatigue occurs due to disturbance in Sleep Cycle (Circadian Rhythm) which is out of design control. But TR fatigue occurs for occupational Work Load, Work Stress and Work Performance which can be avoided by proper designing drivers' environment.

# Drowsiness

The word “Drowsy” simply means an inclination to fall asleep.

According to *National Centre for Biotechnology Information*
Stages of sleep are categorized by –
(i) Awake,
(ii) Non-Rapid Eye Movement Sleep (NREM) and
(iii) Rapid Eye Movement Sleep (REM).

Stages of NREM are:
(i) Transition from awake to asleep (Visual Feedback works)
(ii) Light sleep (Audio Feedback works)
(iii) Deep sleep (Haptic Feedback works)

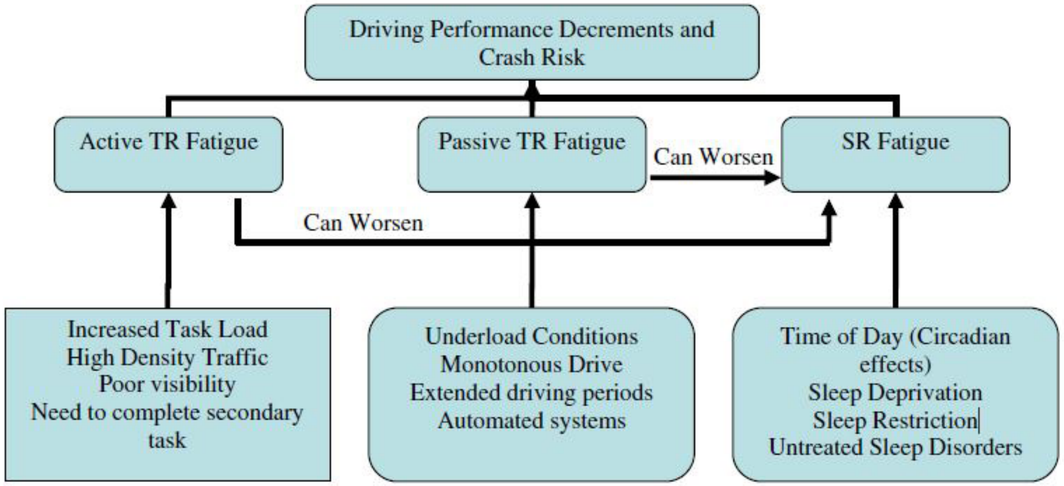


Image 2.3 - Reasons for Driving Performance Decrements
Source: J. F. May, C. L. Baldwin, Transportation Research Part F 12 (2009) 218–224

# Causes of Drowsiness

There are lots of probable reasons for drowsiness which generally caused from fatigue during driving car for a long journey. Few of them are -
[A] Related to driving environment:
(i) Low volume of traffic
(ii) No visual stimuli (like Darkness at night)
(iii) Monotonous route
(iv)Continuous flow of traffic with almost same density
(v) Predictability of Driving Tasks
(vi) Constant Noise of same intensity

[B] Related to lifestyle:
(i) Circadian Rhythm

# Symptoms of Drowsiness

There are few symptoms of drowsiness -
(i) Yawning frequently
(ii) Trouble to keep head up
(iii) Difficulty for focusing
(iv) Frequent eye blinking with heavy eye-lid
(v) Unable to remember last few miles
(vi) Miss exits and traffic signage
(vii) Drifting from lanes

# Influence of automated driving

Driver Assistant System (DAS) and Driver Interaction System (DItS) represent of driver-vehicle interaction systems that differ by the type and the level of the Division of labour. The meaning of DAS in recent years has increased across all vehicle classes. The development of controls on a higher degree of automation of part in vehicles with the long-term goal of fully autonomous driving. In this chapter to a Division be made DAS and worked out, how a monotony-related mileage drop of DAS can be favored.

Seeck, Gasser and Smith (2015)classified DAS in motor vehicles in three categories depending on the destination and the degree of automation [3].

**Category A: informational and warning functions**

These systems have the function, the driver of the system to inform driver condition and, where appropriate, to warn. So, you have no direct, indirect influence on the actual vehicle leadership, will continued to be completely taken over by the driver.
Examples for DAS with informational and warning functions are traffic sign recognition, fatigue warning and lane departure warning.
These DAS have the properties on that the driver of new information and stimuli received by signals or warnings and must actively respond to these. Parameters which can abruptly raise fatigue as a result of demanding are: (i) environment change, (ii) alarm status and (iii) interest arouse new information.
Therefore, a reinforcing effect on a monotony-related mileage drop is not available.

**Category B: continually automating functions**

Continually automating DAS have the property that the tasks associated with driving on the driver and the system will be divided. The driver deliberately transfers tasks to the system, which thus indirectly affects the driving.
Examples for DAS of Category-B are the adaptive cruise control (ACC), the lane or the automatic transmission.
This DAS work continuously and relieve the driver in demand situations by taking on tasks. As a result, they favour but monotony-related fatigue in already irritable poor, monotonous situations of driving because they permanently remove tasks to the driver and the driving task is thus more like a monitor as an active action. The performance requirements for the driver as well as the activating stimuli are reduced, which in turn decreases the vigilance.
A reinforcing effect on a monotony-related performance drop may be the result.

**Category C:-operating emergency systems**

Invasive emergency systems take control of vehicle functions, if the driver loses control of the vehicle functions. Situations in which this may be the case, are enabling accident situations in General. The system adopts safety-relevant functions of driving in situations, where an accident is likely and no longer by the driver can be averted.
Automatic assistants or alternative systems are example of intervening emergency systems.
Such systems have an indirect influence on the driving that does not continuously but suddenly. Usually, the intervention of the system associated with a warning to the driver. The environment State suddenly changes, the driver enters an alarm or even anxiety and receives new information and stimuli. A revoking of monotony-related fatigue is therefore likely.
A reinforcing effect on a monotony-related mileage drop is not available.
The trend brings down while increasing savings by continuously-acting, automated driver's a higher degree of comfort for the driver assistance systems. However a monotony-related mileage waste can also be favoured. Against this background, the objective of the to concept Ionians ends DItS is to counteract a such monotony-related drop in mileage.

# 03

## Measuring Drowsiness

Image Source - http://ossekeag.ca/well-rested-drowsy-driving/

**Table 3.1. - Karolinska Sleepiness Scale (KSS)**

| Rating | Verbal descriptions |
|---|---|
| 1 | Extremely alert |
| 2 | Very alert |
| 3 | Alert |
| 4 | Fairly alert |
| 5 | Neither alert nor sleepy |
| 6 | Some signs of sleepiness |
| 7 | Sleepy, but no effort to keep alert |
| 8 | Sleepy, some effort to keep alert |
| 9 | Very sleepy, great effort to keep alert |

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3571819/

# Methods for measuring drowsiness

There are several ways to measure drowsiness in laboratory scenario, but very few are applicable in real time driving condition. Any way some of the measuring methods are given below.

**(i) Subjective measurement : Karolinska and other Sleepiness Scales**
Subjective measures that evaluate the level of drowsiness are based on the driver's personal estimation and many tools have been used to translate this rating to a measure of driver drowsiness. The most commonly used drowsiness scale is the Karolinska Sleepiness Scale (KSS), a nine point scale that has verbal anchors for each step, as shown in Table 3.1. *Hu et al.*measured the KSS ratings of drivers every 5 min and used it as a reference to the EoG signal collected [4]. *Portouli et al.* evaluated EEG data by confirming driver drowsiness through both a questionnaire and a licensed medical practitioner. Some researchers compared the self-determined KSS, which was recorded every 2 min during the driving task, with the variation of lane position (VLP) and found that these measures were not in agreement [5]. *Ingre et al.* determined a relationship between the eye blink duration and the KSS collected every 5 min during the driving task [6].

Researchers have determined that major lane departures, high eye blink duration and drowsiness related physiological signals are prevalent for KSS ratings between 5 and 9. However, the subjective rating does not fully coincide with vehicle based, physiological and behavioral measures.

Because the level of drowsiness is measured approximately every 5 min, sudden variations cannot be detected using subjective measures. Another limitation to using subjective ratings is that the self-introspection alerts the driver, thereby reducing their drowsiness level. In addition, it is difficult to obtain drowsiness feedback from a driver in a real driving situation. Therefore, while subjective ratings are useful in determining drowsiness in a simulated environment, the remaining measures may be better suited for the detection of drowsiness in a real environment.

**(ii) Vehicle based measurement**
**Steering Wheel Movement(SWM), Standard Deviation of Lane Position(SDLP)**

Another method to measure driver drowsiness involves vehicle-based measurements. In most cases, these measurements are determined in a simulated environment by placing sensors on various vehicle components, including the steering wheel and the acceleration pedal the signals sent by the sensors are then analyzed to determine the level of drowsiness. *Liu et al.* published a review on current vehicle-based measures[8]. Some researchers found that sleep deprivation can result in a larger variability in the driving speed. However, the two most commonly used vehicle-based measures are the steering wheel movement and the standard deviation of lane position.

**Steering Wheel Movement (SWM)**

It is measured using steering angle sensor and it is a widely used vehicle based measure for detecting the level of driver drowsiness. Using an angle sensor mounted on the steering column, the driver's steering behavior is measured. When drowsy, the number of microcorrections on the steering wheel reduces compared to normal driving. *Fairclough and Graham* found that sleep deprived drivers made fewer steering wheel reversals than normal drivers[7]. To eliminate the effect of lane changes, the researchers considered only small steering wheel movements (between 0.5° and 5°), which are needed to adjust the lateral position within the lane. Hence, based on small SWMs, it is possible to determine the drowsiness state of the driver and thus provide an alert if needed. In a simulated environment, light side winds that pushed the car to the right side of the road were added along a curved road in order to create variations in the lateral position and force the drivers to make corrective SWMs. Car companies, such as Nissan and Renault, have adopted SWMs but it works in very limited situations. This is because they can function reliably only at particular environments and are too dependent on the geometric characteristics of the road and to a lesser extent on the kinetic characteristics of the vehicle.

**Standard Deviation of Lane Position (SDLP)**
This is another measure through which the level of driver drowsiness can be evaluated. In a simulated environment, the software itself gives the SDLP and in case of field experiments the position of lane is tracked using an external camera. *Ingre et al.* conducted an experiment to derive numerical statistics based on SDLP and found that, as KSS ratings increased, SDLP (meters) also increased[6].

For example, KSS ratings of 1, 5, 8, and 9 corresponded to SDLP measurements of 0.19, 0.26, 0.36 and 0.47 respectively. The SDLP was calculated based on the average of 20 participants however, with some drivers, the SDLP did not exceeded 0.25 m even for a KSS rating of 9. In the above experiment by performing correlation analysis on a subject to subject basis significant difference is noted. Another limitation of SDLP is that it is purely dependent on external factors like road marking, climatic and lighting conditions. In summary, many studies have determined that vehiclebased measures are a poor predictor of performance error risk due to drowsiness. Moreover, vehicularbased metrics are not specific to drowsiness. SDLP can also be caused by any type of impaired driving, including driving under the influence of alcohol or other drugs, especially depressants.

**(iii) Behavioral measurement**
**Face detection, Head nodding detection, Eyelid movement**

A drowsy person displays a number of characteristic facial movements, including rapid and constant blinking, nodding or swinging their head, and frequent yawning. Computerized, non-intrusive, behavioral approaches are widely used for determining the drowsiness level of drivers by measuring their abnormal behaviors. Most of the published studies on using behavioral approaches to determine drowsiness, focus on blinking.
PERCLOS (which is the Percentage of Eyelid Closure over the pupil over time, reflecting slow eyelid closures, or "droops", rather than blinks) has been analyzed in many studies. This measurement has been found to be a reliable measure to predict drowsiness and has been used in commercial products such as Seeing Machines and Lexus. Some researchers used multiple facial actions, including inner brow rise, outer brow rise, lip stretch, jaw drop and eye blink, to detect drowsiness. However, research on using other behavioral measures, such as yawning and head or eye position orientation, to determine the level of drowsiness is ongoing.
The main limitation of using a vision based approach is lighting. Normal cameras do not perform well at night. In order to overcome this limitation, some researchers have used active illumination utilizing an infrared Light Emitting Diode (LED). However, although these work fairly well at night, LEDs are considered less robust during the day. In addition, most of the methods have been tested on data obtained from drivers mimicking drowsy behavior rather than on real video data in which the driver gets naturally drowsy. Mostly, image is acquired using simple CCD or web camera during day and IR camera during night at around 30 fps. After capturing the video, some techniques, including Connected Component Analysis, Cascade of Classifiers or Hough Transform, Gabor Filter, Haar Algorithm are applied to detect the face, eye or mouth. After localizing the specific region of interest within the image, features such as PERCLOS, yawning frequency and head angle, are extracted using an efficient feature extraction technique, such as Wavelet Decomposition, Gabor Wavelets, Discrete Wavelet Transform or Condensation Algorithm. The behavior is then analyzed and classified as either normal, slightly drowsy, highly drowsy through the use of classification methods such as support vector machine, fuzzy classifier,

neural classifier and linear discriminant analysis. However, it has been found that the rate of detecting the correct feature, or the percentage of success among a number of detection attempts, varies depending on the application and number of classes. The determination of drowsiness using PERCLOS and Eye Blink has a success rate of close to 100% and 98%, respectively. However it has to be noted that, the high positive detection rate achieved by was when the subjects didn't wear glasses. Likewise, as most researchers conducted their experiments in simulated environment they achieved a higher success rate. The positive detection rate decreased significantly when the experiment was carried out in a real environment.
Another limitation of behavioral measure was brought out in an experiment conducted by *Golz et al.* They evaluated various drowsiness monitoring commercial products, and observed that driver state cannot be correlated to driving performance and vehicle status based on behavioral measures alone[9].

**(iv) Physiological measurement**

As drivers become drowsy, their head begins to sway and the vehicle may wander away from the center of the lane. The previously described vehiclebased and vision based measures become apparent only after the driver starts to sleep, which is often too late to prevent an accident.
However, physiological signals start to change in earlier stages of drowsiness. Hence, physiological signals are more suitable to detect drowsiness with few false positives making it possible to alert a drowsy driver in a timely manner and thereby prevent many road accidents.
Many researchers have considered the following physiological signals to detect drowsiness: electrocardiogram (ECG), electromyogram (EMG), electroencephalogram (EEG) and electrooculogram (EoG). Some researchers have used the EoG signal to identify driver drowsiness through eye movements. The electric potential difference between the cornea and the retina generates an electrical field that reflects the orientation of the eyes this electrical field is the measured EoG signal. Researchers have investigated horizontal eye movement by placing a disposable AgCl electrode on the outer corner of each eye and a third electrode at the center of the forehead for reference. The electrodes were placed as specified so that the parameters Rapid

eye movements (REM) and Slow Eye Movements (SEM) which occur when a subject is awake and drowsy respectively, can be detected easily.

The heart rate (HR) also varies significantly between the different stages of drowsiness, such as alertness and fatigue. Therefore, heart rate, which can be easily determined by the ECG signal, can also be used to detect drowsiness. Others have measured drowsiness using Heart Rate Variability (HRV), in which the low (LF) and high (HF) frequencies fall in the range of 0.04–0.15 Hz and 0.14–0.4 Hz, respectively. HRV is a measure of the beat-to-beat (RR Intervals) changes in the heart rate. The ratio of LF to HF in the ECG decreases progressively as the driver progresses from an awake to a drowsy state.

The Electroencephalogram (EEG) is the physiological signal most commonly used to measure drowsiness. The EEG signal has various frequency bands, including the delta band (0.5–4 Hz), which corresponds to sleep activity, the theta band (4–8 Hz), which is related to drowsiness, the alpha band (8–13 Hz), which represents relaxation and creativity, and the beta band (13–25 Hz), which corresponds to alertness. A decrease in the power changes in the alpha frequency band and an increase in the theta frequency band indicates drowsiness. It is observed that the success rate of using a combination of EEG and EMG signals to detect drowsiness is higher than using either signal alone.

The measurement of raw physiological signals is always prone to noise and artifacts due to the movement that is involved with driving. Hence, in order to eliminate noise, various preprocessing techniques, such as low pass filter, digital differentiators, have been used.

The reliability and accuracy of driver drowsiness detection by using physiological signals is very high compared to other methods. However, the intrusive nature of measuring physiological signals remains an issue to be addressed.
To overcome this, researchers have used wireless devices to measure physiological signals in a less intrusive manner by placing the electrodes on the body and obtaining signals using wireless technologies like Zigbee, Bluetooth. Some researchers have gone further ahead by measuring physiological signals in a non intrusive

way by placing electrodes on the steering wheel or on the driver's seat. The signals obtained were then processed in android based smart phone devices and the driver was alerted on time. The accuracy of a non-intrusive system is relatively less due to movement artifacts and errors that occur due to improper electrode contact.

However, researchers are considering to use this because of its user friendliness. In recent years, experiments are conducted to validate non-intrusive systems. The advantages and disadvantages of the different type of measures are summarized below.

From this table we can say that a **Hybrid System of Behavioral and Vehicle based measures** is actually applicable in real time driving situation as these are non-intrusive.v

| Measures | Parameters | Advantages | Limitations |
|---|---|---|---|
| Subjective measures | Questionnaire | Subjective | Not possible in real time |
| Vehicle based measures | Deviation from the lane position | Nonintrusive | Unreliable |
| | Loss of control over the steering wheel movements | | |
| Behavioral Measures | Yawning | Non-intrusive; Ease of use | Lighting condition Background |
| | Eye closure Eye blink | | |
| | Head pose | | |
| Physiological measures | Statistical & energy features derived from ECG EoG EEG | Reliable; Accurate | Intrusive |

Table 3.2 - Different measures to monitor Drowsiness
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3571819/

# Relation of SLDP and Eyeblink duration with KSS

This is the graphical representation of the respective relationship of Standard deviation of Lateral Position (SDLP) and Eye Blink Duration with respect to Karolinska Sleepiness Scale(KSS). According to this data time frame for monitoring drivers' state can be developed in the Drowsiness Prevention System.

