# Estimation of Primary Task Demand using Naturalistic Field Operational Test Data

Master’s Thesis in Automotive Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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## ABSTRACT

Driver's attention on the driving task is vital for safe travel. Intelligent vehicle systems (IVSs) are systems which assist the driver by, for instance, providing extra information about the vehicle, the environment, or the driver to make driving more comfortable and safe. IVSs have a high potential to improve driving, however they should not distract the driver by, for example, inducing the driver to take his/her eyes off the road in critical situations; rather IVSs shall direct the driver to shift focus to the direction of immediate danger.

The objective of this thesis was to estimate 'primary task demand' (i.e. create a mathematical model describing the demand of the current driving situation) using naturalistic driving data. Such estimation may be used to increase the effectiveness of IVSs by 1) preventing such systems from distracting the driver when the primary task demand is high and 2) helping such systems providing information according to the current driving situation.

Naturalistic driving data from the SeMiFOT field operational test was used to select several driving situations which were ranked by 40 drivers based on their perceived primary task demand. Further, this study focused on roundabouts since they are a very common scenario for low speed crashes and require continuous maneuvering from the driver. Finally, this study also elucidates the extent to which perception of primary task demand is influenced by cultural difference by comparing results from 20 Indians and 20 European drivers.

**Keywords** – Traffic Safety, Naturalist Driving, Field Operational Test, Workload, Active Safety, Roundabouts.

# Contents

# Acknowledgement

We thank Safer for providing us with access to the FOT rooms and hence the FOT databases, euroFOT and SeMiFOT.

The lack of subjective data pertaining to the drivers in the FOT databases enforced the need to conduct an experiment which involved a total of 40 participants, 20 Indians and 20 Europeans. We thank all the participants for their time and doing. The subjective data collected were the main input for our thesis work.

We thank Prof. Mike Regan and Prof. Kip Smith for their valuable inputs in Distraction and Human Factors.

Special thanks to the euroFOT and SeMiFOT data collection teams.

Finally we are ever grateful to our Supervisor Prof. Marco Dozza for his immense support and knowledge since the very beginning of this thesis work.

# Notations

| | |
|---|---|
| NDS | Naturalistic Driving Study |
| SEK | Swedish Krona |
| FCA | Frontal Collision Avoidance System |
| FCW | Frontal Collision Warning System |
| TTC | Time to Collision |
| IDIS | Intelligent Driver Information System |
| LDW | Lane Departure Warning System |
| euroFOT | EuroFot Database |
| SeMiFOT | Semifot Database |
| FOT | Field Operational Test Data |
| LIDAR | Light Detecting and Ranging |
| GPS | Global Positioning System |
| GLM | Generalized Linear Model |
| $\beta_i$ | Regression weights of the GLM |
| satnav | Satellite Navigation System |

# 1 Introduction

The automobile world at present is abuzz about two major issues – hybrid vehicles and improving safety to higher levels. The safety of the occupants of the car has gained tremendous importance in the recent time. This has led to the era where the production vehicles are equipped with safety systems that works at all times to prevent an impending danger. Safety systems in vehicles can be split into two broad categories – Active Safety and Passive Safety.

Any crash can be split up into three different phases, *Pre Crash*, *In-Crash* and *Post Crash* Phase. Figure 1, shows the timeline of a crash with the three phases and the safety systems on board the car functioning during the overall period of the crash.

Systems that work all along till the *In-Crash* phase are classified under *Active Safety Systems*. A 'Parking Assist' is an example of the Active Safety System, the main function of which is to monitor the presence of an obstacle in and around the ego[1] vehicle by means of ultrasonic sensors and/or camera. If the path of the ego vehicle is such that it interferes with these obstacles, the systems warn the driver about the impending danger.

On the other hand, a *Passive Safety System* works in the in-crash and post-crash phase. Air Bags that deploy in case of a crash to protect the occupants from injuries are an example of a Passive Safety System.

Further advancements in the field led to the development of *Integrated Systems*, as the name suggests, they are systems that combines the functionalities of both the Active and Passive Safety Systems. Active Seatbelts are seatbelts with pretensioners. The pretensioners are used to reduce the slack on the belt in case of an impending crash. Once the system confirms an impending crash, the pretensioner starts to reduce the slack on the belt thereby inducing a gentle load on the occupant's chest than a normal seatbelt. This is an example of an Integrated System. Figure 1 shows the functioning of the integrated systems in case of a crash.

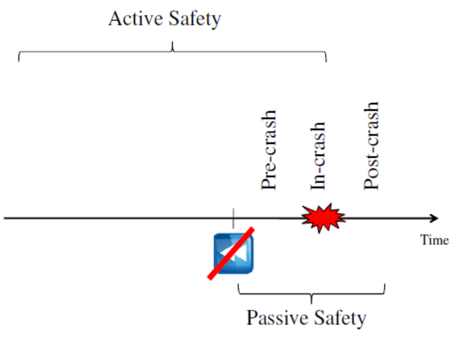

*Figure 1 - Active and Passive Safety Systems*

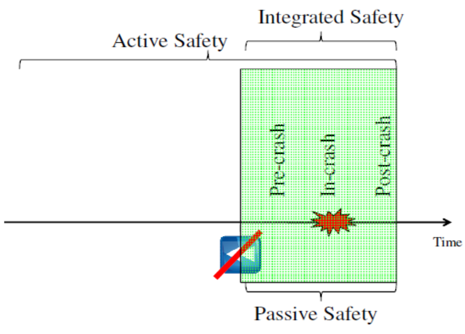

*Figure 2 – Integrated Safety*

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[1] The vehicle which has the active safety system onboard

## 1.1 Accidents

From the 100 Car Data, a Naturalistic Driving Study conducted in the recent past, the cause for 80% crashes and 65% of near crash was found to be Inattention(Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006).

Inattention can be defined as diminished attention to activities that are critical for safe driving in the absence of competing activity. The term ‘Competing Activity’ represents an explicit activity other than driving, which calls for attention from the driver. Presence of such an activity forces the driver to offer less attention to the task of driving and this is termed as Distraction (Regan, Lee, & Young).

Distraction as discussed before varies from Inattention. Any external activity that forces the driver to offer less cognition to the primary task of driving is termed as Distraction. Distraction is a subset of inattention.

## 1.2 Naturalistic Driving Studies

Naturalistic Driving Studies (NDS) are being carried out to assist in the research of active safety systems. Field operational test data is predominantly used to evaluate the effectiveness of active safety systems, analyse the driver behaviour and to define new active safety systems and features. For example, these data enables the study of collisions and if a similarity in the causes for a collision is estimated, a new system can be developed to counter this issue.

Test data includes instantaneous data from all the on-board sensors, information about the instantaneous driver state and video data from cameras’ mounted on various positions in the car (e.g. frontal camera, pedal camera, driver facial camera, the vehicle’s cabin camera and rear facing camera).

All these sensors and cameras record data continuously right from the time the engine starts till the engine is turned off. Hence to simplify understanding, the FOT database has all the individual trips under individual files. (N.Boyle, D.Lee, M.Neyens, V.McGehee, Hallmark, & J.Ward, 2009)

### 1.2.1 SeMiFOT

The SeMiFOT database was jointly created by 13 partners amongst whom SAFER Vehicle and Traffic Safety Centre at Chalmers and University of Michigan Transport Research Institute (UMTRI) (SeMiFot a Safer Project) were the two major players. More than 20 vehicles were used in this project with a total cost of 18 million SEK. The project spanned for a period of 18 months from January 2008 to March 2009 and a total 4221 hours of naturalistic driving data was collected.

### 1.2.2 euroFOT

euroFOT is the most recent and the most extensive of the FOT databases available. 28 different partners across Europe which include vehicle manufactures, automotive suppliers, universities and research centres and other organisations are involved in the creation of this database. From Sweden 100 Volvo cars and 50 trucks are involved for the creation of the database. A total 3 million kilometres has been covered for this purpose(euroFOT - official site).