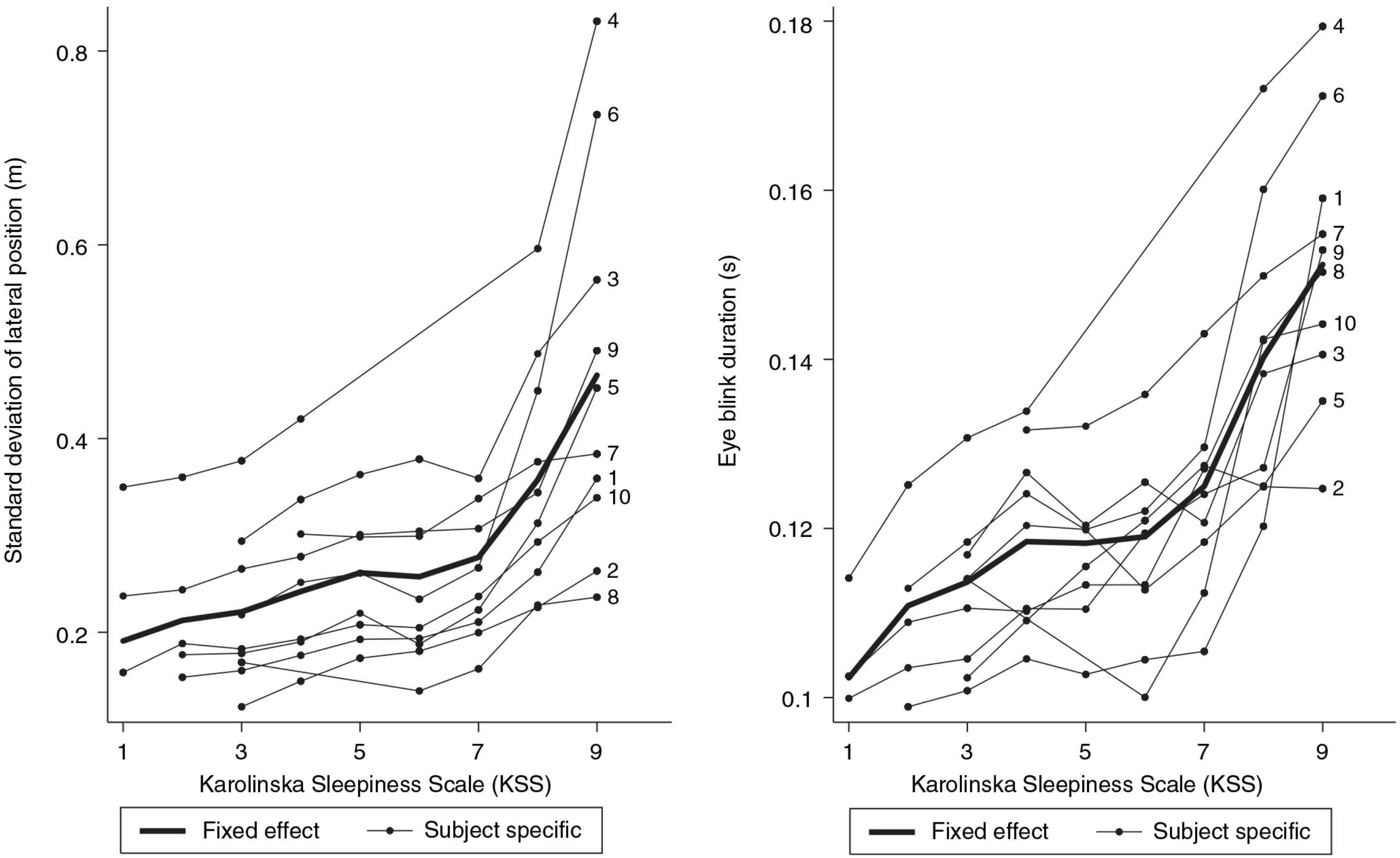


Image 3.1 - Relation of SDLP and Eyeblink Duration with KSS
Source: Ingre et. al. (2005)[6]

## Application processing Time

This time frames can be easily incorporated in the Drowsiness Prevention System for monitoring Drivers' behavioral state.

| State | Time (s) |
|---|---|
| Sensors Reading and Encoding Conversion | 0.001 |
| Eyes detection and PERCLOS calculation | 0.050 |
| ECG R-R wave detection and heart rate derivation | 0.010 |
| PPG peak-to-valley detection and blood pressure derivation | 0.010 |
| Temperatures reading and speed derivation | 0.020 |
| FBN analysis | 0.100 |
| Update display screen | 0.005 |

# 04

# Case Studies

Image Source - http://ossekeag.ca/well-rested-drowsy-driving/

# Driver Ergonomics

Before starting this project regarding drowsiness of drivers it is essential to be aware of different ergonomical issues with respect to drivers so that new products will be within the ergonomical permissibles.

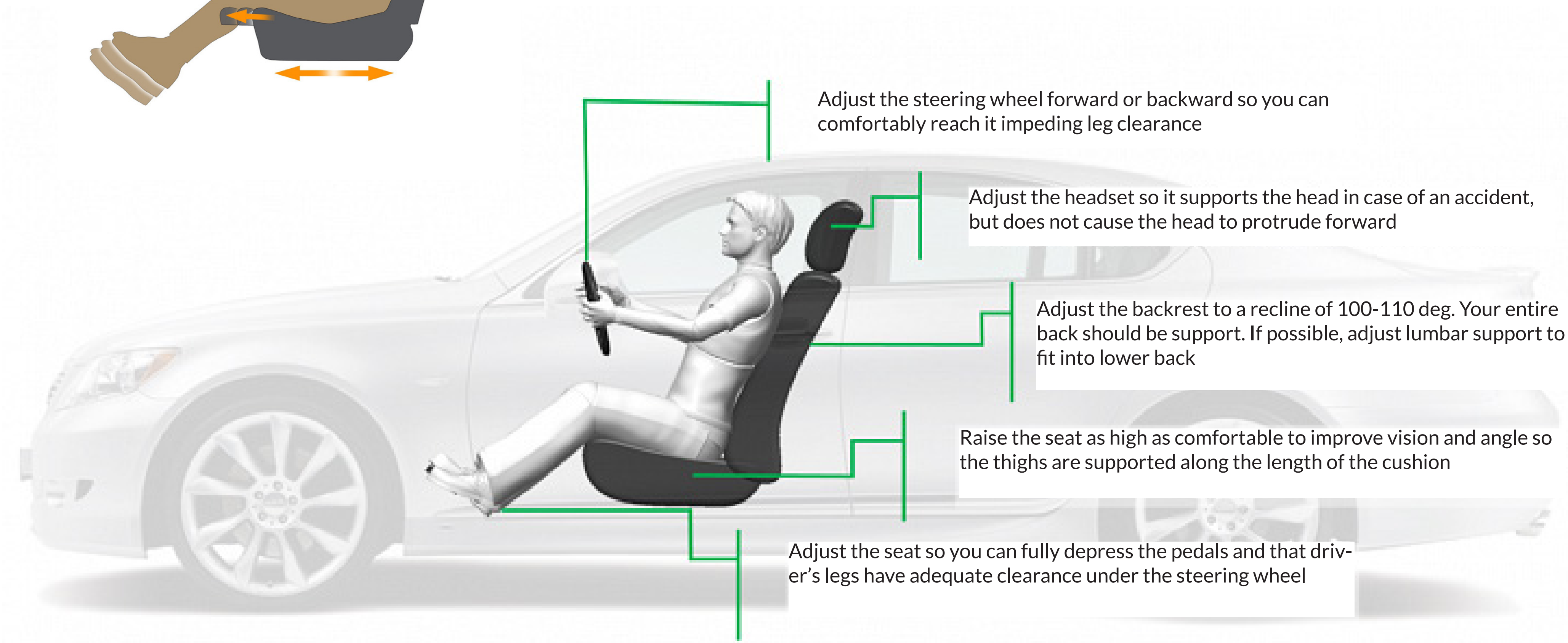


Image 4.1 - Different Ergonomic adjustments at the time of driving
Source: http://ewiworks.com/news/post.php?s=2015-04-09-road-trip-ergonomics

# Simulated Environment for Drowsiness Manipulation

It is not safe and ethical to make a drowsy driver drive on road. Hence, researchers have used simulated environments to carry out their experiments. Experimental control, efficiency, low cost, safety, and ease of data collection are the main advantages of using simulators. The driving simulators can be broadly classified as:

(1) Lowlevel simulators consisting of a computer, a monitor, a realistic cockpit, a steering wheel, manual gear box and pedals (clutch, brake and accelerator).

(2) Midlevel (Fixedbase) simulators comprising of advanced imaging techniques, a large projection screen, a realistic car, and possibly a simple motion base and

(3) Highlevel (Motionbased) simulators typically providing a view close to 360° and an extensive moving base.

One important limitation of using driving simulators is that the drivers do not perceive any risk. The awareness of being immersed in a simulated environment might give a behavior which is different than that on real road. However, researchers have validated that driving simulators can create driving environment that are relatively similar to road experiments. Researchers have observed behavioral, vehicle based and physiological similarity between simulated and on road experiments.

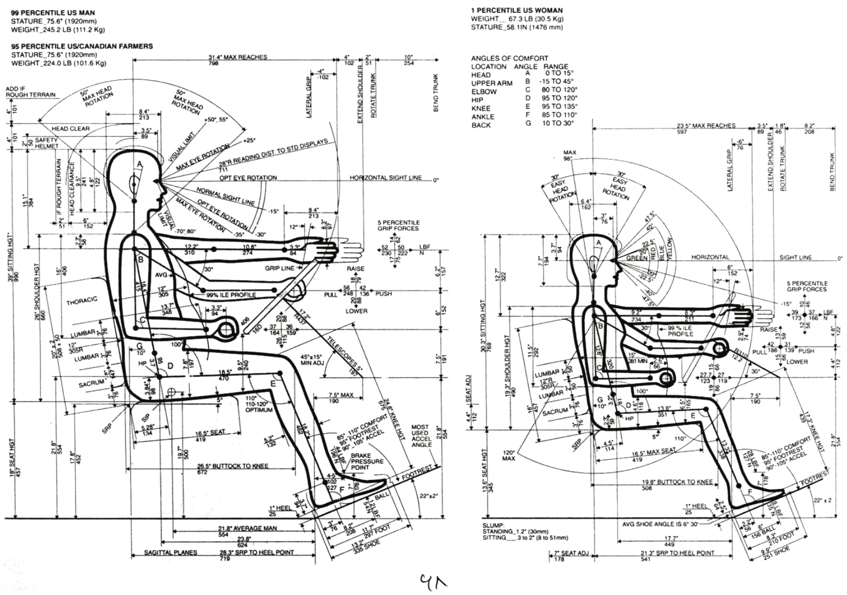

Image 4.2 - Driver Ergonomics
Source: https://in.pinterest.com/pin/175992297916894140/

# Simulated Environment for Drowsiness Manipulation

Image 4.3 - Driving Simulator with 180 degree viewing screen
Source: http://www.nads-sc.uiowa.edu/media.php?pageno=4&showAll

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# Drowsiness Manipulation for study purpose

One of the challenges in developing an efficient drowsiness detection system is how to obtain proper drowsiness data. Due to safety reasons, drowsiness cannot be manipulated in a real environment thus, the drowsiness detection system has to be developed and tested in a laboratory setting. However, in a laboratory setting, the most reliable and informative data that pertains to driver drowsiness relies only on the way in which the driver falls into the drowsy state.

Driver drowsiness mainly depends on: (i) the quality of the last sleep (ii) the circadian rhythm (time of day) and (iii) the increase in the duration of the driving task. In some research experiments, the subjects were fully deprived of sleep, whereas they were only partially deprived of sleep in others. In addition, some researchers recruited night shift workers as their subjects in these cases, the subjects were totally deprived of sleep because the experiments were conducted in the morning. *Kokonozi et al.* conducted an experiment in which they monitored the participants for 24 h before the experiment began to ensure that they were completely sleep deprived[10]. In certain experiments, researchers partially deprived the subjects of sleep by allowing them to sleep for less than 6 h. *Peters et al.* studied the same subjects during four consecutive days and considered the effects of no sleep deprivation, partial sleep deprivation and total sleep deprivation on their drowsiness level[11]. They observed that, even in the case of partial sleep deprivation, the subjects tend to get drowsy after some time. Hence, the quality of the last sleep is an important criteria that influences drowsiness.

The performance of the driver deteriorates when physiological activity diminishes. A circadian rhythm is used to refer to any biological variations or rhythms that occur in a cycle of approximately 24 h. These rhythms are self-sustaining (i.e., free running) and will persist even when the organism is placed in an environment devoid of time cues, such as constant light or constant darkness. Recent statistics from countries such as the United Kingdom, the United States, Israel, Finland, and France indicate that an increased number of vehicle accidents caused by driver drowsiness occurred during the peak drowsiness periods of 2:00 am to 6:00 am and 2:00 pm to 4:00 pm. During these time frames, the circadian rhythm shows higher chance of getting

Image 4.4(a) - Driving Simulator at IAD, TU Darmstadt
Source: Clicked by Anirban Maiti (Self)

drowsy and drivers are three times more likely to fall asleep at these times than at 10:00 am or at 7:00 pm. *Liu et al.* pointed out that the circadian rhythm produces small, but significant, changes in vehiclebased measures[8]. Researchers have asked subjects to drive between 2:30 pm and 5:30 pm in order to monitor drowsiness by measuring eyelid movement, ECG and EEG.
The duration of the driving task also plays a major role in influencing drowsiness. *Otamani et al.* found that sleep deprivation alone does not directly influence the brain signals that control drowsiness, whereas the duration of task has a strong influence[12]. Researchers have also inferred that prolonged driving on a monotonous environment stimulates drowsiness. In fact, it has been observed that the subjects can become drowsy within 20 to 25 min of driving. This last finding, reported by Philip et al., contradicts the observation made by *Thiffault et al.* that, in a real environment, the duration of the drive does not impact the performance during the first two hours[13]. In addition, researchers have found that drowsiness related crashes are more probable in a monotonous environment than in a stimulating environment.
Therefore, there is a very high probability that a partially sleep deprived driver will become drowsy when driving in a monotonous environment at a constant speed for three hours during a time when their circadian rhythm is low. This should be taken into consideration when designing an experiment relating to recording driver drowsiness.

Image 4.4(b) - Driving Simulator at IAD, TU Darmstadt
Source: Clicked by Anirban Maiti (Self)

# Comparison of Simulated and Real Driving Conditions

It is not advisable to force a drowsy driver to drive on roads. Consequently, many experiments have been conducted in simulated environments and the results of the experiments are then elaborately studied. *Dinges et al.* presented various challenges involved in real time drowsiness detection[14]. The subjective self assessment of drowsiness can only be obtained from subjects in simulated environments. In real conditions, it is unfeasible to obtain this information without significantly distracting the driver from their primary task. Some researchers have conducted experiments to confirm the validity of simulated driving environments. For example, *Blana et al.* observed that the mean lateral displacement of the vehicle from the center of the roadway, obtained in real and simulated environments is statistically different for speeds higher than 70 km/h[15]. This finding implies that real road drivers feel less safe at higher speeds and, as a result, increase their lateral distance. The drivers in a simulated environment, however, did not appear to perceive this risk. Most experiments using behavioral measures are conducted in a simulated environment and the results indicate that it is a reliable method to detect drowsiness.

However, in real driving conditions, the results might be significantly different because a moving vehicle can present challenges such as variations in lighting, change in background and vibration noise, not to mention the use of sunglasses, caps, etc. *Philip et al.* compared drowsiness in simulated and real conditions and concluded that it can be equally studied in both environments but the reaction time and the sleepiness self-evaluation are more affected in a simulated environment which provides a more monotonous task[16]. *Engstorm et al.* observed that the physiological workload and steering activity was higher in a real environment[17]. This result can be interpreted as an indication of increased effort, which seems reasonable given the higher actual risk in real traffic. Hence, while developing a drowsiness detection system, the simulated environment should be as close to a replica of the real environment as possible.

# Hybrid Measures

Each method used for detecting drowsiness has its own advantages and limitations. Vehicle-based measures are useful in measuring drowsiness when a lack of vigilance affects vehicle control or deviation. However, in some cases, there was no impact on vehicle-based parameters when the driver was drowsy, which makes a vehicle-based drowsiness detection system unreliable. Behavioral measures are an efficient way to detect drowsiness and some real-time products have been developed. However, when evaluating the available real-time detection systems, Lawrence et al. observed that different illumination conditions affect the reliability and accuracy of the measurements. Physiological measures are reliable and accurate because they provide the true internal state of the driver however, their intrusive nature has to be resolved. Among all physiological parameters investigated, ECG can be measured in a less intrusive manner. EEG signals require a number of electrodes to be placed on the scalp and the electrodes used for measuring EoG signals are placed near the eye which can hinder driving. Non-obtrusive physiological sensors to estimate the drowsiness of drivers are expected to become feasible in the near future. The advantages of physiological measures and the increasing availability of non-intrusive measurement equipment make it beneficial to combine physiological signals with behavioral and vehicle-based measures.

A hybrid drowsiness detection system using multiple sensors is far more better.
Few research studies are attempting to detect driver drowsiness by the fusion of different methods. *Cheng et al.* combined behavioral measures and vehicle based measures and concluded that the reliability and accuracy of the hybrid method was significantly higher than those using single sensors[18]. *Guosheng et al.* used a mixture of subjective, behavioral (PERCLOS) and physiological measures (ECG, EEG) to detect drowsiness and found that this combination resulted in a significantly higher success rate than any individual metric[19]. The average square error while removing physiological features were 1.2629, while the average square error for fusion was 0.5269. Although hybrid systems using different sensors have not been tested in a real environment, it would be interesting to investigate the ability to detect drowsiness using a combination of physiological signals with other measurements.

# Overview of Existing Lane Departure Systems

It is not advisable to force a drowsy driver to drive on roads. Consequently, many

| OEM | System | Technology (Video Camera) | Trigger Speed | Driver Alert |
|---|---|---|---|---|
| Lexus | LDW | Mounted behind windscreen monitors vehicle position in relation to lane markings | - | Audio-visual Warning |
| After Market | SafeTRAC | do | - | Visual Lane Position Display |
| Mercedes | SPA | do | 80 km/h (50 mile/h) | Vibrating Drivers' Seat |
| Nissan | LDW | do | 72 km/h (45 mile/h) | Dashboard Display & Audible |
| Audi/VW | Lane Assist | do | 65 km/h (41 mile/h) | Steering Wheel Vibration |
| BMW | LDW | do | 70 km/h (44 mile/h) | Dashboard Display or Steering Wheel Vibration |
| GM | LDW | do | 56km/h (35 mile/h) | Audible & Visual |
| Citroen | LDWS | do | 80 km/h (50 mile/h) | Vibrating Drivers' Seat |
| Volvo | LDW | do | 64 km/h (40 mile/h) | Audible |

Table 4.1 - Exisitng Lane Departure Systems
Source: Lee et. al. (2012), A Smartphone-Based Driver Safety Monitoring System Using Data Fusion

# Overview of Existing Drowsiness Detection Systems

Each method used for detecting drowsiness has its own advantages and limitations.

| System/Sensors/Parameters | Algorithm | Accuracy |
|---|---|---|
| EEG, ECG | Mean power frequency | - |
| Respiration Rate, Heart Rate, Heart Rate Variability | Power Spectrum | - |
| Cameras/Eyelid movement, Gaze movement, head movement and facial expression | Kalman filtering tracking | Yawn–82%<br>PERCLOS–86%<br>AECS–95% |
| IR Camera | Thresholding, Mean | - |
| Camera/Facial features of eyes, mouth and head | Fuzzy reasoning | Only focused on detection rate for facial tracking and face tracking rate |
| EEG | Principal Component Analysis (PCA) | Training - 92.6%<br>Testing - 74.6% |
| ECG, EEG | Dynamic Bayesian network, first-order Hidden Markov Model | Drowsy (best) - 91%<br>Active (best) - 91% |
| Eye movement, driving performance data | Support Vector Machines (SVMs) | Distraction detection (average) - 81.1% |
| Smartphone Display and Front Camera, ECG, PPG | Fuzzy Bayesian network | True Awake - 96%<br>True Drowsy - 97% |

Table 4.2 - Existing Lane Departure Systems

Source: Lee et. al. (2012), A Smartphone-Based Driver Safety Monitoring System Using Data Fusion

# Context of Use for Drivers

### Technical context

In this chapter the equipment, which is required for the drowsiness assistant system (DAS), is defined. It is separated into three subthemes. Basically, it is a car with a high technical standard and it has already several assistant systems, which relieve the driver to steer the vehicle.