## 1.3 Active safety systems

An active safety system, as described before, works in tandem with the driver assisting him in the task of driving. The way the system assist the driver is unique and might also vary from one automobile manufacturer to the other based on the system design. The current age of automobiles has numerous Active Safety Systems which constantly monitor the driver and several happenings in and around the vehicle. The terabytes of information are processed with a goal, *make driving more comfortable and prevent an impending danger or reduce the adverse effect of the crash. In short, protect the passengers with very less or no injury.*

## 1.4 Need for active safety systems

Active Safety Systems were introduced to reduce the crashes that are caused by inattention of a driver. The various systems achieve this in their unique way. To begin with, there are systems that monitor the drowsiness level of the driver at all times and gives a warning and suggest him to take a break. A small brief about two systems, the Frontal Collision Warning (FCW) System and Frontal Collision Avoidance (FCA) System are as follows –

In case of a Frontal Collision Warning (FCW) System in Volvo Cars, the distance of the vehicle in front of the ego vehicle (assessed by using the ego vehicle's radar signals) and the present speed of the ego vehicle are fused to determine the Time to Collision (TTC) (Time to collision for the ego vehicle with the vehicle in front). If this TTC then reduces beyond a threshold, a warning is issued to the driver about the impending danger. If a Frontal Collision Avoidance System (FCA) is present in place of the above mentioned FCW, the ego vehicle brakes automatically instead of issuing a warning. The rate of braking depends on the speed at which the ego vehicle is travelling at. (Thinking Cars - an EC funded project)

These systems have their own ways of warning the driver and these warnings can be either *visual* or *audible* or *haptic* which depends entirely on the direction in which the driver's attention has to be diverted (Wickens, Gordon, & Liu, 1998).

With these systems increasing in number in a car, attempts are made to make the driver more comfortable i.e. including the instantaneous driver attention data improves the performance of these systems.

## 1.5 System to counter accidents

The driver distraction and inattention is controllable up to some extent. In case of a controllable distraction, *Workload Managers* (Thinking Cars - an EC funded project) are designed which continuously assesses the current level of concentration of the driver and decides if he is capable of comprehending extra information. If he is not, the messages that can be ignored are not passed on to the driver.

One such example is Volvo's Intelligent Driver Information System (IDIS) which continuously monitors the driver's workload and delays the phone calls and other non-essential messages in busy driving situations.

The inattention of the driver is monitored with the use of head trackers and eye trackers where the position of the head, direction of gaze and eyelid closure are monitored continuously and a message or a warning is sent to the driver to get his concentration back to the road.

Attention monitoring systems are being used by Mercedes, Toyota and Volvo cars. End state of drowsiness can be monitored by tracking the consistency of lane keeping by the driver(Lane Departure Warning (LDW)) (Thinking Cars - an EC funded project) and the driver is alerted appropriately. Early signs of drowsiness are detected with the use of eye tracking cameras which look for the eye blink patterns. All these systems monitor the attention of the driver and issue a warning if the driver is predicted to move into a dangerous threshold.

There is one more factor that has gained importance in the recent past – *deciding if a perfectly valid warning can be ignored from reaching the driver because at the moment he is not in a position to perceive any extra information*. In order to make this happen, *Workload Managers* are designed which assesses the current situation the driver is in and decides if he is capable of comprehending extra information. If he is not, the warnings that can be ignored are not passed on to the driver. Apart from this, phone calls routed through the car [2] can also be either delayed or rejected depending on the Workload Manager. There by the driver is left undisturbed during scenarios which require him to have maximum concentration on the road.

## 1.6 Primary task demand

Primary task of any driver is driving and hence the name ‘Primary task demand’. In this thesis, an attempt is made to estimate the primary task demand from the environmental conditions. The factors from the immediate environment of the car are considered in to make this model a reality.

In case of situations which are demanding to the drivers, avoiding a distraction helps in the cause of safe travel. For example, in case of a high demanding scenario delaying an incoming call will avoid distraction. The primary task demand provides with instantaneous attention requirement of the driver based on the ego vehicle’s immediate environment.

In this thesis, the SeMiFOT database is used to create a mathematical model based on the environment which provides an estimate of the primary task demand. Since the model here is based on the environment, the model becomes highly scenario specific i.e. the model cannot be generalized for all driving situations. For example, the driving demand in case of presence of snow on the road varies when the road is straight and when there is a turn approaching. Hence the model created here is targeted towards roundabouts.

## 1.7 SeMiFOT over euroFOT

From Section 1.2, SeMiFOT’ and ‘euroFOT’ are the two FOT databases that were available for the thesis work. The SeMiFOT was finally chosen over the euroFOT considering the following issues –

1. In case of the SeMiFOT, map data was present which assisted in finding out the location of roundabouts in each of the trips from the database. (At the time of thesis work, euroFOT’s map data was not available to use)
2. Moreover, in case of SeMiFOT, the frontal camera had a large field of view (two frontal cameras were used and the output was fused to increase the field of view) which was very essential for the thesis work as it involved people looking at videos and rating them.

The euroFOT on the other hand had two great advantages, the data was extensive (more number of trips) compared to the other database. But considering the two main advantages, the SeMiFOT was chosen over the euroFOT. However, the same algorithms created and the methods followed to form the model in SeMiFOT can be carried over and used in euroFOT.

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[2] The current cars have the facility to route the mobile phone of the driver through the car via a Bluetooth connection.

## 1.8 Roundabouts

Roundabouts are constructed to reduce severe accidents. The major reasons for this reduction are slower speeds of travel, reduced collision angles and fewer collision points for pedestrians and motorists. Generally intersections are converted to roundabouts to make use of the latter's advantages.

Some studies were conducted by TRL, UK(Transport Research Lab , UK) by converting some intersections into roundabouts which also resulted in reduced accident fatality in USA, Australia and Great Britain.

*Table 1- Accident in intersections and roundabouts*

| | No of accidents | % of fatal accidents | Average accident cost (£) |
|---|---|---|---|
| All roads | 214,000 | 15% | 61,100 |
| Roundabouts | 18,700 | 8% | 34,600 |
| Other Junctions | 111,000 | 14% | 52,000 |

Table 1 shows the comparison of accidents in roundabouts with intersections as of 2005 in United Kingdom. *It can be inferred that the percentage totality of accidents is comparatively less in roundabouts than in intersections, but the average accident cost is comparatively higher in spite of the reduction in fatal accidents.*

According to the IIHS Status Report(Insurance Institute for Highway Safety Status Report ; Vol.43 ; No.4, 2008), crashes reduced by 40% and those crashes involving injuries reduced by 80% in the cases where the intersections were converted to roundabouts. From the European and Australian studies(Insurance Institute for Highway Safety Status Report ; Vol.43 ; No.4, 2008), the main reasons for crashes occurring in roundabouts –

- Collision between entering and circulating vehicles
- Run off road crashes
- Rear end collisions

Moreover amongst all the crashes, 80% were accounted for 'Collision between entering and circulating vehicles' and Run off road crashes(Insurance Institute for Highway Safety Status Report ; Vol.43 ; No.4, 2008) were predominantly happened at evening / night time raising concerns about visibility.

Assessing the required attention levels in a roundabout will help in reducing distractions which will further reduce the accidents in roundabouts. Since Sweden has a lot of roundabouts, creating a model to estimate the primary task demand in a roundabout became the prime concern of this thesis.