### Sensors

For the DAS a sensor which monitors the drowsiness of the driver must be existent. (examples in the basic chapter). Furthermore, driving data like speed, steering ankle, lane position, distance to the car ahead must be collected and analysed by a board-computer.

### Interaction system

The interaction system between driver and vehicle consist of different input and output channels. To interact with the vehicle a voice control system is necessary and a haptic interface. This could be a touchscreen or a Multifunctional button or a combination of these two ways.
For the communication with the driver the vehicle requires optical and acoustic output channels. For the DAS a head-up display is mandatory, to present information and instructions without looking away from the street. Further an ordinary display can be used to interact with the driver. Another possibility would be an interaction in form of voice output comparable to navigation instructions.

### Social Context

The social aspect of the system context considers the drivers interaction with his social environment. In systems context an involvement with other drivers is possible as well as with passengers. However in the presented system in which there is no contact with other humans and hence, the social aspect will not be considered.

Image 4.5 - Major interactive componenets of a Driver Dashboard are Head-up Display (HUD), LED Display/ Touchscreen, Audio System (Microphone with enough noise cancellation power and speaker)
Source: https://acs2.blob.core.windows.net/imgcatalogo/xl/VA_3b663ebfefbd4cf4a187934c93f30bb1.jpg

# Context of Use for Drivers

## Legal Context

The legal boundaries of the concept design of the HCI within the system of object are defined by the European Principle Catalog of HCI, the DIN EN ISO 2575, 3958, 4040, 4513 and 15006-15008 and the code of practice for the design and evaluation of ADAS (Advanced driver assistance system). The compliance with the european principle catalog is not obligatory. It contains the essential security aspects for communication and information system in terms of HCI which are used during the driving. Similar to that but focussing on ADAS the code of practice for the design and evaluation of ADAS is a compromised recommendation for the design of HCI in a vehicle. The DIN EN ISO 2575, 3958, 4040, 4513 and 15006-15008 are according to EU law the european standards for the design of HCI in a vehicle. In the following a brief summary of design rules defined by the previously mentioned legal regulation is presented.
According to the legal boundaries assistance system has to support the driver without distracting him. Furthermore the vehicle has to work even in the case of an unexpected even or an incorrect input. In any situation the driver has to have the control over the assistance system and the driver should be able to stop the system. In the case of an interactive HCI an action request has to help the driver to drive more safely. Therefore the driver has to be able to detect optical information instantly and must not interfere with the driving situation. Also audible signals must not interfere with warn signals and must be controllable by the driver. The feedback system has to be clear. Moreover the drivers should not be pressured to give an input. In the case of security the assistance system must not interfere with high security priority information. Lastly, personal data of the driver has to be secured.
In DIN EN ISO 9241-110 additional requirements for the HCI are described. These includes that the HCI can be used without pre-knowledge and helps the driver to learn how to use the assistance system. Moreover the assistance system should correspond to the general convention and the driver can change its settings to his favour. Additionally the StVO is to mention. It the law regulation on german public roads and streets which is applied on every participant.

# Context of Use for Wizard of Oz (Experimenter)

**Basic Structure of a simulator for experimenter:**
There is basically two parts of the simulator to be simulated -(i) Live driving data from the vehicle itself and (ii) Respective instruction according to driving behaviour. For the simulator(person), it should be easy enough to receive and analise driving data and trigger the instructions to monitor overall simulator smoothly to give the test drivers the actual feeling of driving a car.

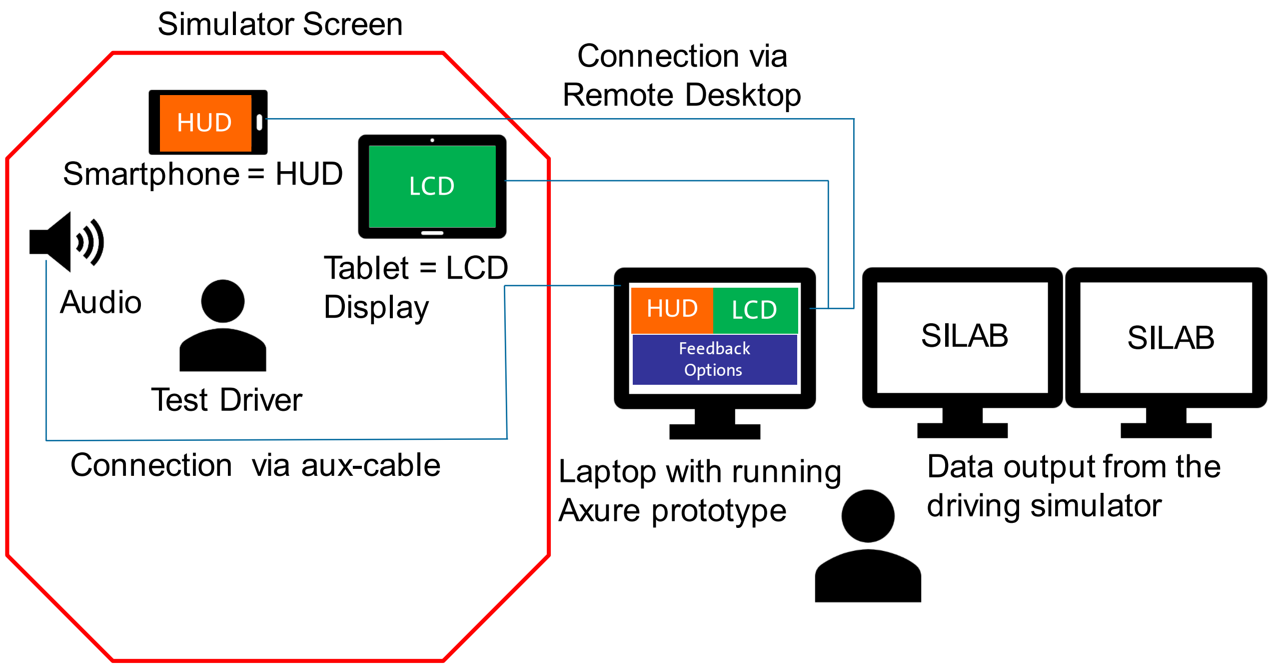



Image 4.7 - Basic structure of the simulator at IAD, TU Darmstadt

Image 4.6 - Experimenter at Driving Simulator of IAD, TU Darmstadt
Source: Clicked by Anirban Maiti (Self)

# User Study

As the implementation scale is huge, it is better to user study with different types of users and focusing by making persona.

From this user study it is found that, **vehicle level non-intrusive drowsiness prevention system**, will work the best at the critical scenarios.

| Type of Vehicles | Class of Vehicles | Owned by | Type of Drivers | Maintenance of Vehicle | Faith Level | Responsibility Level | Probability of Drowsiness | Possible Intervention |
|---|---|---|---|---|---|---|---|---|
| Four Wheeler Vehicles | Private Car | Owner | Owner of the car | Very Good | Very Good | Very Good | Very Less | Driver/Vehicle level |
| | Private Car | Owner | Employed Driver | Very Good | Good | Good | May be | Driver/Vehicle level |
| | Private Car | Owner | Hired Driver | Very Good | Satisfactory | Satisfactory | May be | Vehicle level |
| | Public - Taxi | Owner | Owner of the car | Satisfactory | Bad | Bad | High | Driver/Vehicle level |
| | Public - Taxi | Owner | Hired Driver | Satisfactory | Very Bad | Bad | Very High | Vehicle level |
| | Public - Ola, Uber | Owner | Owner of the car | Good | Good | Good | Less | Driver/Vehicle level |
| | Public - Ola, Uber | Owner | Hired Driver | Good | Satisfactory | Satisfactory | May be | Vehicle level |
| | Public - Rental | Private Organisation | Employed Driver | Good | Good | Good | Less | Driver/Vehicle level |
| | Public - Rental | Owner | Hired Driver | Satisfactory | Satisfactory | Satisfactory | May be | Vehicle level |
| | Public - Rental | Owner | User | Satisfactory | Good | Good | Less | Driver/Vehicle level |
| Bus | Public | Govt.(State TC) | Employed Driver | Bad | Bad | Bad | High | Vehicle level |
| | Public | Private TC | Hired Driver | Satisfactory | Very Bad | Very Bad | Very High | Vehicle level |
| | Private | Private Organisation | Employed Driver | Satisfactory | Very Bad | Very Bad | Very High | Vehicle level |
| Truck | HCV | Private Organisation | Employed Driver | Satisfactory | Very Bad | Very Bad | Very High | Vehicle level |
| | HCV | Govt. Organisation | Employed Driver | Bad | Bad | Bad | High | Vehicle level |
| | MCV/LCV | Owner | Hired Driver | Satisfactory | Bad | Bad | High | Vehicle level |

| | | | | | |
|---|---|---|---|---|---|
| Scale 1 (for first 3 factors) | Very Good | Good | Satisfactory | Bad | Very Bad |
| Scale 2 (for drowsiness) | Very Less | Less | May be | High | Very High |

**Explaination of the parameters**

| Maintenance of Vehicle | Faith Level | Responsibility Level | Probability of Drowsiness |
|---|---|---|---|
| It denotes to the level of maintenance for the respective vehicle by the owner/driver | It denotes to the level of faith on the driver from the perspective of passangers | It denotes to the level of faith on the driver from the perspective of passangers | It denotes to possibility of getting drowsy with respect to other issues |

Table 4.3 - Categories of Different drivers with type of vehicles

# Persona

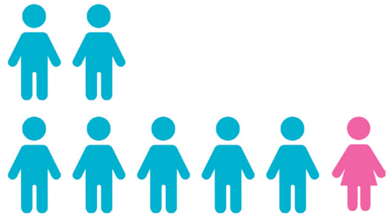
Based on user study it is important to make personas to focus on the specific user group.

## Sample Size

Total nos. of drivers for user study is 8

Germany | 2

India | 6



## Persona I

**Type of people**
Lower Class
Lower Middle Class

**Sex** Male - Unmarried
**Age** 25yrs.
**Nos. of Family Members**
3-4 people
**Educational Qualification**
Able to read and write English but not speaking
**Occupation**
Hired or Employed driver
**Sector** Public 4wheelers on Rental basis
**Family Income per month**
Rs.10000 - Rs.15000

**Mobile User** | Yes **Smartphone User** | Yes **Internet User** | Yes
**Familiarity with Electronic Gadgets** | Yes
**Familiarity with Drowsiness Prevention System** | No

**Touch points**

It should help in safe driving | It should not put too much cognitive load on the driver | It should not distract driver from driving | Some Fun is good | Gamified driving experience is accepted

## Persona II

**Type of people**
Lower Class

**Sex** Male - Married
Age 35yrs.
**Nos. of Family Members**
3-5 people
**Educational Qualification**
Able to read English but not able to writing and speaking
**Occupation**
Hired or Employed Driver of Bus/Truck
**Family Income per month**
Around Rs. 10000 + facilities

**Mobile User** | Yes **Smartphone User** | Yes **Internet User** | Yes
**Familiarity with Electronic Gadgets** | No
**Familiarity with Smart User Interface** | Yes

**Touch points**

Driving Assistance is more preferred | It should not put too much cognitive load on the driver | It should not distract driver from driving | No fun is required with serious issues (music is accepted)

# Interview with the drivers

Overall, there were mixed perceptions regarding the use of game elements for an drowsiness prevention system. However, some people had positive perceptions towards gamified elements. Specifically, a number of participants suggested that the system could be engaging and decrease the negative effects of driving monotony. It was argued that young drivers in particular may benefit from the increased engagement with the driving task associated with a gamified system who are also more prone to drowsiness.

More specifically, many suggested that their preference would instead be for a system that provided informative and personalized feedback regarding their safe driving behavior, and in particular feedback designed to help them improve their driving.

Some of the driver feedbacks are given below for further reference:
1. “I disagree with the game concept of it, it almost takes it away from safety and driving and makes it not as serious”
2. “I don’t think I’d use the game features. I’d be interested in it helping me drive safer and be more aware”
3. “I think it’s going to be fun, because sometimes a driver is going to get bored so if you have something fun, it makes your time pass smoothly”
4. “It would be good to have something a little bit fun in the car so for them [younger drivers] the game might be good for making it, sort of a little bit fun and engaging”
5. “I think being able to turn that off would be good because I think personally I might be interested in the game aspect for like a week or something and then I’ll probably get over it and just want the information.”
6. “I think it might improve my driving for a while but then, if I can’t reach any other like challenges or achievements in the game, if it was a game, then I might just like forget it and go back to my old driving.”
7. “I think for me, the problem will be the consistency of usage. How long are you going to use it for? There’s always this period when people start using and then they are like super excited and after a point where they like, “oh, it’s too much of a hassle”

## Users' Feedback received

Major characteristics of the new Drowsiness Prevention System which must be followed are given below:
(i) No disturbance is accepted at the time of driving
(ii) There should not be any obstruction(blind spot) in viewing line & angle
(iii) It should accommodate maximum percentile of driver from different socio-economic background
(iv) Safe driving assistance is more preferred rather than gamified experience
(v) Gamified Driving Experience is accepted only by young drivers who are also prone to drowsiness
(vi) Alarm of increasing intensity is the basic solution. After that vehicle control should be interrupted.

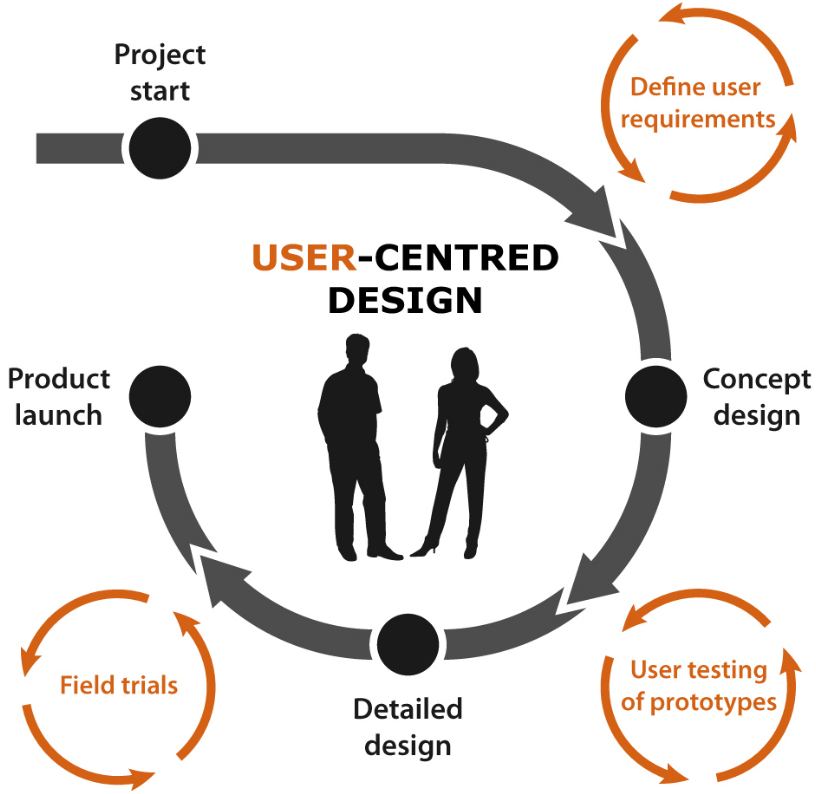



Image 4.8 - Principle of User Centred Design
Source: http://www.designtos.com/postpic/2013/03/user-centered-design-process_334771.jpg

## Human centered Design

It is the basic concept of any design process. New designed object should be based on identified problem or issues with respect to cultural aspects and economic constraints.

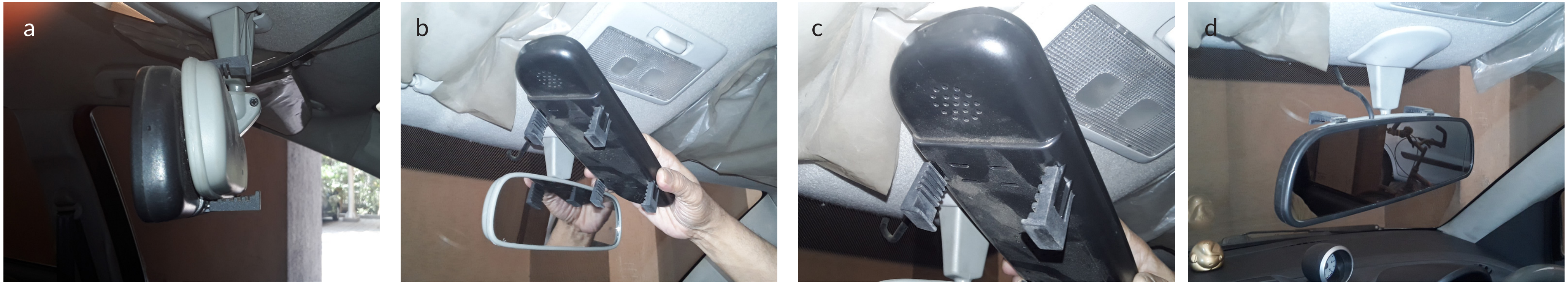
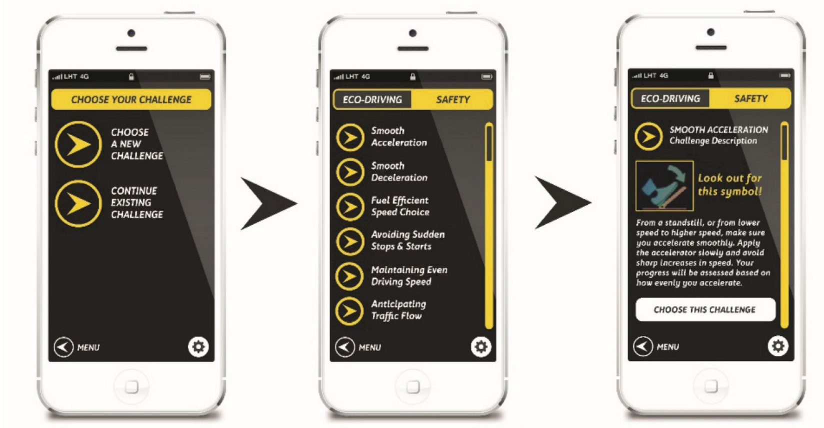



Image 4.9(a-d) - Existing Mirror mounting products of car
Source: Clicked by Anirban Maiti (Self)

# Existing Games & Products with respect to Drivers' Drowsiness

There are few existing driving games which are in use. Some of them are - Driving Miss Daisy, Creative Miles etc. Mainly these are driving activity related and based on reward points to motivate drivers.

Few few physical products are available in the market for drowsiness prevention and driver state monitoring. Most of them are based on behavioural measurements. So according to ongoing research it is better to develope a product of hybrid sytem to keep the driver awake.

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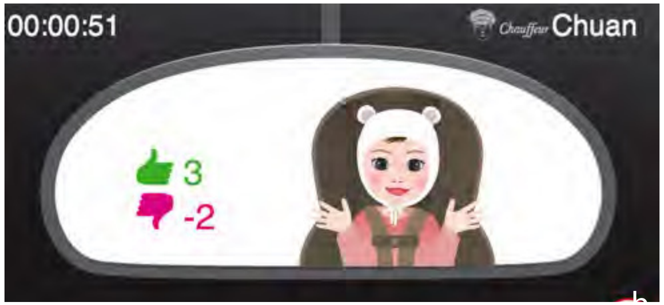



Image 4.10(a-b) - Existing Driving Games

Source: Vaezipour et. al. (2016) Design of a Gamified Interface to Improve Fuel Efficiency and Safe Driving



Image 4.11 - Reference for Wearable Driving Accessories

Image 4.12 - Existing products for Drowsiness Prevention System

# 05

## Scope of Work

Image Source - http://ossekeag.ca/well-rested-drowsy-drivingz

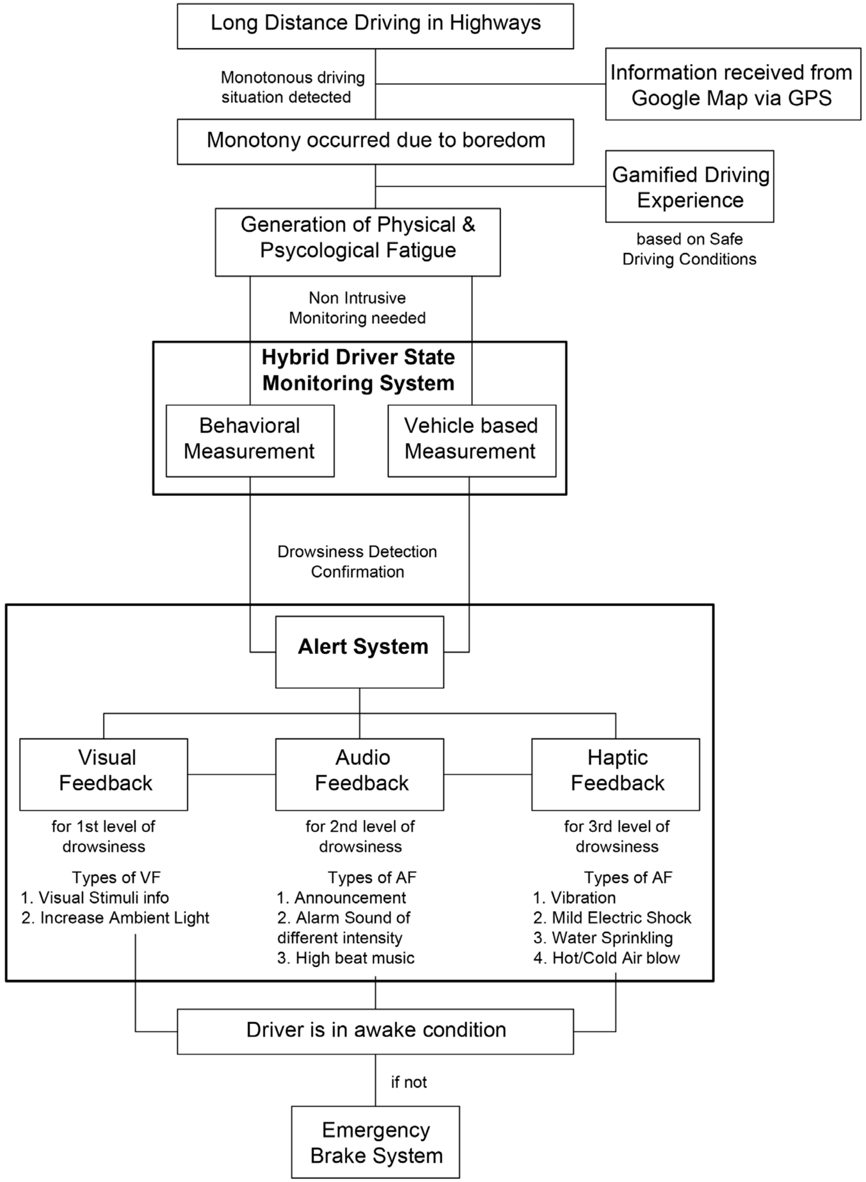



Image 5.1 - The overall system flowchart for driving and areas to focus

# Scope of Work

Keeping drowsiness as a major factor, the focus will be designing a Driving System considering different factors based on case study from both functional and cultural point of views and also available technologies.

Drivers Safety
Alertness Level
Sensor system
Activation Strategies
Drivers behaviour
Physiological Effects
Emergency Brake System
Legal aspects of implementation

Keeping drowsiness as a major factor, the focus will be designing a Driving System considering different factors based on case study from both functional and cultural point of views and also available technologies.

It is found that young drivers are more prone to drowsiness and prefer gamified driving experience more than old and mature drivers.

Major issues found to be taken care at the time of driving are:
(i) Safe Driving - to cover safety factors and develop driving skills
(ii) Avoid generating Fatigue - both physical and psychological
(iii) Overall experience design
(iv) Driver profiling
(v) Restrict misuse of Car and change bad behaviours

# Scope of Work

Keeping drowsiness as a major factor, the focus will be designing a Driving System considering different factors based on case study from both functional and cultural point of views and also available technologies.

Drivers Safety
Alertness Level
Sensor system
Activation Strategies
Drivers behaviour
Physiological Effects
Emergency Brake System
Legal aspects of implementation

It is found that young drivers are more prone to drowsiness and prefer gamified driving experience more than old and mature drivers.

Major issues found to be taken care at the time of driving are:
(i) Safe Driving – safety factors and to develop driving skills
(ii) Avoid monotony and fatigue (including drowsiness) – both physical and psychological

(iii) Fuel efficiency Eco-driving
(iv) Enriching overall experience
(v) Restrict misuse of the car and different driving system
(vi) Monitoring driving behavior and drivers' profiling

There can be three types of intervention:
(i) Driver level intervention
(ii) Vehicle level intervention
(iii) System level intervention

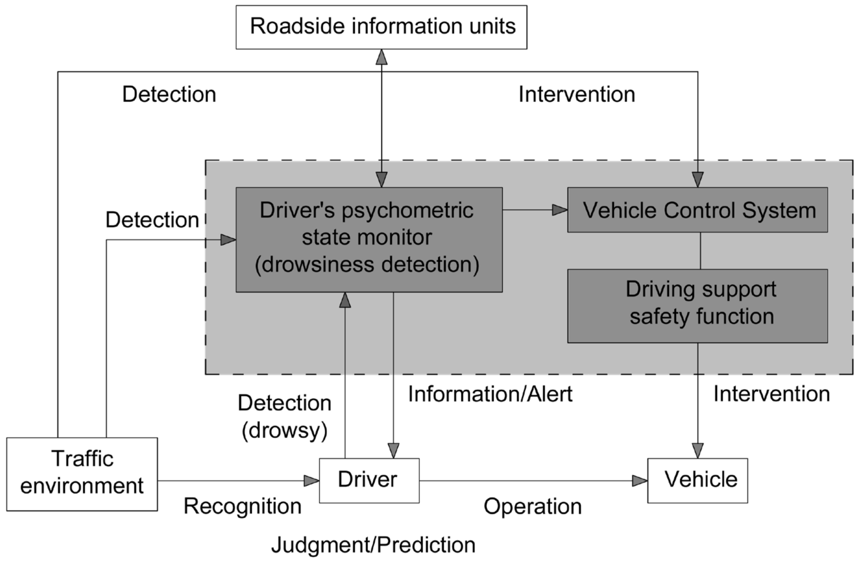



Image 5.2 - The overall system flowchart for driving and areas to focus

# SWOT Analysis

For the feasibility of the project SWOT Analysis will help to figure out the probability of success.

**Strength**
(i) There is a huge potential to save thousands of drivers' life who risk their life everyday for economic and occupational hazards
(ii) There not so much usable product in the global market which fits in driving scenario from the point of ergonomics and usability function
(iii) There are lots of research is going on but unfortunately no Indian product is existing in the market

**Weakness**
(i) Indian drivers are very reluctant to use automated system and gamified driving experience as this is very new to them. Even it is very hard for low educated drivers. So it is very hard to design and convince them for using it.

**Opportunities**
(i) There can be different level of solution to serve different group of users - different categories of drivers

**Threats**
(i) It must be a integrated system, so that any driver can't skip this system; otherwise respective vehicle will not start. But for this reason, few drivers might not install this system in the vehicle. So there is need of mandatory rules to implement in the large scale, otherwise it is very hard to implement.

# 06

## Design Brief

Image Source - http://ossekeag.ca/well-rested-drowsy-driving/

# Design Brief

Design a Drowsiness Prevention System which will take care of Safety at the time of long driving focusing Drowsiness which is apparently not a deliberate reason for accidents but possible to avoid.

Focused group of users are Employed/Hired Drivers in Public vehicles – rented cars, bus and truck in long driving scenario. (Though for limited scope of work only private four wheeler vehicle scenario is taken care of).

And also it should go with Indian context and should cater maximum drivers to have mass implementation and secure maximum drivers.

**Core benefits to the users**
(i) It will keep driver safe enough at the time driving.
(ii) It will counter the scenario when the driver will go in the state of drowsiness.

**User and User Experience related issues**
(i) It should give a good driving experience at the monotonous situation and keep the driver safe at the time of long driving especially at the night.

**Ergonomics related issues**
(i) There should be no ergonomic problem which may disturb at the time of driving or deteriorate driving experience.

**Manufacturing related issues**
(i) The built form must be very well enough to be durable and long lasting.

**Integration related issues**
(i) It can be well integrated to the vehicle system to give less cognitive load to the respective driver.

# 07

# Probable Deliverables

Image Source - http://ossekeag.ca/well-rested-drowsy-driving/

# List of possible product outcome

There can be family of products which will monitor physiological and behavioral activity of the driver at the time of driving  and also will keep him/her away from driving monotony.

Based on monitoring sensors final products can be Next Generation Steering Wheel, Seat Belt, Driver Seat and also Wearables which will take care the overall driving comfortability and safety issues or maybe the Driving Simulator for the wizard itself for testing driving scenarios in laboratories.

Some product which is independent of car will have a greater impact in Indian context as most of the people are not using modern cars.

# Preliminary Concepts for Driving Games

According to research, we found that young drivers are more prone to get drowsy easily. But this group of drivers are good at challenging something and driving and acing games and get motivated with respective reward points.
From this point of view and concept of virtual co-driver, some conceptual games are developed to counter this drowsiness related scenarios.

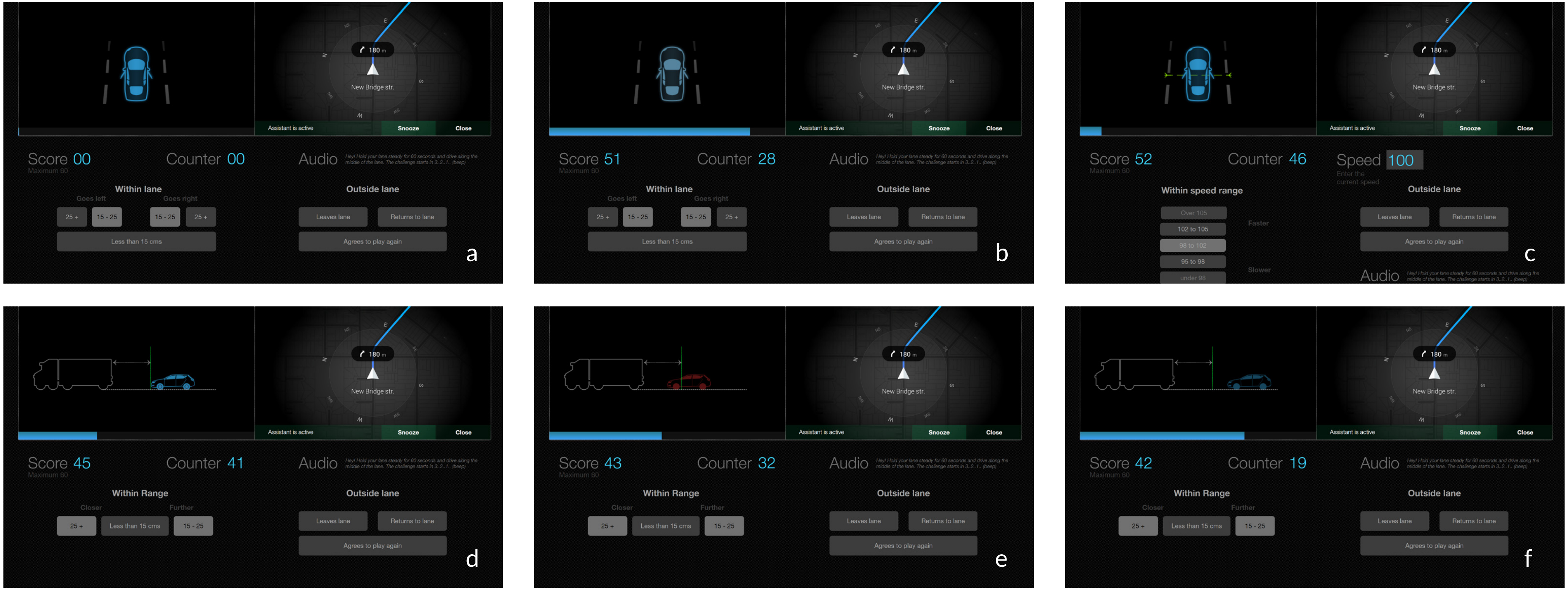



Image 7.1 (a-f) - Few screen shots from the developed Game to keep driver awake at drowsy scenarios

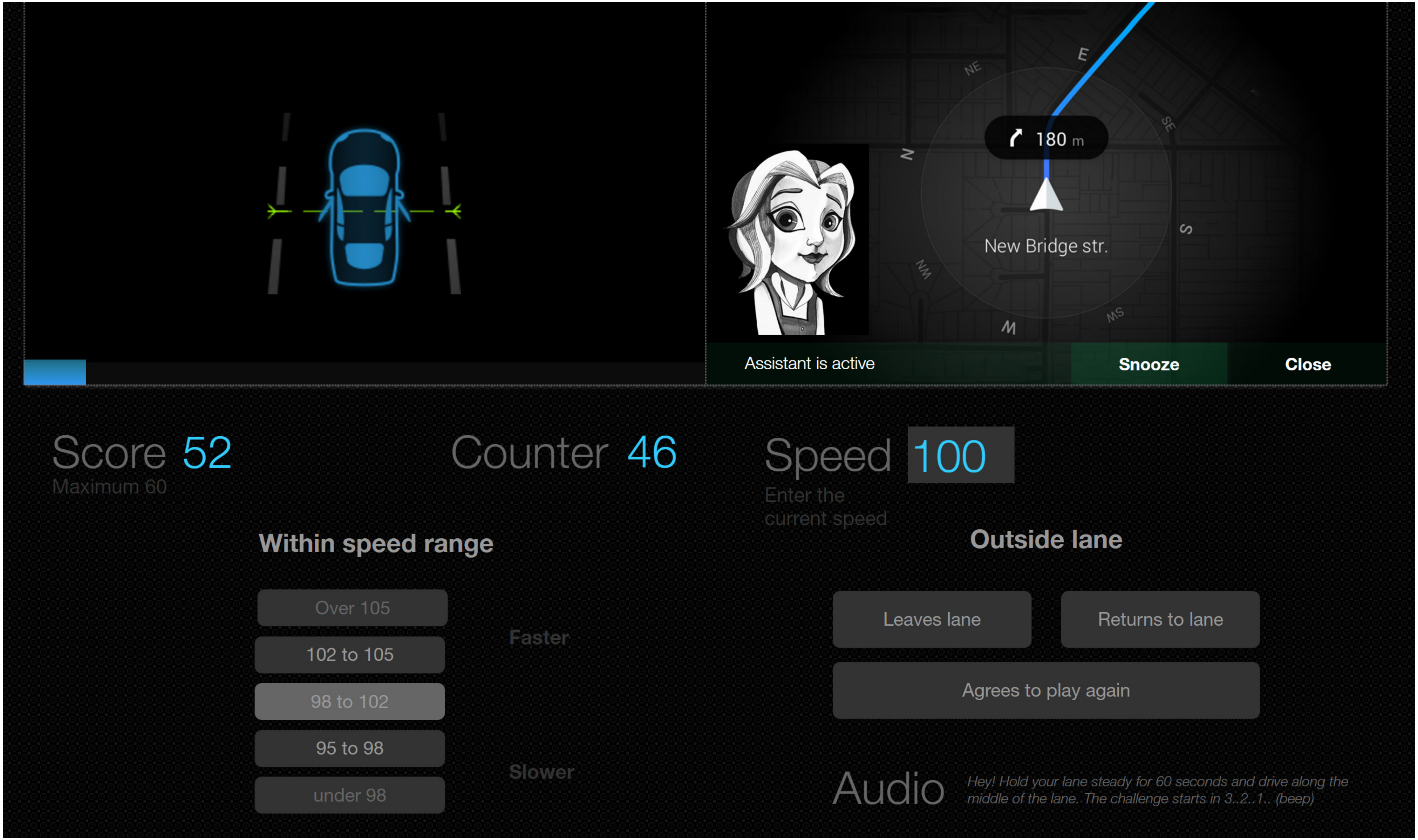



Image 7.2 - Introduction of an animated character to enrich the Gamified Driving Experience

# Preliminary Ideations for relevant Physical Product

Based on Gamified Driving Experience there is a need of physical product which will be synced with live driving data, human biological data and will give feedback through Drowsiness Prevention alert system.

**Ideation 1**
This ideation is influenced from spectacles and google glass but there are few more facilities which is necessary to monitor driver state at the time of driving long journey.
Pros:
(i) A projection device will be placed at the spectacle frame between two eyes to project visual information on the wind shield
(ii) vibration feedback can be provided through the temple of the spectacles

Cons:
(i) There is no audio feedback

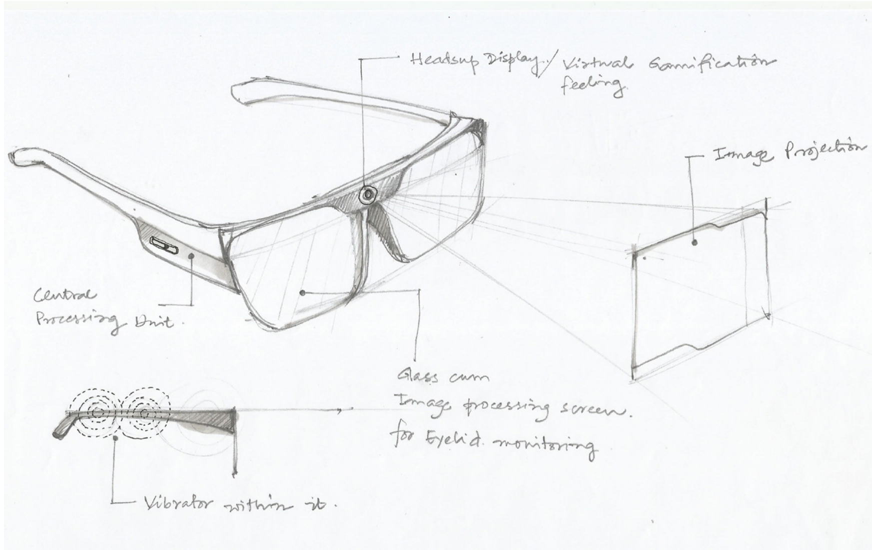



Image 7.3 - Ideation 1

**Ideation 2**
This idea is influence by the position of different points needed for EEG for a human. All the respective points can be joined and create a structure for a design of a head gear for the driver. Headphone and a vibrator band will be inbuilt to give respective feedback to the driver.