## 1.9 Factors that affect safe travel in a roundabout

Based on driving experience and data availability from the FOT database, four factors were shortlisted from six –

- Stop and Go – The decision made in the ego vehicle to join in the roundabout due to already present traffic
- Weather – The weather conditions in the immediate environment of the ego vehicle
- Time of Day – This was essentially classifying the presence of day light
- Car in front – A car in front of the ego vehicle which influences the driving decisions of the ego vehicle.
- × Car joining from another exit – Presence of car form another exit which joins or appears to join in - front of the ego vehicle, this again is a decision making scenario.
- × Pedestrians and bi-cycles – presence of pedestrians and bi-cycles in the roundabout

The factor ‘Car joining from another exit’ requires radar data from a larger field of view and the factor ‘Pedestrians and bicycles’ requires LIDAR data. Since both of the mentioned data were absent in the FOT databases, these two factors were not considered in the thesis work.

# 2 Methodology

As described before, the motive of the thesis is creating a mathematical model that determines the Primary Task Demand of the driver based on the instantaneous environment around the vehicle. Since there in no proper defined value or unit for the Primary Task Demand, the best way to determine this model is to conduct an experiment with human participants. Finally, regression analysis was used to form this mathematical model. The participants had to watch different videos on the computers, assume that they are driving in that scenario and rate them based on the demand of situation according to them.

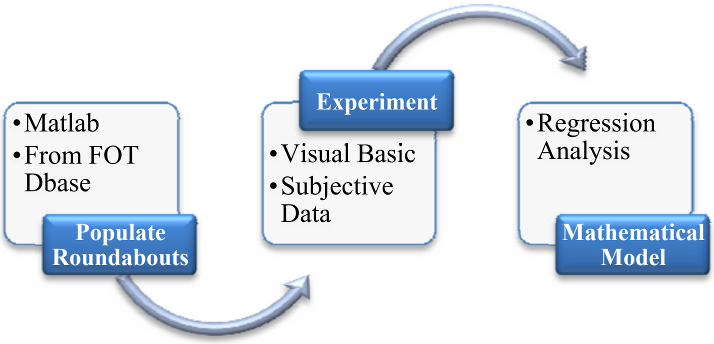

*Figure 3 – Methodology*

Figure 3 describes the overall approach to the ultimatum of the thesis – the model. The first step was populating all the roundabouts from the FOT data (SeMiFOT). The environmental factors that influence driving were determined (section 1.9) and a full factorial design was made to form the various factor combinations. Videos that depicted these combinations were chosen from the database.

An experiment was conducted to collect subjective data for regression. Participants were shown the chosen videos and were asked to rate them. The rating was typically the demand, that specific scenario required for safe travel.

This was later used for regression, the factors and their values in each of the combinations were already known. This was used with the corresponding user data and regression analysis was performed to get the weights of the factors.

Matlab was used to populate the roundabouts from the FOT databases. The Oracle databases were linked up with matlab and all the data collected in each of the trips (e.g. Steering Angle Degrees, Vehicle Speed, Yaw Rate etc.) were stored as individual variables. All the variables in a trip were related to each other by the time stamps. The data was secure on an intranet and are accessible only with authorisation. The videos corresponding to teach of the trips were also related by means of the time stamps. The videos could be viewed on ‘Simple Viewer’.

Visual Basic was used to create the questionnaire for the experiment. This form was linked to excel to store the data obtained from the user in real time. More explanation about the forms is given in the following chapters.

Finally SPSS was used in statistical analysis of the results. GLMFIT was used in the construction of the model using the input data.

## 2.1 Populating roundabouts

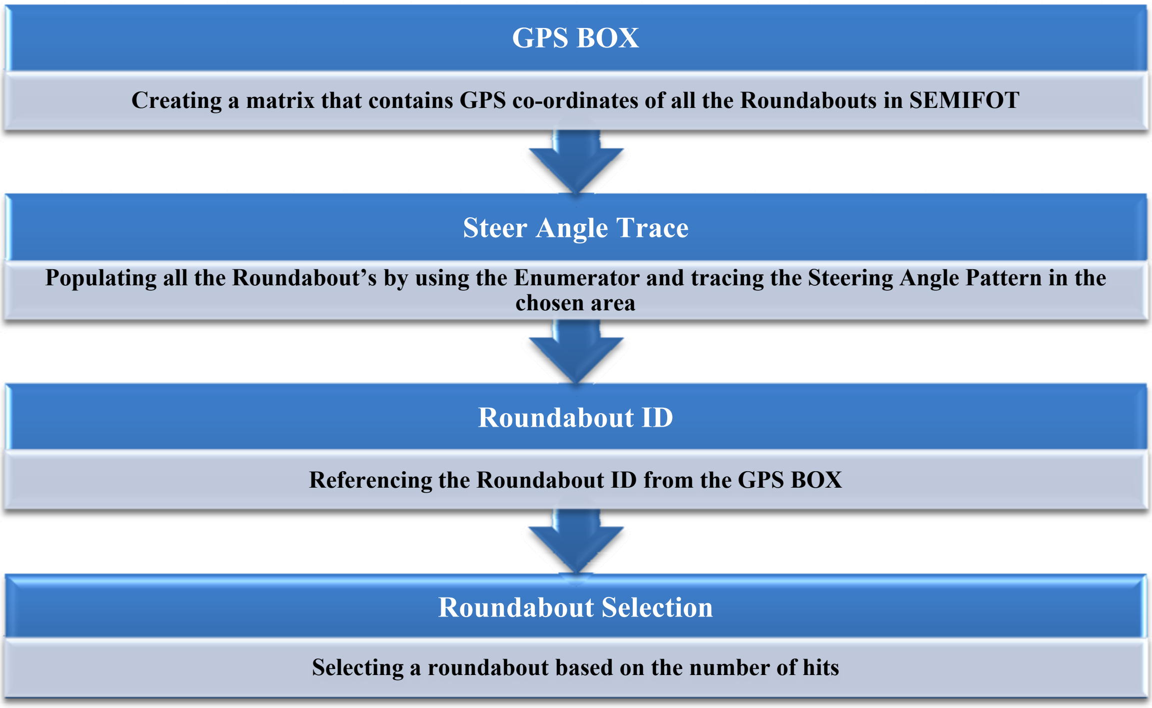

*Figure 4 - Populating Roundabouts*

Steering pattern was primarily used to fix the start and end of roundabouts. For uniformity, the start and end of a roundabout was fixed at the instant where the steer angle was made zero before and after the roundabout.

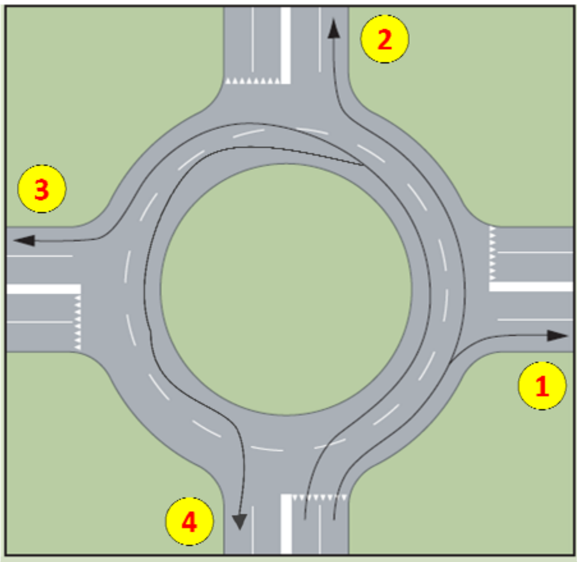

*Figure 5 - Travel in a roundabout from one exit to the various exits* (Vagverket - Swedish National Road Administration - Driving in a Roundabout)

A vehicle entering a common form of a roundabout (having a total of 4 arms), can exit the roundabout in any of the available 4 exits as show in Figure 5. Hence for the travel marked '2', '3' and '4' in Figure 5, the steer angle pattern is a constant as shown in Figure 6 but varies in magnitude unlike the case marked '1' in Figure 5, where the vehicle exits taking the 1st exit.