Pros:
(i) Good looking shaped head gear
(ii) Having all types of feedback system - audio, visual and haptic

Cons:
(i) It will reduce comfortability of a driver and cant be wore over spectacles.

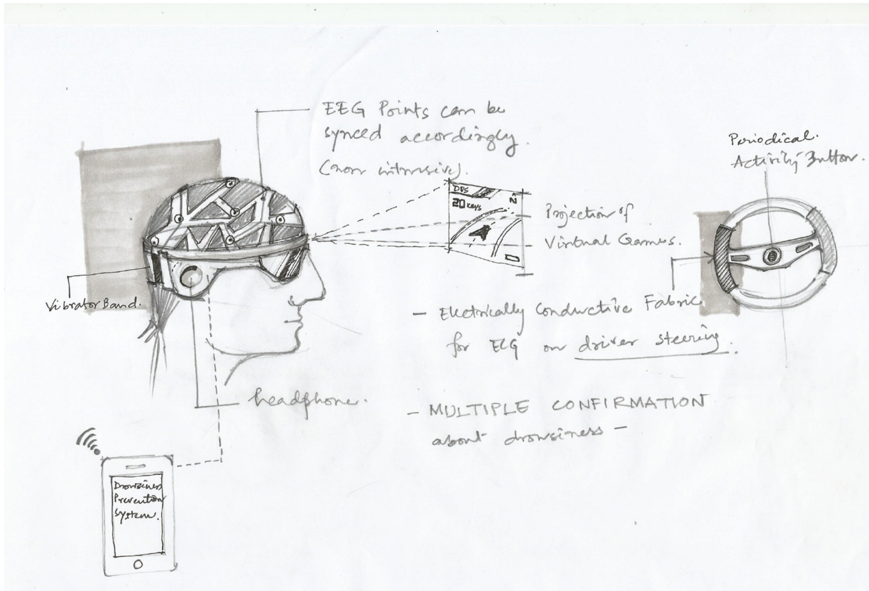



Image 7.4 - Ideation 2

# Preliminary Ideations for relevant Physical Product

Based on Gamified Driving Experience there is a need of physical product which will be synced with live driving data, human biological data and will give feedback through Drowsiness Prevention alert system.

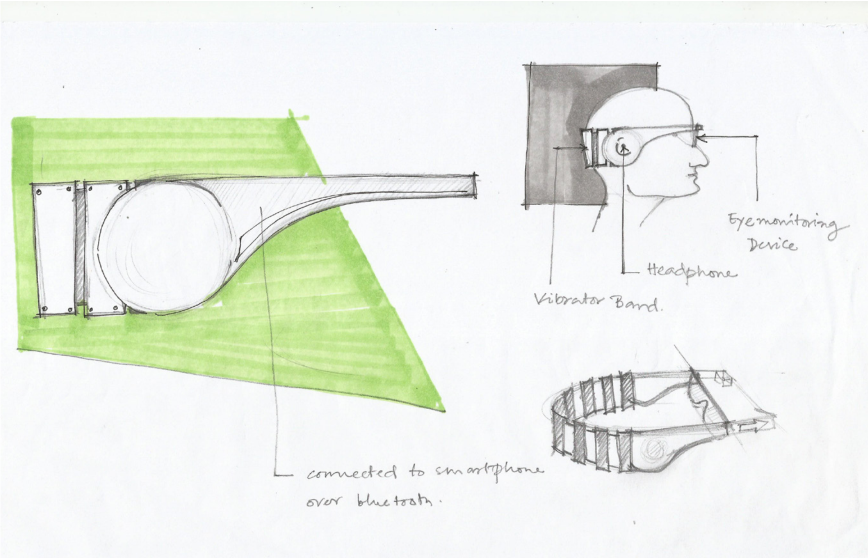



Image 7.5 - Ideation 3

**Ideation 3**

Modification of Ideation 2, much more minimal, gives less cognitive load.

Pros:

(i) Good looking shaped head gear

(ii) Having all types of feedback system - audio, visual and haptic

(iii) Glasses can be customizable according to different driver

Cons:

(i) (i) It will reduce comfortability of a driver.

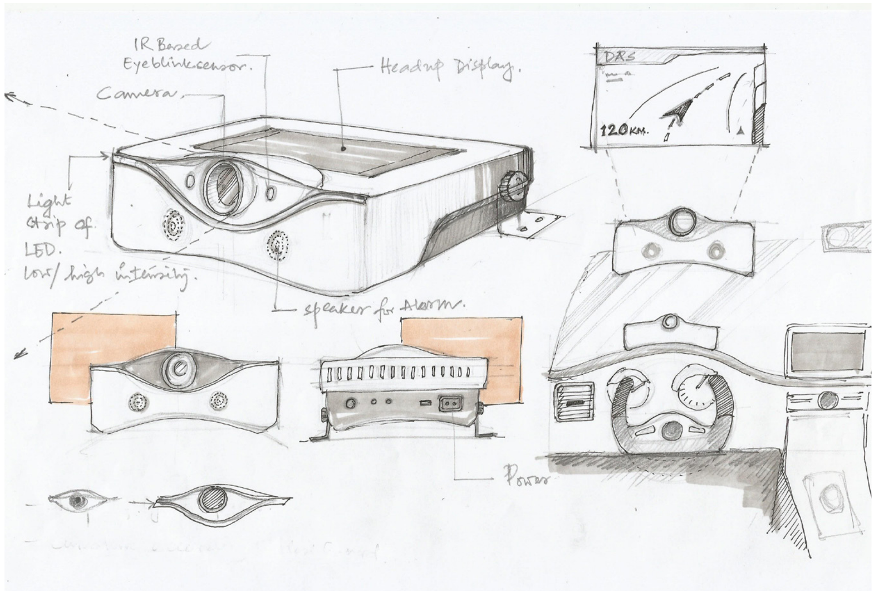



Image 7.6 - Ideation 4

**Ideation 4**

It is a totally different approach, an independent device to monitor driver state very non-intrusively which can be positioned on the dashboard with respect to human ergonomics.

Pros:

(i) Non-intrusive

(ii) Can be implemented to any vehicle

Cons:

(i) It might create blind spot on the viewing line of the driver.

# Evaluation of the ideations

Based on user feedback the concepts are evaluated with respect to several parameters and shown in table given below.

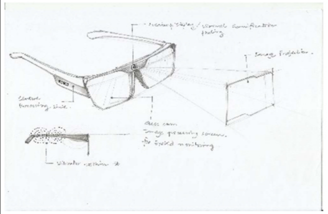
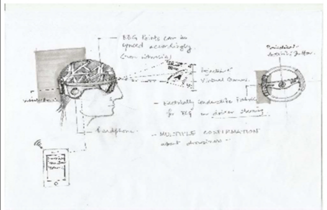
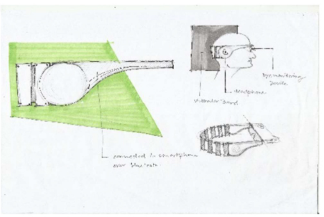
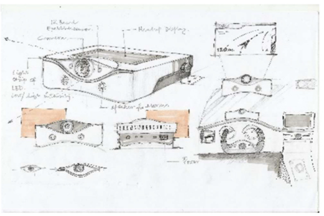
| Ideation Evaluation based on User Feedback | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ideations | Monitoring methods | Works at night | Type of Feedback | | | Provision of Adjustment | Usability Issues | Design Form | Type of ownership |
| | | | Audio | Visual | Haptic | | | | |
|  | only eyelid movement monitoring by IR sensors | Yes | No | Yes, by Augmented Reality | Yes, vibration at the both side of the head by temple of the spectacles | No | People with spectacles can't use this | Not so appealing | Must be owned by the driver |
|  | only eyelid movement monitoring by IR sensors, also non-intrusive EEG by the head structure but very difficult to implement in the actual driving condition | Yes | Yes, by the integrated headphone | Yes, by Augmented Reality | Yes, vibration at the back portion of the head by a vibrator band | Not that much | People with spectacles can't use this | Appealing but will reduce driver comfortability | Must be owned by the driver |
|  | only eyelid movement monitoring by IR sensors, easy to implement in the actual driving condition | Yes | Yes, by the integrated headphone | Yes, by Augmented Reality | Yes, vibration at the back portion of the head by a vibrator band | Yes | People with spectacles can't use this | Function and form and both are appealing | Must be owned by the driver |
|  | Full face monitoring by Image Processing by IR Camera with night mode | Yes | Yes, by the inbuilt speaker | Yes, HUD projection | Yes | Not required but positioning of the device will matter | it might create blind spot on the viewing line of the driver | Not a big issue, if is not visible | Must be owned by the driver |

Table 7.1 - Evaluation of Ideations

# Different ways to keep the driver awake

**Visual Stimuli**
- new information within eye range and viewing angle
- increase ambient lighting aroung driver

**Auditory Stimuli**
- Music with high beats
- disturbing sounds
- beeping sound
- audible information
- alert alam
- conversation with passenger/co-driver

**Haptic Feedback**
- Vibration at head, hand
- Jerking in Seat, Steering
- Low voltage shock
- Hot/Cold Air to face & Water Sprinkling
- Change in ambient tempefrature
- Physical actuvity (periodical/regualar)

# Activity Analysis

(i) Check fuel
(ii) Seat position adjustment
(iii) Seating height adjustment
(iv) Check visibility of car front edge
(v) Adjust side view mirror
(vi) Adjust rear view mirror
(vii) Wear seat belt
(viii) Start the vehicle
(ix) Check surrounding
(x) Start the journey

# Vehicle level intervention

System Level intervention for monitoring Drowsiness:

**Entry Level System**
1. IR based Eye blink Detector
2. Alarm Sound with increasing intensity

**Mid Level System**
1. Camera with night vision mode for Face Detection
    - Eye lid monitoring
    - Mouth monitoring
    - Head nod monitoring by nose movement
2. Alarm Sound with increasing intensity
3. Increasing Ambient Light
4. Steering Wheel Movement (SWM) monitoring

**High Level System**
1. Camera with night vision mode for Face Detection
    - Eye lid monitoring
    - Mouth monitoring
    - Head nod monitoring by nose movement
2. Alarm Sound with increasing intensity
3. Increasing Ambient Light
4. Steering Wheel Movement (SWM) monitoring
5. Integrated Heads-up Display (HUD)
6. Electricity carrying Fibre
7. Vibrator (in different location)

# Final System Level Concept


Image 7.7 - Graphical representation of the Drowsiness Prevention System with tentative positioning in the car

After extensive User Study it is found that for Indian context the best option for preventing drowsiness is to develop a vehicle level system which will give minimum cognitive load to the driver but will give him/her a safe driving experience.

Ideally for monitoring driver state and preventing from drowsiness these are the parts of system which are necessary to install within the car in respective location or we can use some of the available elements within the car itself to reduce cost.

1. IR Camera with night vision mode on the rear view mirror, as all the drivers always adjust that before driving and it also get proper alignment with the drivers' face.
2. Alarm Sound with increasing intensity (we can use vehicle audio system itself)
3. Increasing Ambient Light
4. Steering Wheel Movement (SWM) monitoring sensor
5. An Activity Button at the centre of the steering wheel
6. Integrated Heads-up Display (HUD)/ Projection with the camera
7. Electricity carrying Fiber to wrap the steering wheel
8. Vibrator (in different location - behind the steering wheel and below the seat)
9. A Control Unit
10. Emergency Alert Screen (existing one can be used)

It can be further clubbed up into three enclosures.
**(i) Driver State Monitoring Device**
**(ii) Feedback System - in the Steering Wheel Cover or Seat**
**(iii) Connection unit between these two part with the Steering Wheel Monitor (SWM) Sensor**

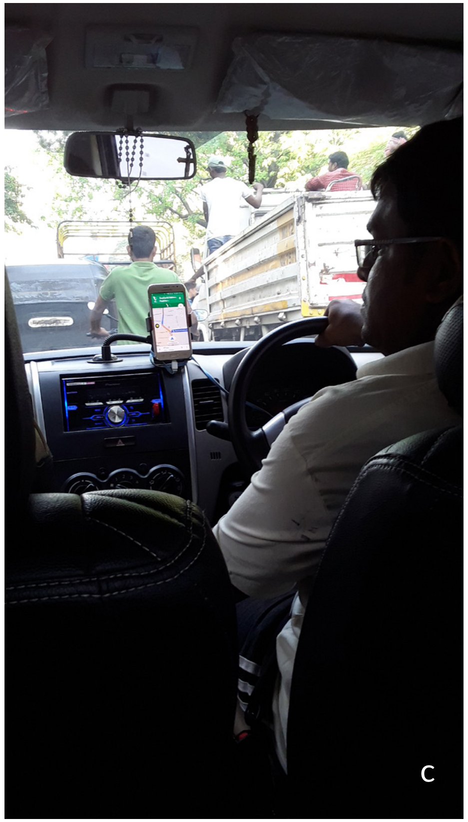
# Concepts for Driver State monitoring

According to User Study in Indian context, it is found that most of the driver is very reluctant to use modern drowsiness system which put cognitive load on the drivers. So it is preferred to design intuitive system which will monitor drivers with minimum direct interactive inputs. It should act like a virtual co-driver which will interact with the driver very smoothly.

From the above noted point of view, user study and different vehicle study, some of the inferences are found given below:

**Hardware needed for Monitoring Device**
(i) IR Camera module with night mode (for signal in)
(ii) Image processing system (in a form of electronic chip)
(iii) Signal out for haptic, visual and auditory feedback
(iv) Microphone for voice recognition
(v) Speaker for Alarm Tone
(vi) Cooling Fan
(vii) Digital clock as a feature (it will also show that the system is on, as it will be a mandatory system and will turn on automatically when the vehicle engine will start. There will be no manual button for switch on the system, otherwise few driver might skip this system)
(viii) Small projector which will project visual information on the windshield like Heads-up Display (for gamified driving experience for young drivers). It will be available only in a special version of the product.


Image 7.8 (a-c) - Different driving style and average covering area of steering wheel




# Concepts for Driver State monitoring

**Placement of Monitoring Device**

As the scope of work was limited to the domain of 4wheeler cars, all the concepts is generated based on that. But as the solution provided is a system level, it is easy to implement in other types of vehicle based on their interior layout.

According to user study and driving context it is found that Centre Rear View Mirror is the best option to focus for Driver State Monitoring which is majorly based on Face Detection System by IR Camera Module with night vision mode. As every driver reset the angle of the centre rear view mirror before starting the vehicle it every time aligns with the face of the driver and by that procedure it is more safe and reliable position to put the Driver State Monitoring Device there.

Majorly, the driver state monitoring device will be installed/**mounted over the centre rear view mirror in the cars**, whether it will be **installed on centre pillar or A pillar in the context of buses or trucks as a separate unit**.

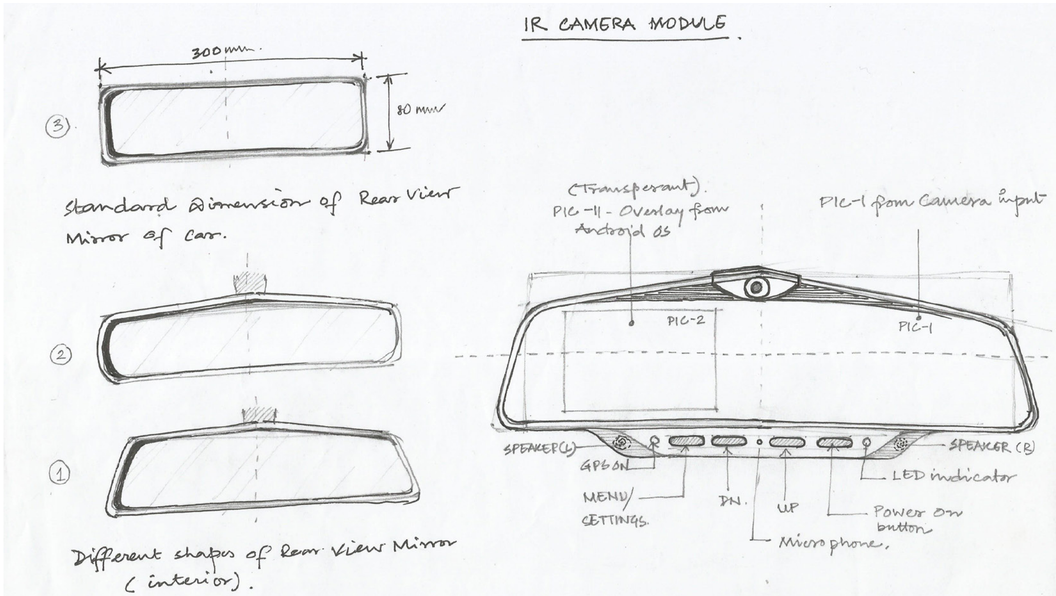



Image 28 - General Study of Car Mirrors

# Concepts for Driver State monitoring

**Concept - I**
This is a total concept of new centre rear view mirror which will replace the existing mirror.

It is based on twisting feature, which might accommodate more driver ergonomically. There will the whole image processing unit behind the mirror, which includes IR Camera, Microphone, Speaker and a Control Panel. In the twisted part of mirror there can be some display system which will use PIP(Picture in picture) Technology.

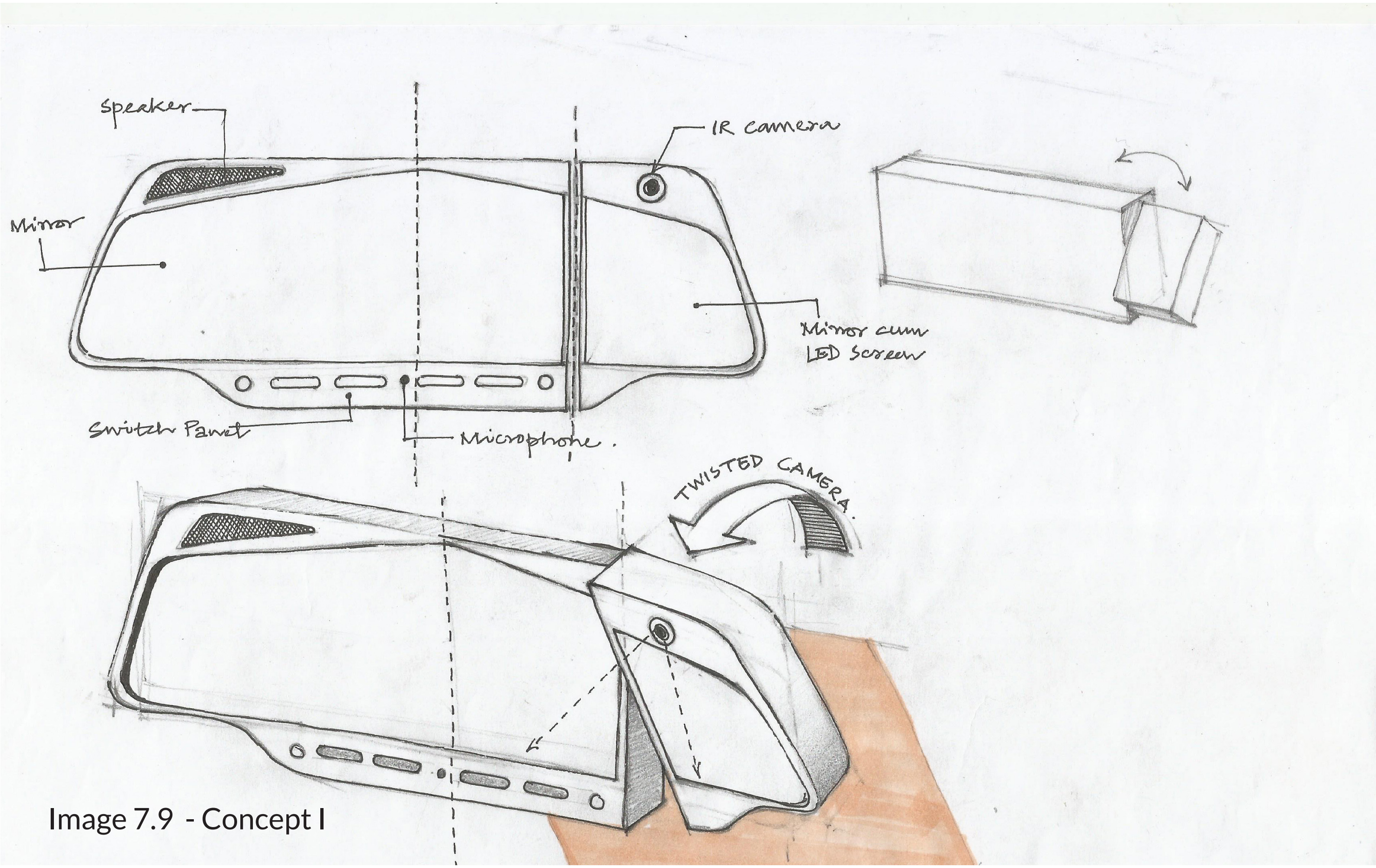



Image 7.9 - Concept I

# Concepts for Driver State monitoring

**Concept - II**

This concept is about using the existing mirror but to use that Driver State Monitoring device as an add-on attachment which will be mounted over the existing centre rear view mirror.

As there is always a part for the fixing that mirror with the car, there can be two part of this device which will be attached through a snap on hinge and then mounted over the mirror and fixed with good looking rubber band which will not restrict the visibility.

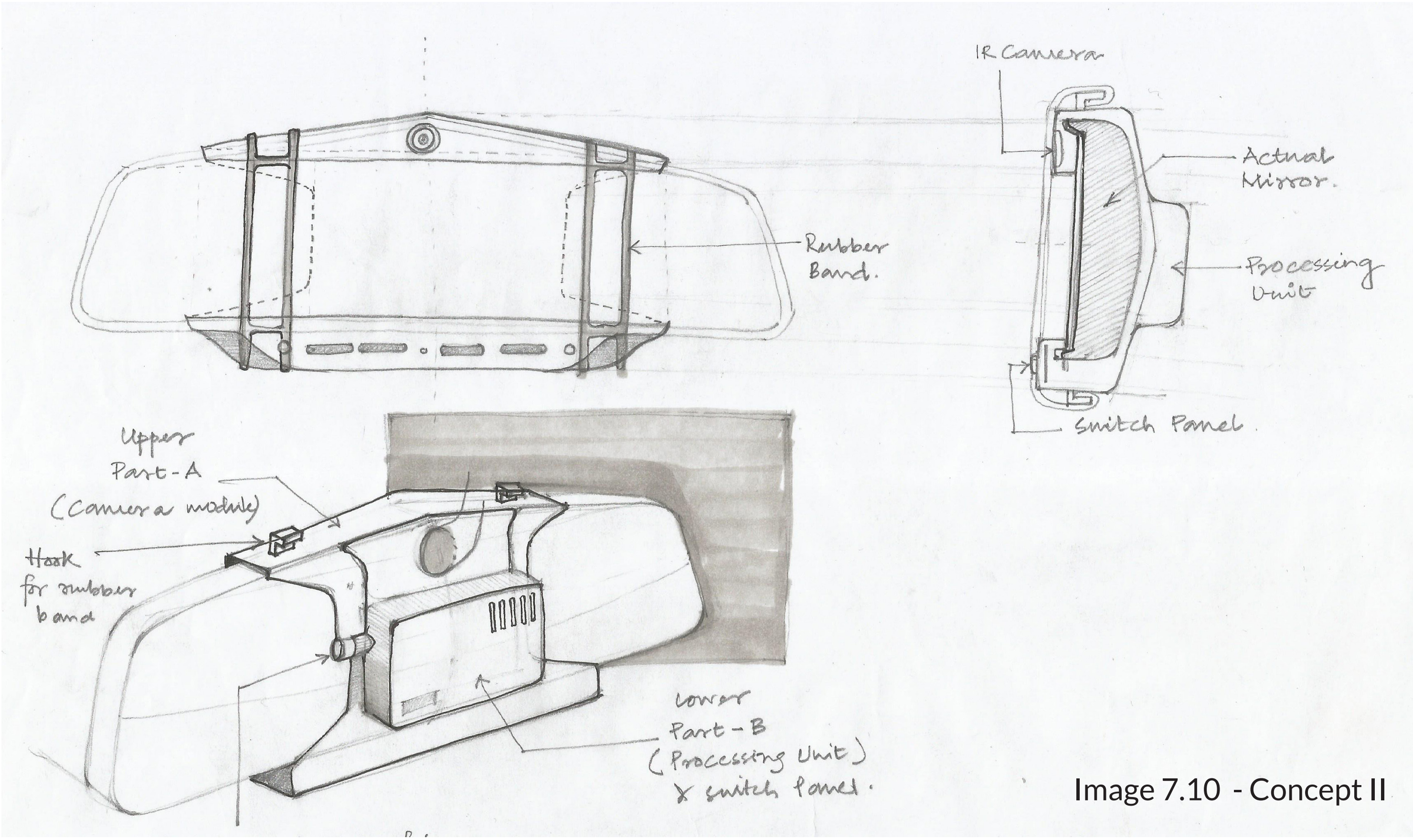



Image 7.10 - Concept II

# Concepts for Driver State monitoring

**Concept - III**
It is an advanced special version of the concept - II product.
It can be also a new mirror or the mounting accessories.
Other than concept II, it will include a Projector, which will project visual informations on the windshield, preferred by young drivers who love gamified driving experience. Here camera module and speaker module is designed for Indian context(left hand traffic), which can be reversed for foreign countries(right hand traffic).

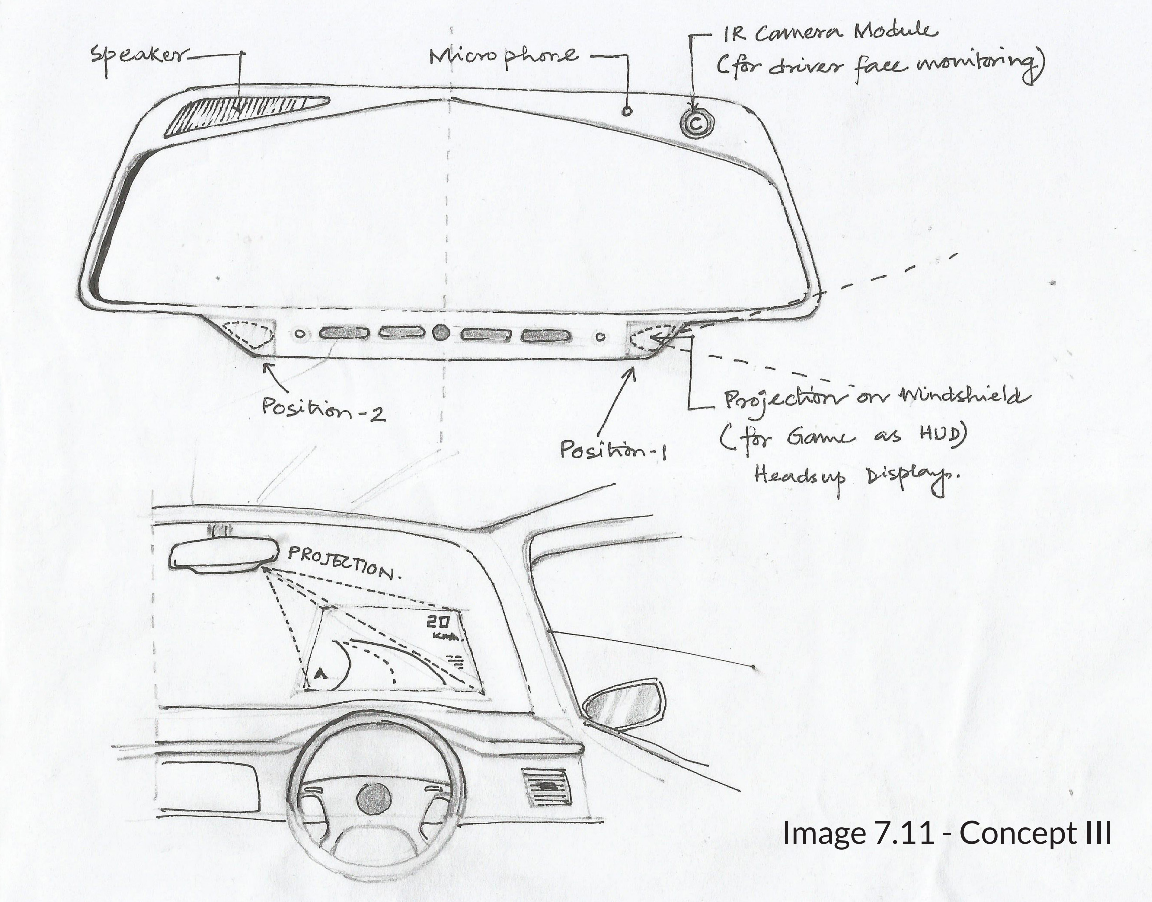



Image 7.11 - Concept III

# Concepts for Feedback System to keep driver awake

According to User Study and interviews with different drivers, few ways are found to keep driver awake are given below:
(i) Haptic feed back - vibration at steering wheel and seat
(ii) Audio Feedback - alarm sound with high intersity
(iii) Visual feedback - enlightening surrounding ambience
Feedbacks are listed above with respect to preference according to degree of disturbation/distraction at the of driving in the highway specially at the time of driving.

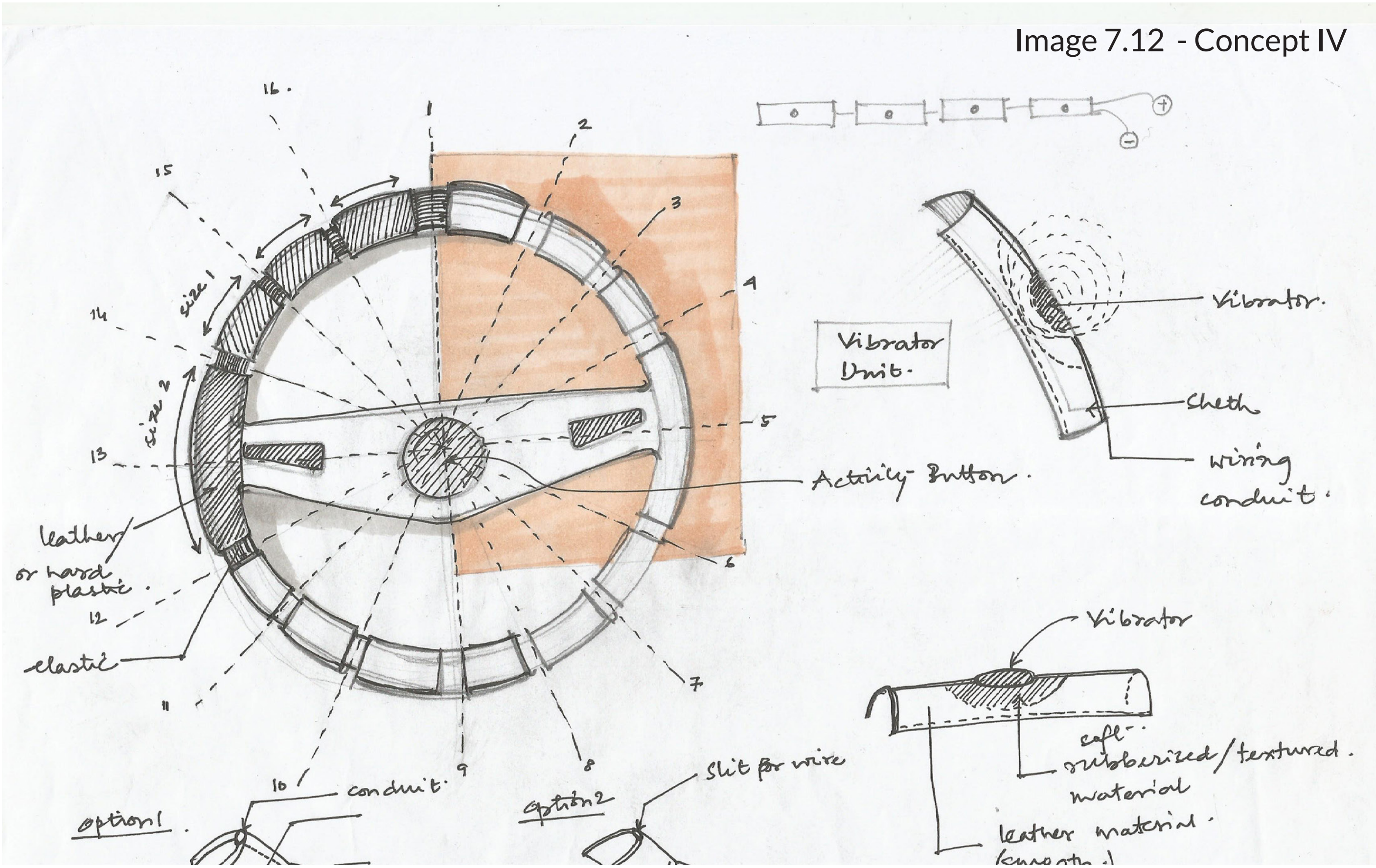


Image 7.12 - Concept IV

# Concepts for Feedback System to keep driver awake

Here is the different iteration of the concept of steering wheel with haptic and visual feedback facilities.

At the time of sketching cover for steering wheel with the activity button, it is the found that there is a huge range of steering wheel is available in the market. So, it is better to go for only steering wheel cover and the **existing horn button can be used as the activity button.**

Image 7.13 - Concept IV

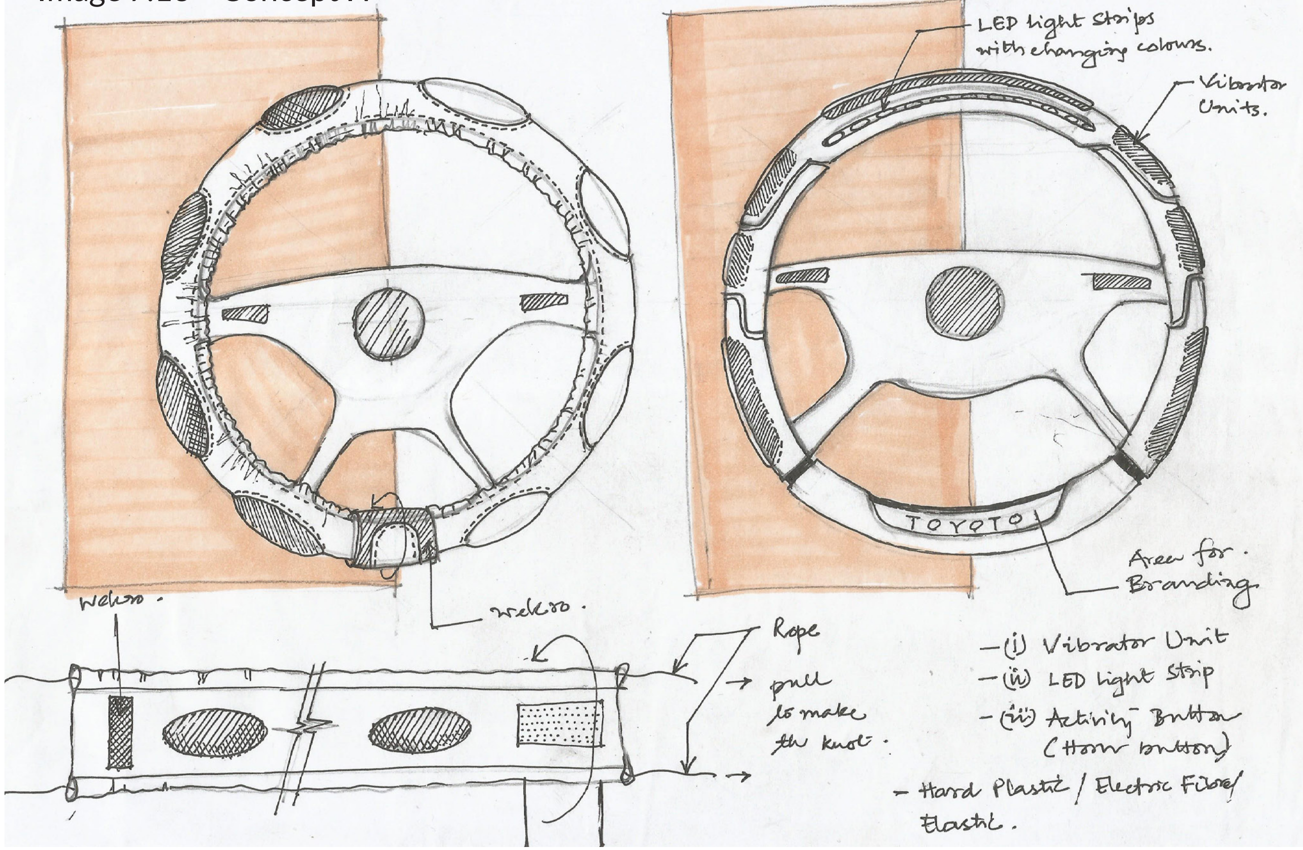



Image 7.14 - Different types of existing steering wheels

# Concepts for Feedback System to keep driver awake

In these iterations, some smooth contours came up to give drive better experience and materials will PU Leather, which is widely in use in the current available products.
There can be two layer of PU Leather stitched according to design of putting vibrator units and conduits. Contours created by the vibrator units will help in griping also. Otherwise one layer of PU Leather and the other layer can be some rubberised material.