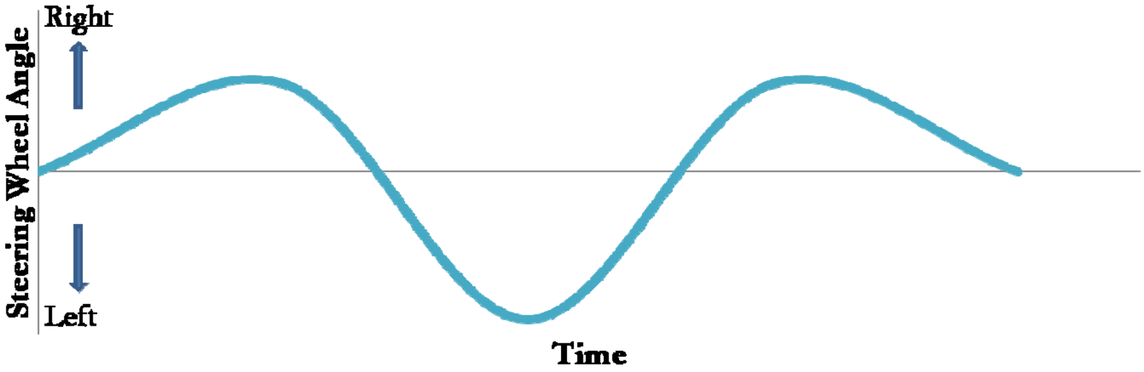

*Figure 6 – Steer Angle Pattern*

However, this was not sufficient to confirm the scenario to be a roundabout as the same steer pattern can also result from any other manoeuvre e.g. parking. Another strong confirmation was needed and GPS was the best solution.

Hence the task was to use GPS data and find all the roundabouts, name them and group all the passes in a roundabout under the corresponding names.

The SeMiFOT data has an enumerator which helps to find out roundabouts. This enumerator is a time varying signal which has a '1' at every instant the vehicle is in a roundabout and is '0' at all other instant. This was used in finding the presence of Roundabout.

### 2.1.1 GPS box

In order to confirm the presence of a roundabout, as mentioned in the previous section, GPS data present in the FOT database was used. To group all the passes made in a single roundabout, a box was created enclosing each of the roundabouts and they were named distinctly. The boxes (Figure 8) created around each of the roundabout was a square of side 66.55 m covering an area of 4429 $m^2$. The size of the box was fixed based on trial and error as it had to enclose the biggest of the roundabout in the SeMiFOT data. From SeMiFOT data, random roundabouts were checked on google maps and the size of the biggest roundabout assisted in fixing the box to this size.

The method used to form the box around each of the roundabouts is detailed in this section.

1. The enumerator variable was used to track the roundabout. The strings of '1' were targeted. In Figure 7 the yellow line and red line shows two different travels by vehicles in the same roundabout. The Enumerator shows '1' at all the points on the yellow and the red line.
2. From this, the centre point of the array of '1's was stored to be the centre point of this particular roundabout. This was later used to form a box around the roundabout.
3. But there was an issue here, in a particular roundabout there were a lot of passes and from and to different exits. Hence different centre points would be generated depending on the travel direction. Typically as shown in Figure 7, there will be 2 centre points for this roundabout, one for the yellow line and the other for the red line. Hence the duplicate centre points were eliminated and a unique centre point for each of the roundabouts was ensured.
4. Using the centre points, and simple mathematical addition of co-ordinates, a box was constructed around every roundabout as shown in Figure 8. The co-ordinates of the

corner points of the box were of interest here. Latitude and longitude varies with different surface distance per degree change with increase in latitude from 0° through 90°. Hence this had to be considered to make the box a typical square i.e. with sides of same length. At 60° latitude, 1° change in latitude, transverse a distance of 111.412 km and 1° change in longitude transverse a distance of 55.800 km. To accommodate this, from the centre point co-ordinate, the longitude and latitude were affected with different values to form the four corners of the box (McCarthy & Petit, 2003)(National Imagery And Mapping Agency Technical Report 8350.2, 1984).

5. Each of these boxes was set a unique name (typically a number) and hence this was used to group all the various passes through a roundabout.
6. A database was now created that had all the distinct roundabouts with their names and the co-ordinates of corners for the corresponding boxes. (this database is referred to as GPS BOX in the rest of the document)

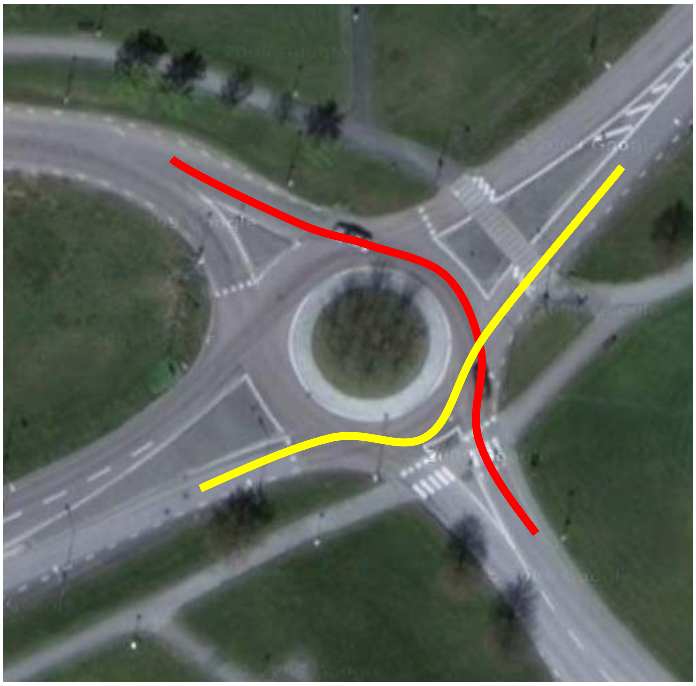

*Figure 7 - GPS Passes*

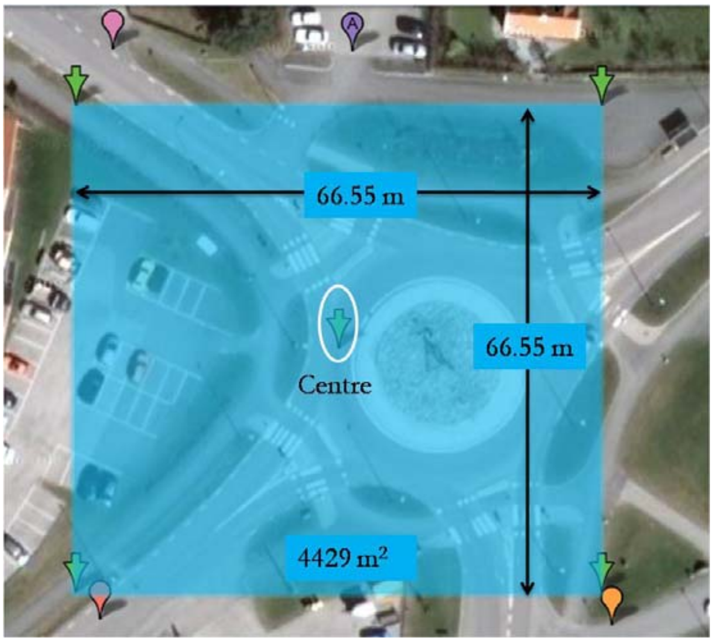

*Figure 8 - GPS Box*

### 2.1.2 Steer angle trace

As discussed before, all the passes in roundabouts had a constant steer angle pattern. This was used to fix the start and end of a pass in a roundabout.

1. Each of the trips were analysed with the enumerator variable. Whenever the vehicle passed through a roundabout'1's were encountered.
2. The section confirmed to be a roundabout was extracted, and the steer angle pattern (Figure 6) was used to set the start and end of the roundabout.
3. A simple code was also made to determine the 1st exit passes as the steer angle pattern was not followed in this case as discussed before.
4. The indices of start and end of a roundabout were stored in another database. (this database is referred to as 'Steer angle Trace' in the rest of the document)

### 2.1.3 Roundabout ID

The most important part here was to group all the passes with the respective roundabout names. From the 'Steer Angle Trace[3]' database, since the start and end of the roundabout was stored, the GPS data taken from within will contain the GPS data of the roundabout.