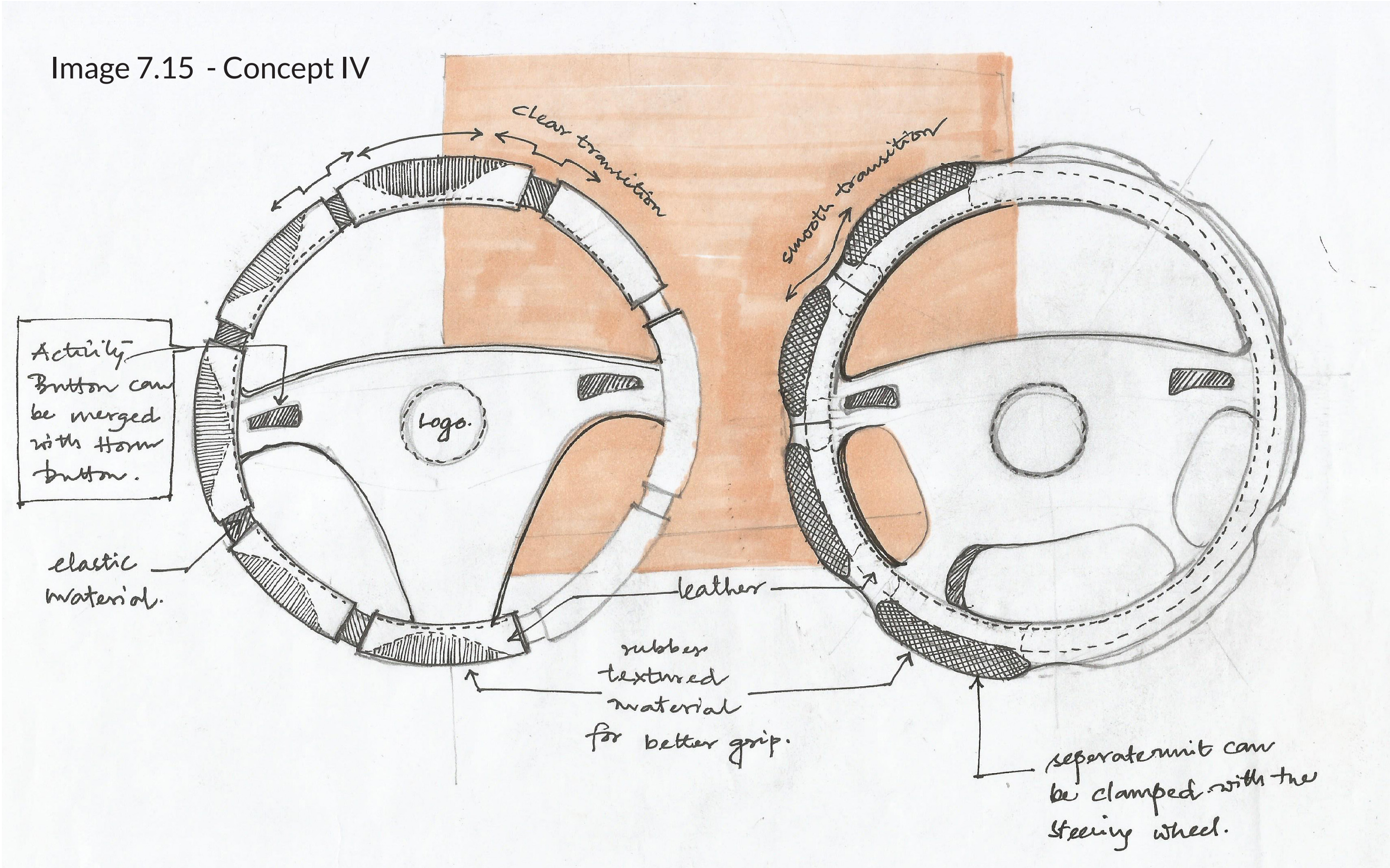



Image 7.15 - Concept IV

# Adaptation to different driving context

Basic concept is generated on the car scenario, whether the other focused group is bus and truck drivers who drive on the highway for a long time at the night time.

Different types of vehicle has different types of dashboard and driving ambience. As the problem is very similar and the design solution is very generic to implement in any driving condition, it is very important to find out proper positioning of the elements of the Drowsiness Prevention System according to design of that respective vehicle.

Like in buses and trucks dashboard height is pretty low and the windshield is big enough, generally don't use the centre rear view mirror. But both the type of vehicle generally has centre pillar in the front, where wiper is installed. So in the same place we can place this Driver State Monitoring Device or near to Pillar A.

Image 7.16 - Different driving scenario in different types of vehicles

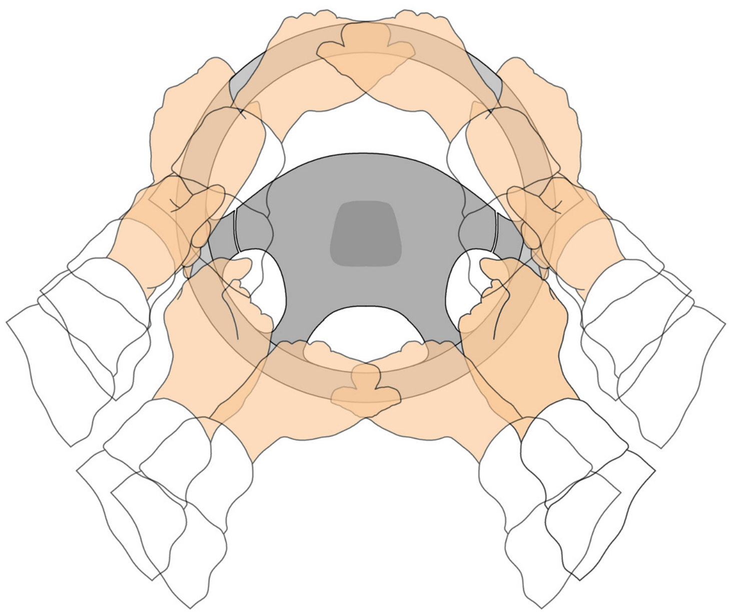


Image 7.17 - Overall area of the Steering Wheel under use of different driving style

# Adaptation to different driving style

According to user study and driving context it is found that Centre Rear View Mirror is the best option to focus for Driver State Monitoring which is majorly based on Face Detection System by IR Camera Module with night vision mode. As every driver reset the angle of the centre rear view mirror before starting the vehicle it every time aligns with the face of the driver and by that procedure it is more safe and reliable position to put the Driver State Monitoring Device.

Image 36 shows that haptic feedback should be provided throughout the whole steering wheel to cover all the driving styles

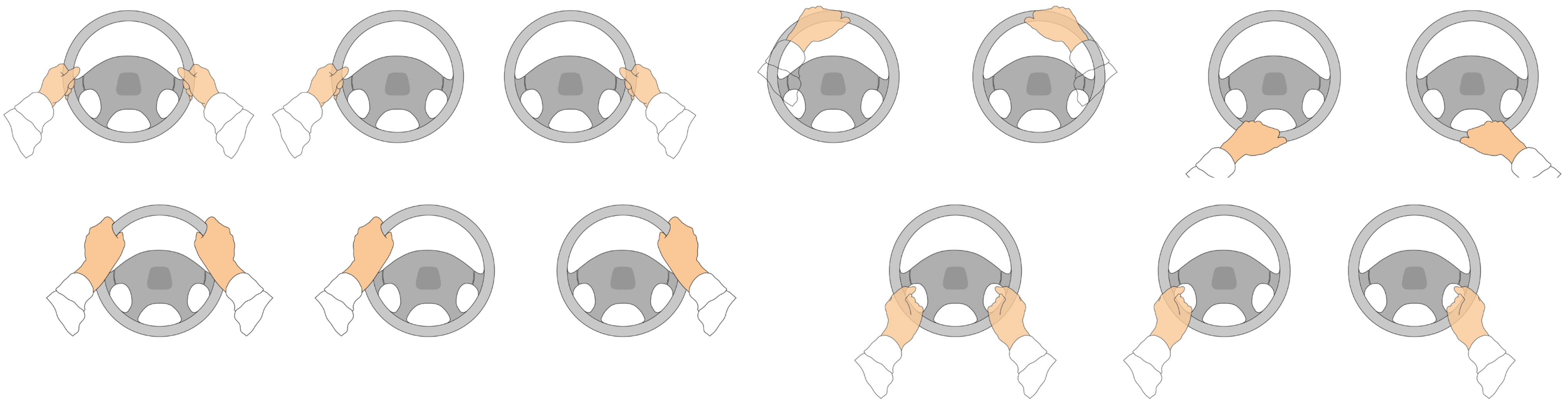
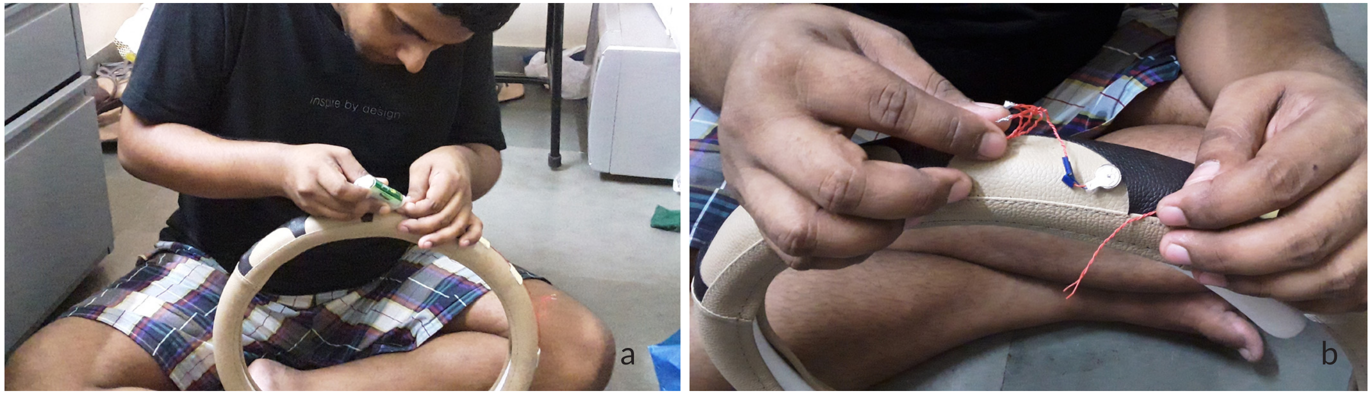


Image 7.18 - Different driving posture found from the User Study in Indian context

# Prototype for the final concept

Images of the prototypes are given below:
It has 16vibrator units around the steering wheel cover which will be connected to vehicle battery of 12V through a 3V-12V step up converter. There is also LED Lights at the back side of the cover which is directly connected to the vehicle battery of 12V.
Haptic feedback signal comes to this part after drowsiness detection by the driver state monitoring system mounted on the rear view mirror.

Image 7.19(a-h) - Prototype for Steering Wheel Cover with Vibration Modules & LED Light




# Details of the Final concept

According to user study and driving context, there will three different level of giving feedback in this concept through Steering Wheel Cover and the Driver State Monitoring Device.

**(i) Atfirst, LED lights placed  on the ceiling of the car & downside of the steering wheel will start glowing to increase ambient luminous intensity. It will act as visual stimuli and will not create much glare to distract driver from driving.**

**(ii) Then, the Alarm sound will start ringing in high intensity from the Driver State Monitoring Device mounted over the centre rear view mirror, though the pattern and intensity of that alarm sound should not distract driver.**

**(iii) Atlast, the haptic feedback will start to work through the vibrator units placed in the Steering Wheel Cover. There can be vibrator of different intensity and different pattern other than the actual vibration of the car to wake the driver up. This pattern should not create any feeling of "massaging" after prolong use and should not create any harmful effect on the driver.**

Schematic diagram of the final concept is given below in the Image No.- 7.20

Though, apparently this concept is going to work and keep the driver awake in the monotonous driving scenario, but it needs rigorous testing on the actual scenario or in  high-end simulator to validate properly.

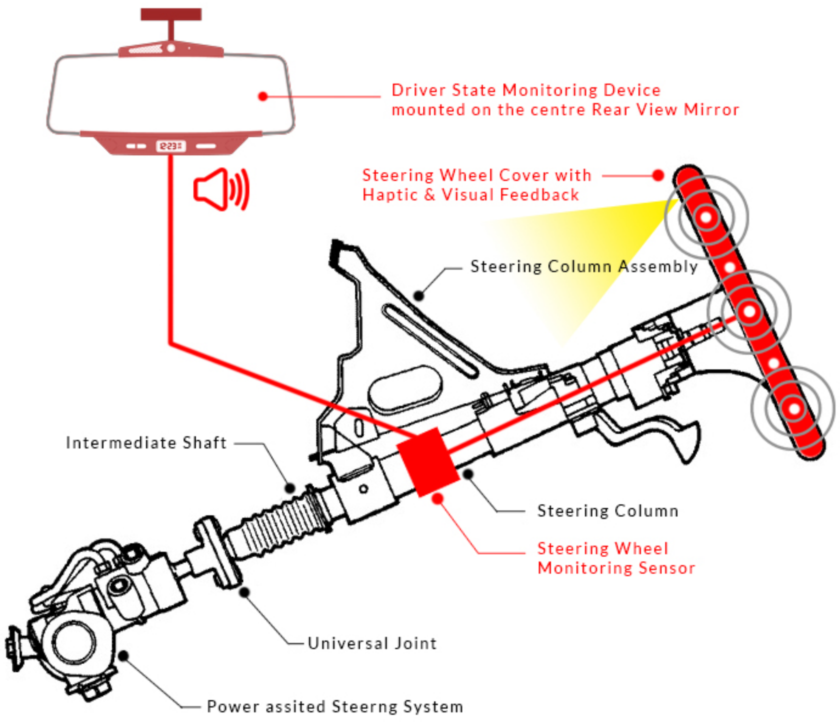
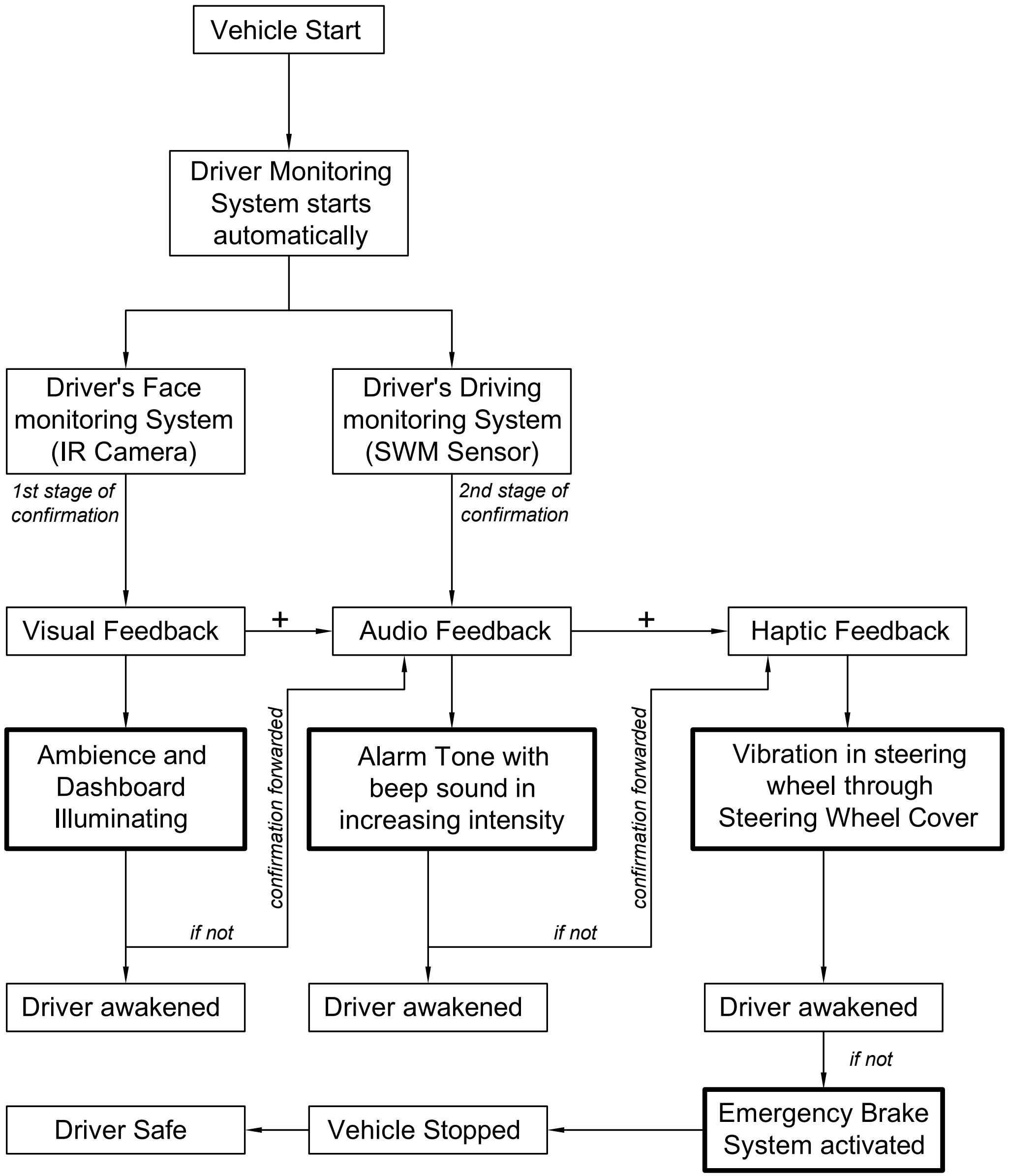