Hence this was compared with the 'GPS Box[4]' database and the box in which this particular GPS data fits in was determined. The corresponding roundabout name was then applied to the specific pass.

This was done for the entire database and all the roundabout passes were extracted and grouped. Consolidated Statistics about the total number of roundabouts obtained is as shown in Table 2. Table 3 shows 6 roundabouts which had the most number of passes from the

---

[3] The database created with the start and end of roundabout (section 2.1.2)

[4] The database created with the co-ordinates of corner points of the box created around each of the roundabout (section 2.1.1)

database. The first column in Table 3 shows the unique names of each of the roundabouts that was set as discussed in this section.

*Table 2 - Total Number of Roundabouts*

| | |
|---|---|
| **Total Number of Roundabouts** | 608 |
| **Total Number of Roundabout Passes** | 7,233 |

*Table 3 - Top 6 maximum number of passes through a few roundabouts*

| Roundabout Ref ID [5] | No. of passes |
|---|---|
| **160** | 357 |
| **1** | 329 |
| **4** | 319 |
| **9** | 230 |
| **5** | 216 |
| **327** | 211 |

### 2.1.4 Roundabout selection

The roundabout with the most number of passes was the obvious choice of selection. 90% of the videos shown to the participants were extracted from this roundabout (Figure 9). For the other 10% of videos, videos from a very similar roundabout (geometry) were used.

*Figure 9 - Roundabout with the most number of passes*

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[5] The IDs are the unique names of each of the roundabouts as discussed in 2.1.3

## 2.2 Experiment

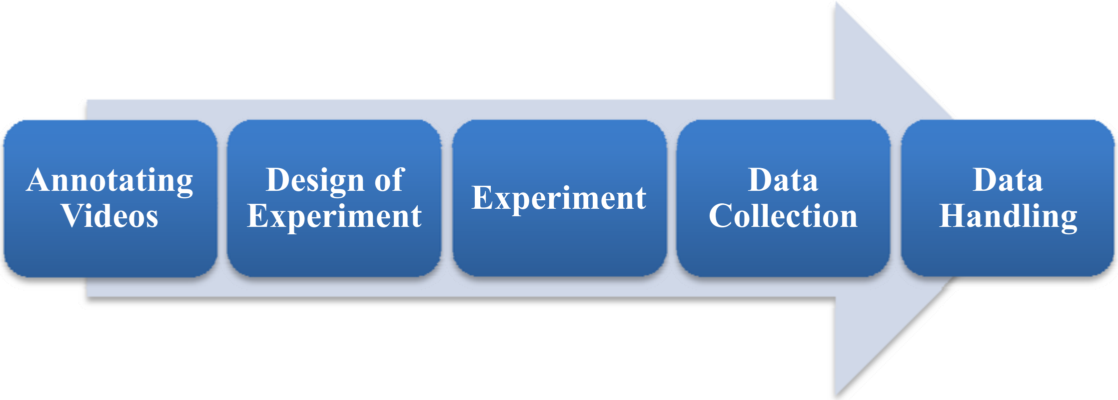


*Figure 10 - Bird's Eye view of the experiment*

Figure 10 shows the bird's eye view of the experiment conducted. This is better explained below.

### 2.2.1 Annotating videos

All the videos (total of 357) corresponding to the roundabout shown in Figure 9 were populated. Each of them were then annotated for the presence of the four factors –

- Stop and Go
- Weather
- Time of Day
- Car in Front

These were the videos amongst which a few were used to show to the participants.

### 2.2.2 Design of experiment

Each of the four factors had two levels of values. This made a total of 16 combinations (Table 4). From the annotated videos, two were chosen for each of the 16 combination.

*Table 4 - Design of Experiment*

| | Weather | Stop Go | Time of Day | Car in Front |
|---|---|---|---|---|
| 1 | Bad | No | Night | No |
| 2 | Good | No | Night | No |
| 3 | Bad | Yes | Night | No |
| 4 | Good | Yes | Night | No |
| 5 | Bad | No | Day | No |
| 6 | Good | No | Day | No |
| 7 | Bad | Yes | Day | No |
| 8 | Good | Yes | Day | No |
| 9 | Bad | No | Night | Yes |
| 10 | Good | No | Night | Yes |
| 11 | Bad | Yes | Night | Yes |
| 12 | Good | Yes | Night | Yes |
| 13 | Bad | No | Day | Yes |
| 14 | Good | No | Day | Yes |
| 15 | Bad | Yes | Day | Yes |
| 16 | Good | Yes | Day | Yes |

A total 32 videos were then chosen from the 16 combinations. But there was an issue here. All the combinations were not available from the same roundabout (Figure 9). 4 more videos (i.e. for 2 combinations) were chosen from a roundabout which was very similar in geometry to the one shown in Figure 9. Apart from this, an anchor video was selected. The anchor video had the simplest of all situations and the demand was practically assumed to be '1'. This was suggested to the participants and they were asked to use this as a reference for their ratings. This was vital value addition as a human is capable of better judgement while comparing rather than making an absolute judgement.(Brown & Paschound, Rational Choice and Judgement)

A total of 33 videos, 2 per combination resulting in 32 videos and 1 anchor were then used for the experiment.

### 2.2.3 Experiment

The FOT data being sensitive, the participants had to sign a Non Disclosure Agreement according to which no information that they get to watch in the videos should be revealed to anybody. The cut videos cannot be moved out of the FOT rooms and hence, the participants had to watch the videos in these rooms. Hence only one participant could do it at a time. The participants were asked to assume to be driving in the videos they watched and were asked to rate the videos on the basis of driving difficulty. **Hence the rating was ultimately the Demand of the situation.**

There were 4 videos for each of the travel from SeMiFOT database –

1. Feed from a single frontal cam
2. Feed from a two frontal cams that were fused for a larger field of view
3. Feed of the cam that showed the driver
4. Feed of the cam that showed the driver's foot along with the pedals

From the above list, the first two video data were used for the experiment. They were cut to show exactly the period when the vehicle was in the roundabout.

### 2.2.3.1 Participants

The participants of the experiment were from two different sects –

- Indians
- Europeans

A total of 40 participants which included 20 Indians and 20 Europeans were called for the experiment. Some information about the participants is shown in Figure 11.

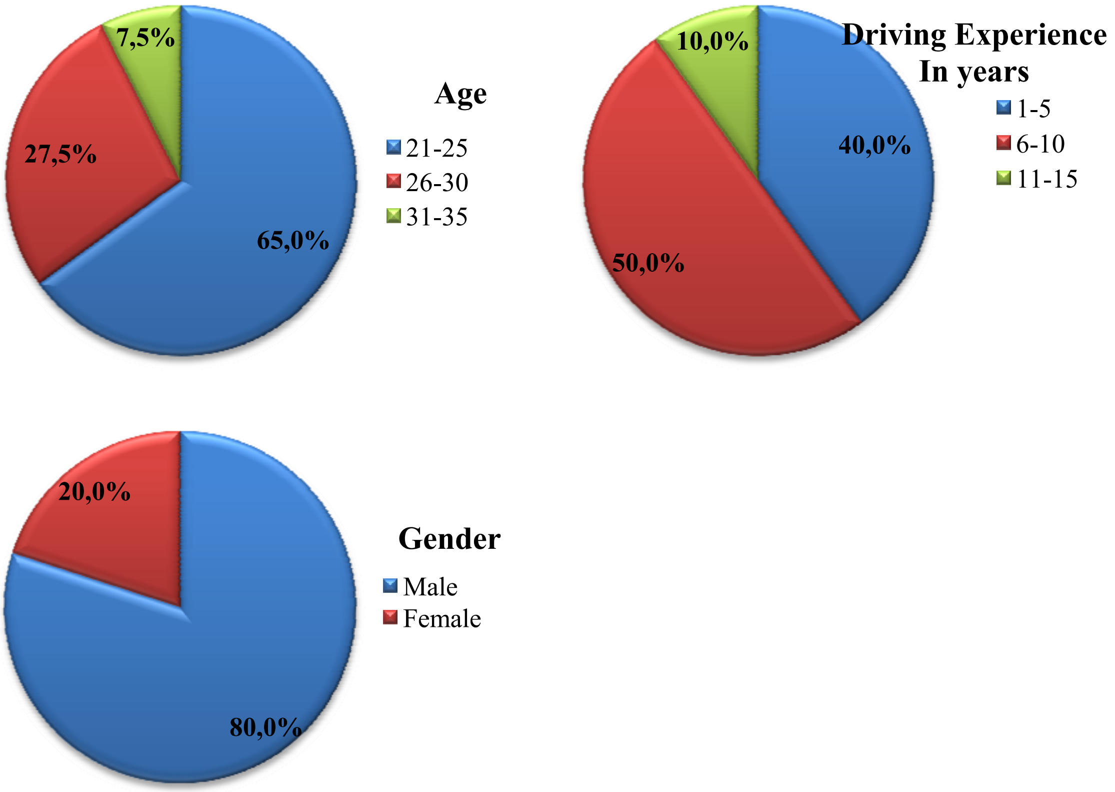


*Figure 11 - Demography*

### 2.2.4 Data collection

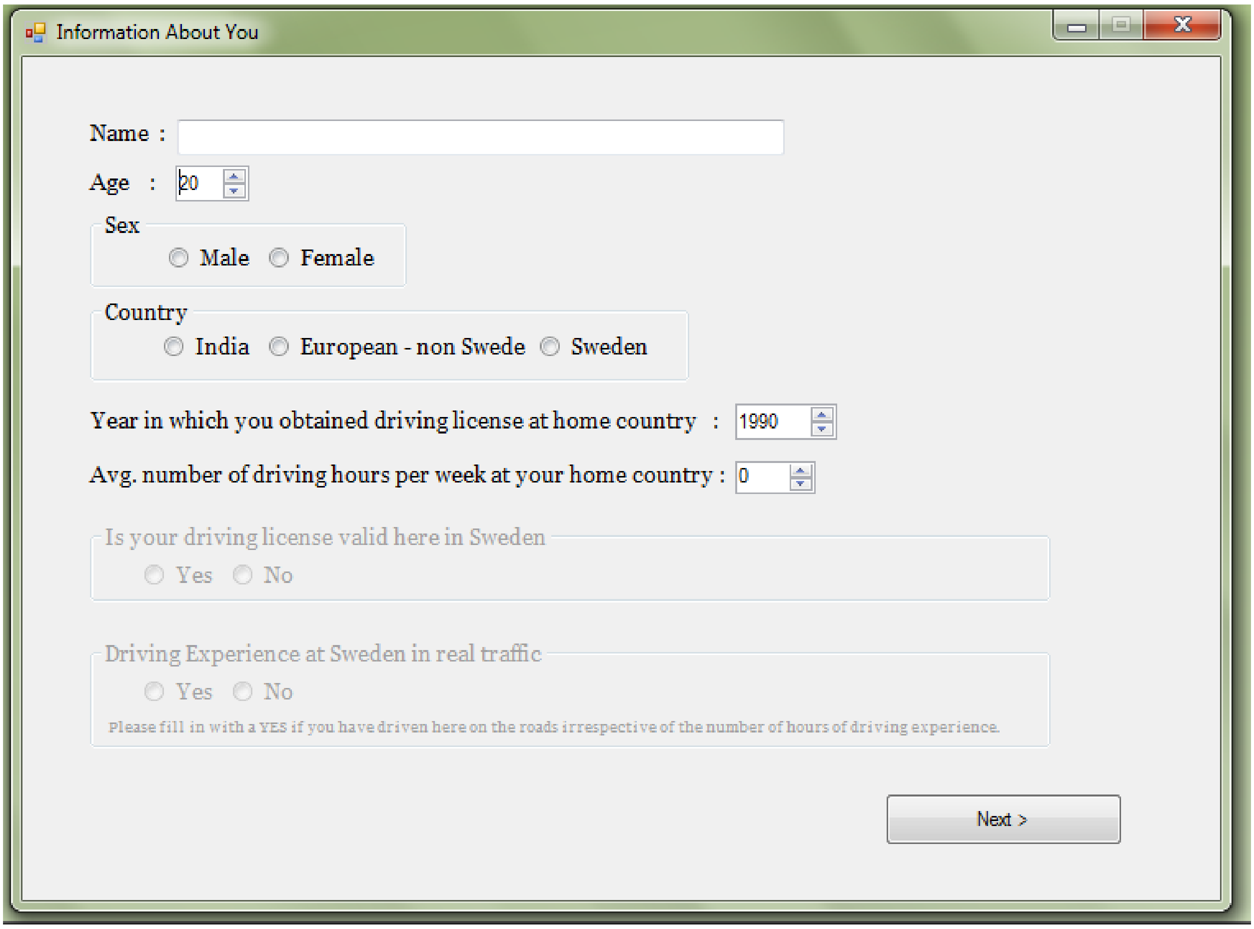
Data collection was simplified by the use of a Visual Basic form. This was used to collect all information that was required from the participants. This form guided the participants throughout the experiment. All the data collected was stored in excel.

#### 2.2.4.1 Visual Basic form

A Visual Basic project was designed with a total of 5 forms. As mentioned before, Excel was used to store the data collected.

The excel workbook created for storage contained 4 sheets – "India" , "Europe" , "val" , "random". The need and the way in which data was written into the sheets and read from the sheets dynamically are explained in this section.

A large scale from 1 to 100 was used to collect rating data from the participants. The large scale helped the participants breathe free while rating as a small scale will make the process much harder(Brown & Paschound, Rational Choice and Judgement).



Name :

Age : 20

Sex
○ Male ○ Female

Country
○ India ○ European - non Swede ○ Sweden

Year in which you obtained driving license at home country : 1990

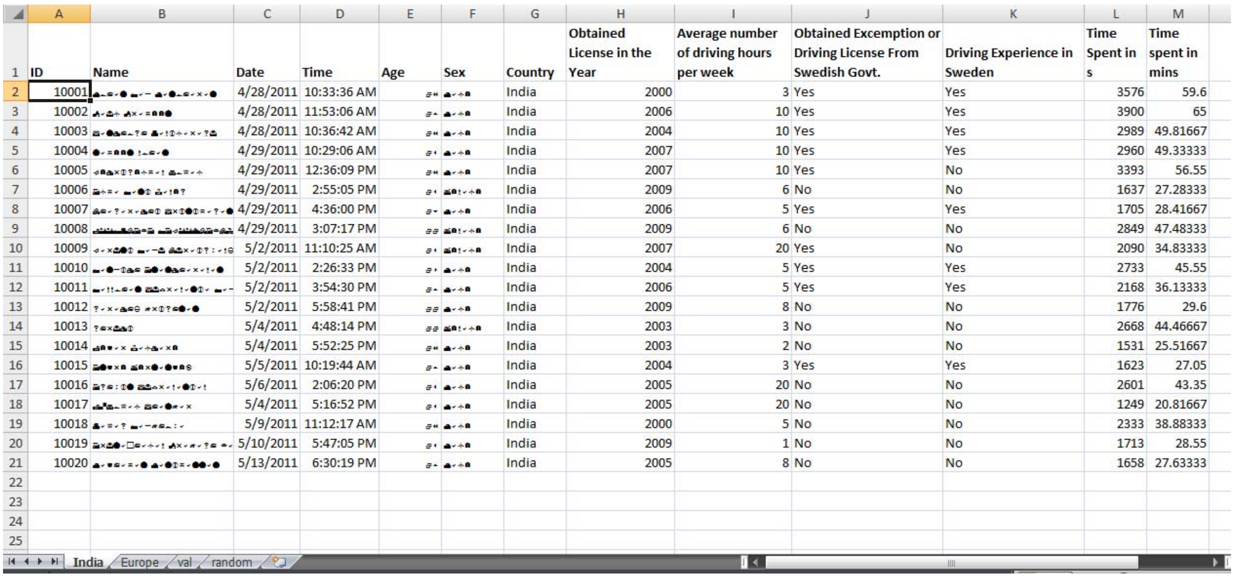
Avg. number of driving hours per week at your home country : 0

Is your driving license valid here in Sweden
○ Yes ○ No

Driving Experience at Sweden in real traffic
○ Yes ○ No
Please fill in with a YES if you have driven here on the roads irrespective of the number of hours of driving experience.