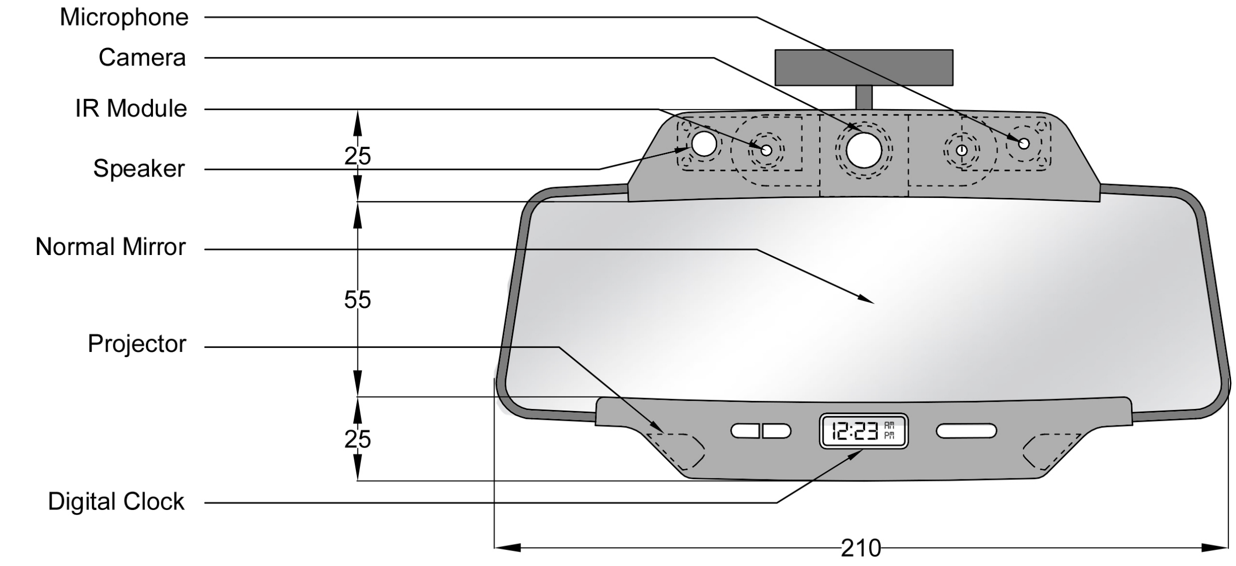

Image 7.20 - Schematic diagram of the Final Concept

# Overall Concept System Flowchart

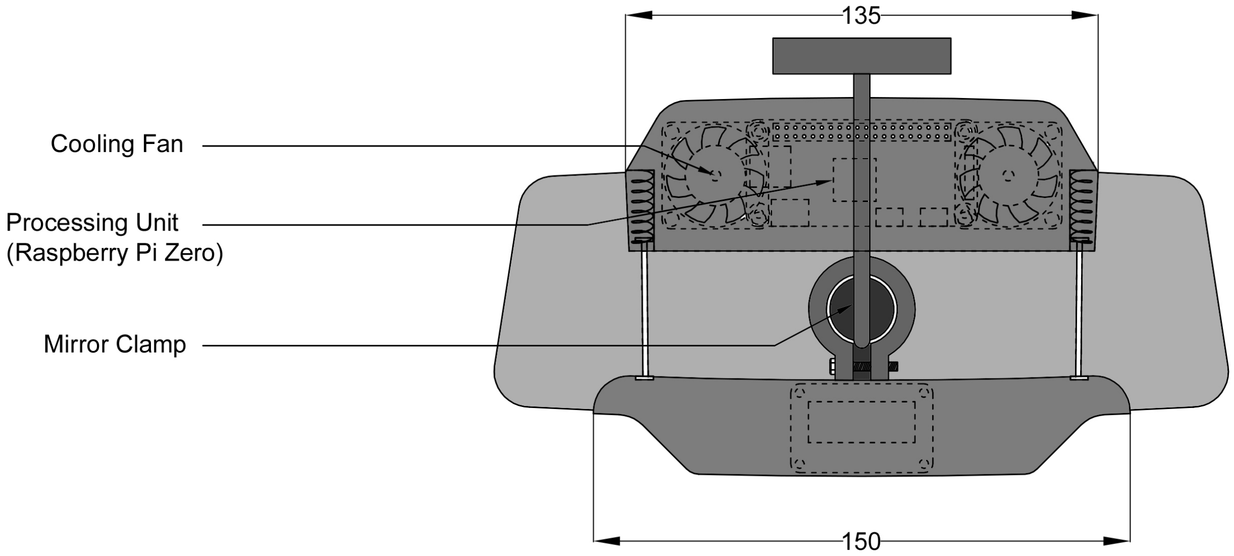


# Detail Drawing for Driver State Monitoring Device

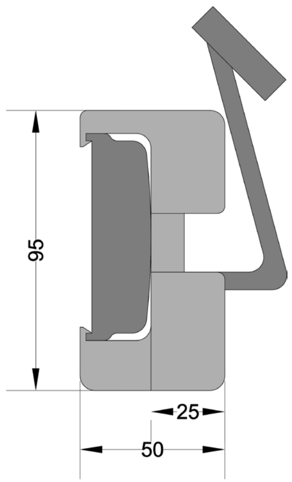
Detail drawing of the Driver State Monitoring Device is given below.




Front View (a)




Rear View (b)




Side View (c)

Image 7.21 (a-c) - Detail drawing of the Driver State Monitoring Device mounted on centre rear view mirror

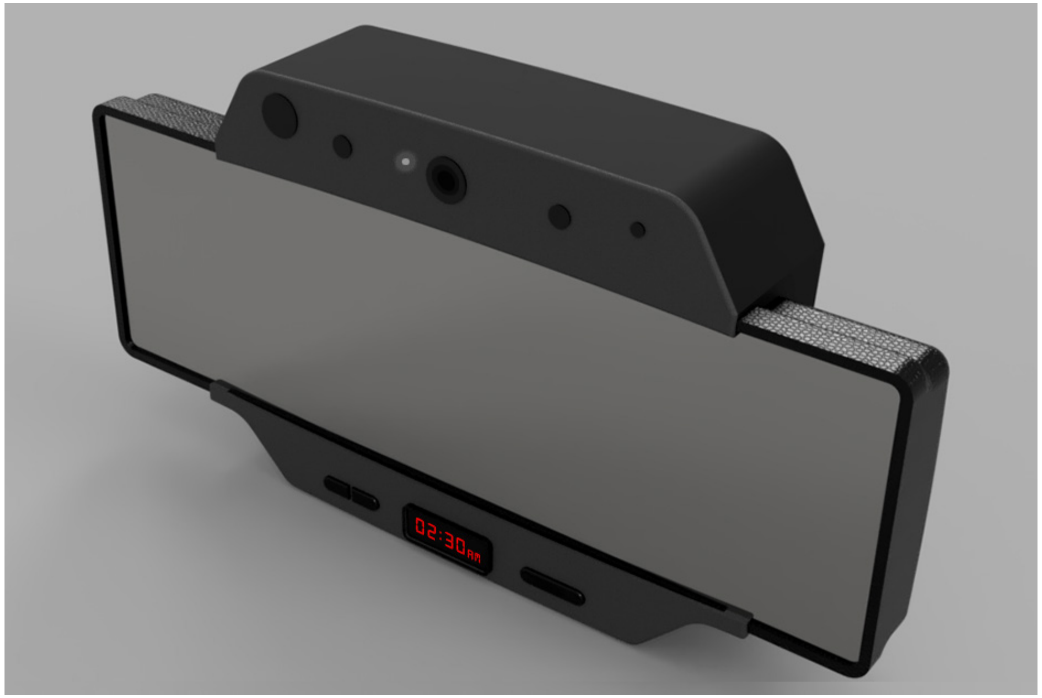



Image 7.22(a) - Front View of Driver State Monitoring Device

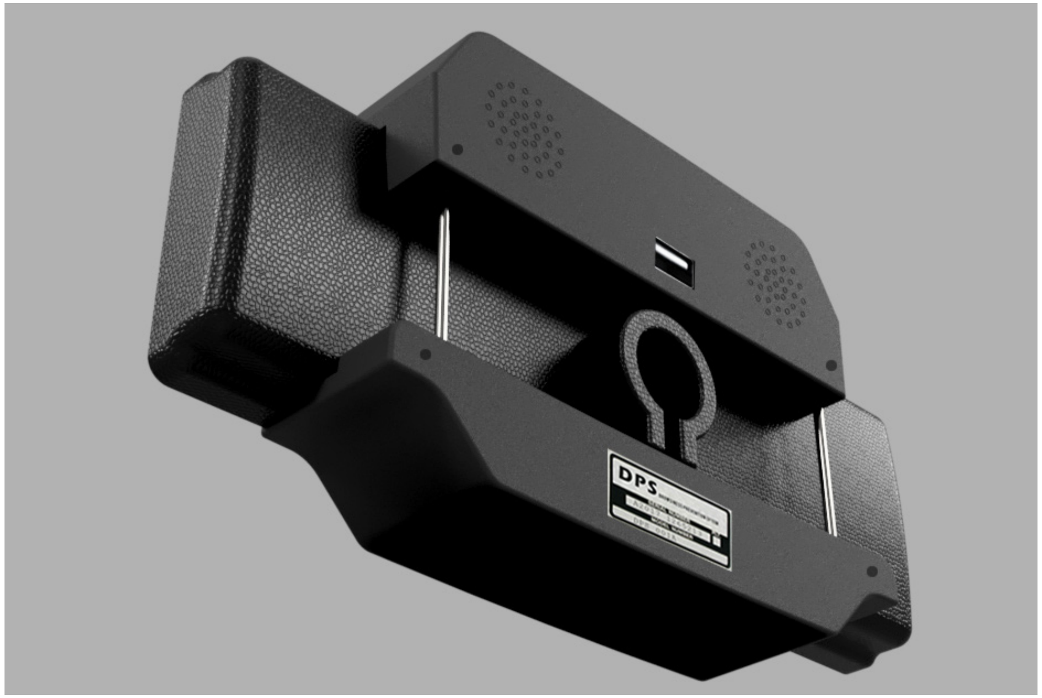



Image 7.22(b) - Rear View of Driver State Monitoring Device

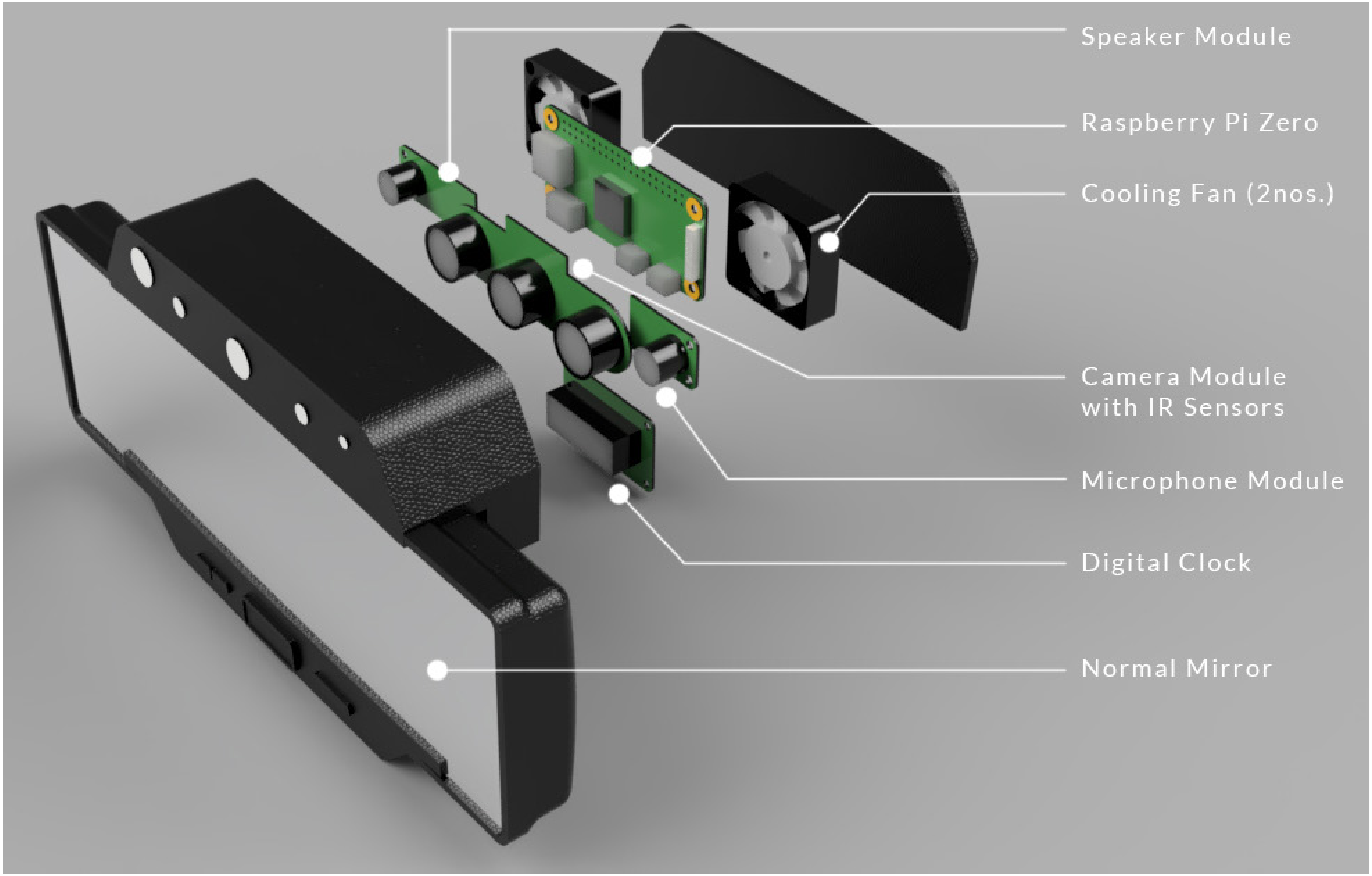



Image 7.22 (c) - Exploded view of the Driver State Monitoring Device

Image 7.23(a) - Steering Wheel Cover with Vibration Units (Front)

Image 7.23(b) - Steering Wheel Cover with Vibration Units (Rear)

# Detail Drawing for Steering Wheel Cover

Detail drawing of the Steering Wheel Cover with the feedback facilities is given below.

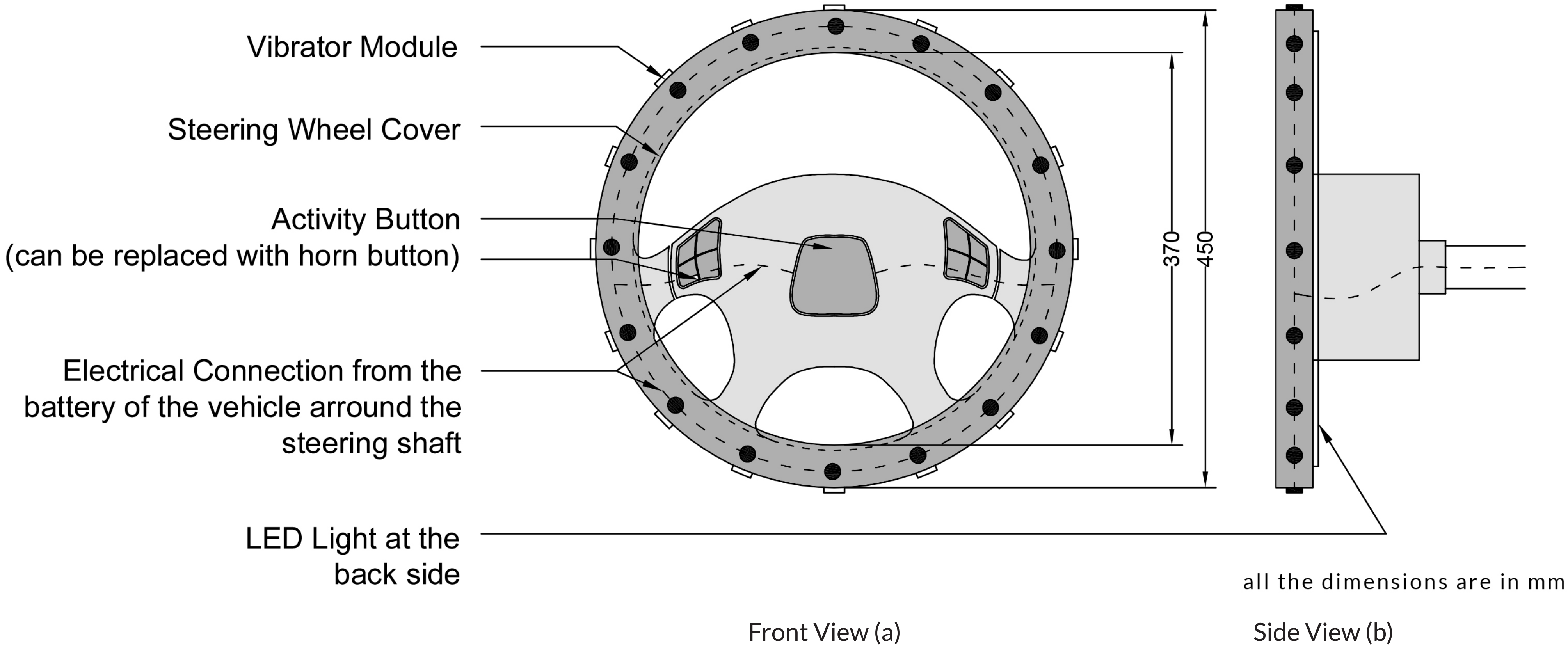



Image 7.23 (c) - Detail drawing of the Steering Wheel Cover

# Steering Wheel Monitoring (SWM) Sensor

(i) Steering Wheel Monitor Sensor -
This sensor will be used for monitoring micro-corrections which reduce at the time of drowsiness. Because at the time of drowsiness, micro-corrc-tions between 0.5-5 degreeC reduces.

This enclosure will be attached with the shaft of the steering wheel behind the dashboard. So it will not be visible but a important component for con-firmation of the drivers' drowsiness.


Image 7.24 - Steering Wheel Monitoring (SWM) Sensor

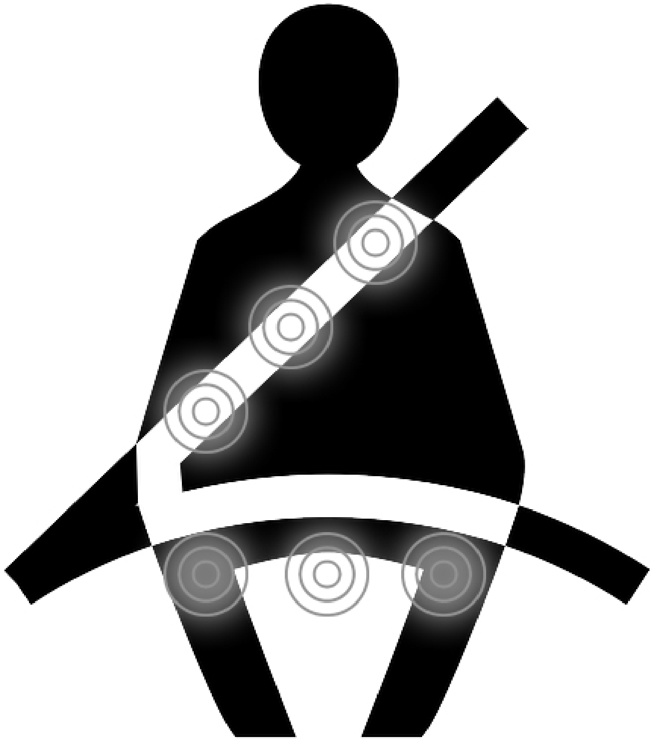



Image 7.24 - Steering Wheel Monitoring (SWM) Sensor

# Future Scope in this project

1. This concept must be validated by other parameters and actual driving scenario or in the driving simulator

2. There can be different monitoring system (like Heart Beat rate etc.) and respective feedback system in other location (like Seat belt, Seat etc.), Fake phone call to the user can be tested.

3. There can be pattern in the vibration to differentiate from actual vibration of the vehicle at the time of driving.

4. Proper design of dashboard to keep monitoring devices.

5. Exploration is some other different feedback system (like giving feedback by ringing the drivers' smartphone etc.)

6. A way to implement mandatory and legally to keep drivers' driving history.

# 08

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Image Source - http://ossekeag.ca/well-rested-drowsy-driving/

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