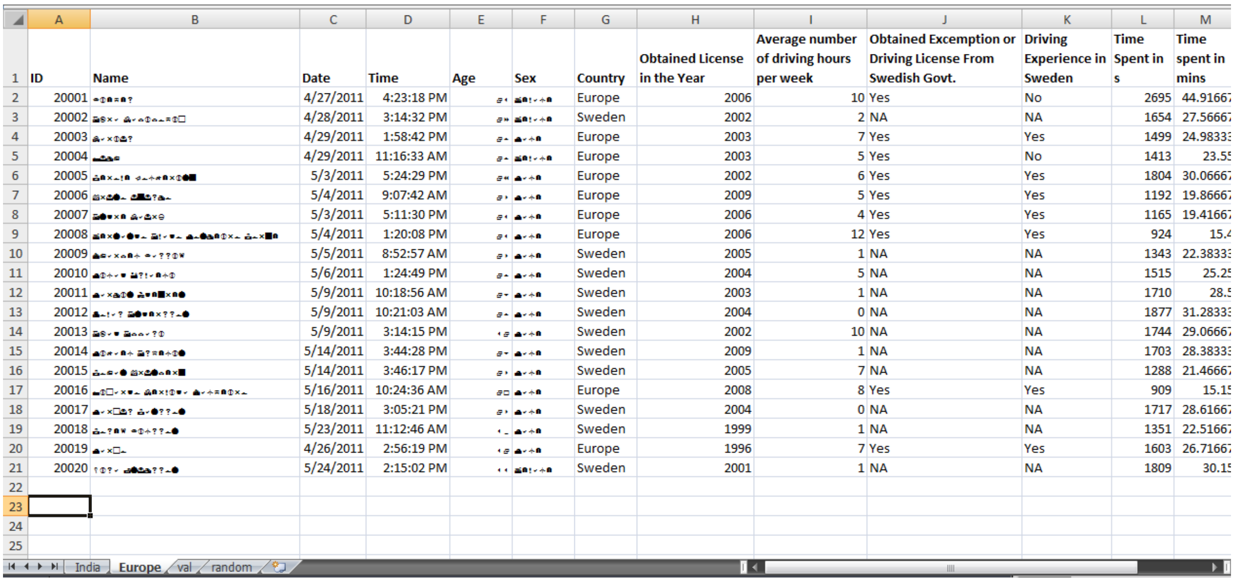
*Figure 12 - VB form (1/5) - Personal Data*

Figure 12 shows the first of the forms. This was used to collect all the required data from the participants. Based on the country chosen by the participant, the data from this form was written into either of the two sheets, "India" or "Europe".



| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ID | Name | Date | Time | Age | Sex | Country | Obtained License in the Year | Average number of driving hours per week | Obtained Exception or Driving License From Swedish Govt. | Driving Experience in Sweden | Time Spent in s | Time spent in mins |
| 2 | 10001 | [illegible] | 4/28/2011 | 10:33:36 AM | [illegible] | [illegible] | India | 2000 | 3 | Yes | Yes | 3576 | 59.6 |
| 3 | 10002 | [illegible] | 4/28/2011 | 11:53:06 AM | [illegible] | [illegible] | India | 2006 | 10 | Yes | Yes | 3900 | 65 |
| 4 | 10003 | [illegible] | 4/28/2011 | 10:36:42 AM | [illegible] | [illegible] | India | 2004 | 10 | Yes | Yes | 2989 | 49.81667 |
| 5 | 10004 | [illegible] | 4/29/2011 | 10:29:06 AM | [illegible] | [illegible] | India | 2007 | 10 | Yes | Yes | 2960 | 49.33333 |
| 6 | 10005 | [illegible] | 4/29/2011 | 12:36:09 PM | [illegible] | [illegible] | India | 2007 | 10 | Yes | No | 3393 | 56.55 |
| 7 | 10006 | [illegible] | 4/29/2011 | 2:55:05 PM | [illegible] | [illegible] | India | 2009 | 6 | No | No | 1637 | 27.28333 |
| 8 | 10007 | [illegible] | 4/29/2011 | 4:36:00 PM | [illegible] | [illegible] | India | 2006 | 5 | Yes | Yes | 1705 | 28.41667 |
| 9 | 10008 | [illegible] | 4/29/2011 | 3:07:17 PM | [illegible] | [illegible] | India | 2009 | 6 | No | No | 2849 | 47.48333 |
| 10 | 10009 | [illegible] | 5/2/2011 | 11:10:25 AM | [illegible] | [illegible] | India | 2007 | 20 | Yes | No | 2090 | 34.83333 |
| 11 | 10010 | [illegible] | 5/2/2011 | 2:26:33 PM | [illegible] | [illegible] | India | 2004 | 5 | Yes | Yes | 2733 | 45.55 |
| 12 | 10011 | [illegible] | 5/2/2011 | 3:54:30 PM | [illegible] | [illegible] | India | 2006 | 5 | Yes | Yes | 2168 | 36.13333 |
| 13 | 10012 | [illegible] | 5/2/2011 | 5:58:41 PM | [illegible] | [illegible] | India | 2009 | 8 | No | No | 1776 | 29.6 |
| 14 | 10013 | [illegible] | 5/4/2011 | 4:48:14 PM | [illegible] | [illegible] | India | 2003 | 3 | No | No | 2668 | 44.46667 |
| 15 | 10014 | [illegible] | 5/4/2011 | 5:52:25 PM | [illegible] | [illegible] | India | 2003 | 2 | No | No | 1531 | 25.51667 |
| 16 | 10015 | [illegible] | 5/5/2011 | 10:19:44 AM | [illegible] | [illegible] | India | 2004 | 3 | Yes | Yes | 1623 | 27.05 |
| 17 | 10016 | [illegible] | 5/6/2011 | 2:06:20 PM | [illegible] | [illegible] | India | 2005 | 20 | No | No | 2601 | 43.35 |
| 18 | 10017 | [illegible] | 5/4/2011 | 5:16:52 PM | [illegible] | [illegible] | India | 2005 | 20 | No | No | 1249 | 20.81667 |
| 19 | 10018 | [illegible] | 5/9/2011 | 11:12:17 AM | [illegible] | [illegible] | India | 2000 | 5 | No | No | 2333 | 38.88333 |
| 20 | 10019 | [illegible] | 5/10/2011 | 5:47:05 PM | [illegible] | [illegible] | India | 2009 | 1 | No | No | 1713 | 28.55 |
| 21 | 10020 | [illegible] | 5/13/2011 | 6:30:19 PM | [illegible] | [illegible] | India | 2005 | 8 | No | No | 1658 | 27.63333 |
| 22 | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | |

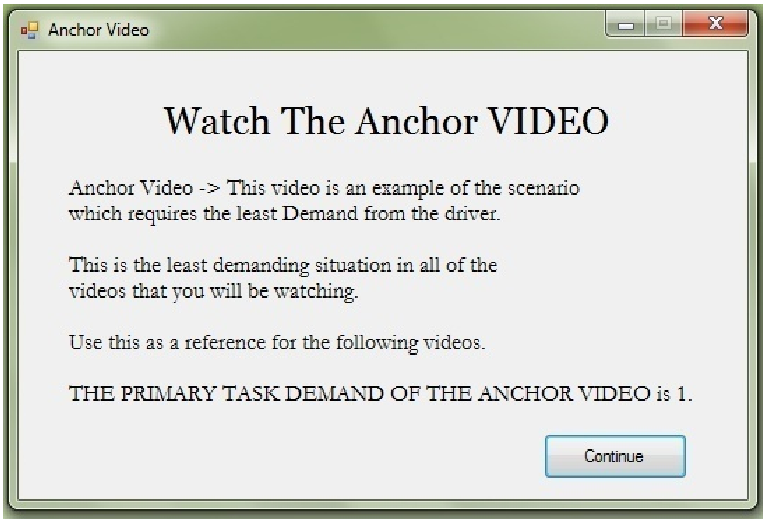
Figure 13 - Excel Sheet (1/4) - "India"



| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ID | Name | Date | Time | Age | Sex | Country | Obtained License in the Year | Average number of driving hours per week | Obtained Exception or Driving License From Swedish Govt. | Driving Experience in Sweden | Time Spent in s | Time spent in mins |
| 2 | 20001 | [illegible] | 4/27/2011 | 4:23:18 PM | [illegible] | [illegible] | Europe | 2006 | 10 | Yes | No | 2695 | 44.9166 |
| 3 | 20002 | [illegible] | 4/28/2011 | 3:14:32 PM | [illegible] | [illegible] | Sweden | 2002 | 2 | NA | NA | 1654 | 27.5666 |
| 4 | 20003 | [illegible] | 4/29/2011 | 1:58:42 PM | [illegible] | [illegible] | Europe | 2003 | 7 | Yes | Yes | 1499 | 24.9833 |
| 5 | 20004 | [illegible] | 4/29/2011 | 11:16:33 AM | [illegible] | [illegible] | Europe | 2003 | 5 | Yes | No | 1413 | 23.5 |
| 6 | 20005 | [illegible] | 5/3/2011 | 5:24:29 PM | [illegible] | [illegible] | Europe | 2002 | 6 | Yes | Yes | 1804 | 30.0666 |
| 7 | 20006 | [illegible] | 5/4/2011 | 9:07:42 AM | [illegible] | [illegible] | Europe | 2009 | 5 | Yes | Yes | 1192 | 19.8666 |
| 8 | 20007 | [illegible] | 5/3/2011 | 5:11:30 PM | [illegible] | [illegible] | Europe | 2006 | 4 | Yes | Yes | 1165 | 19.4166 |
| 9 | 20008 | [illegible] | 5/4/2011 | 1:20:08 PM | [illegible] | [illegible] | Europe | 2006 | 12 | Yes | Yes | 924 | 15. |
| 10 | 20009 | [illegible] | 5/5/2011 | 8:52:57 AM | [illegible] | [illegible] | Sweden | 2005 | 1 | NA | NA | 1343 | 22.3833 |
| 11 | 20010 | [illegible] | 5/6/2011 | 1:24:49 PM | [illegible] | [illegible] | Sweden | 2004 | 5 | NA | NA | 1515 | 25.2 |
| 12 | 20011 | [illegible] | 5/9/2011 | 10:18:56 AM | [illegible] | [illegible] | Sweden | 2003 | 1 | NA | NA | 1710 | 28. |
| 13 | 20012 | [illegible] | 5/9/2011 | 10:21:03 AM | [illegible] | [illegible] | Sweden | 2004 | 0 | NA | NA | 1877 | 31.2833 |
| 14 | 20013 | [illegible] | 5/9/2011 | 3:14:15 PM | [illegible] | [illegible] | Sweden | 2002 | 10 | NA | NA | 1744 | 29.0666 |
| 15 | 20014 | [illegible] | 5/14/2011 | 3:44:28 PM | [illegible] | [illegible] | Sweden | 2009 | 1 | NA | NA | 1703 | 28.3833 |
| 16 | 20015 | [illegible] | 5/14/2011 | 3:46:17 PM | [illegible] | [illegible] | Sweden | 2005 | 7 | NA | NA | 1288 | 21.4666 |
| 17 | 20016 | [illegible] | 5/16/2011 | 10:24:36 AM | [illegible] | [illegible] | Europe | 2008 | 8 | Yes | Yes | 909 | 15.1 |
| 18 | 20017 | [illegible] | 5/18/2011 | 3:05:21 PM | [illegible] | [illegible] | Sweden | 2004 | 0 | NA | NA | 1717 | 28.6166 |
| 19 | 20018 | [illegible] | 5/23/2011 | 11:12:46 AM | [illegible] | [illegible] | Sweden | 1999 | 1 | NA | NA | 1351 | 22.5166 |
| 20 | 20019 | [illegible] | 4/26/2011 | 2:56:19 PM | [illegible] | [illegible] | Europe | 1996 | 7 | Yes | Yes | 1603 | 26.7166 |
| 21 | 20020 | [illegible] | 5/24/2011 | 2:15:02 PM | [illegible] | [illegible] | Sweden | 2001 | 1 | NA | NA | 1809 | 30.1 |
| 22 | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | |

Figure 14 - Excel Sheet (2/4) - "Europe"

Figure 13 and Figure 14 shows the excel sheet that was used to store data from the form. The ID was created dynamically once the participant completed the first form (Figure 12). This was also dependent on the Country of the participant; participants from India and Europe were IDed in the series starting from 10001 and 20001 respectively. The name and other personal details of each of the participant were stored only for our reference.


Anchor Video

Watch The Anchor VIDEO

Anchor Video -> This video is an example of the scenario which requires the least Demand from the driver.

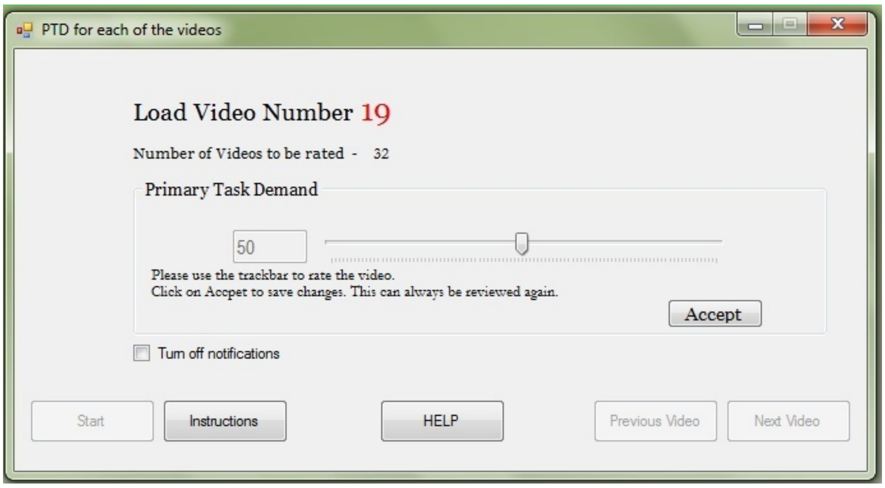
This is the least demanding situation in all of the videos that you will be watching.

Use this as a reference for the following videos.

THE PRIMARY TASK DEMAND OF THE ANCHOR VIDEO is 1.

*Figure 15 - VB form (2/5) - Anchor Video*

Figure 15 shows the second form that popped up after collecting the personal data from the users. This form instructed the users to watch the “Anchor Video”. As mentioned in section 2.2.2, the anchor video has the easiest scenario and the demand was practically assumed to be “1”. The participants were suggested to use this video as a reference. Upon clicking ‘Continue’ in the above figure, the next form, Figure 16 loaded.


PTD for each of the videos

Load Video Number 19

Number of Videos to be rated - 32

Primary Task Demand

50

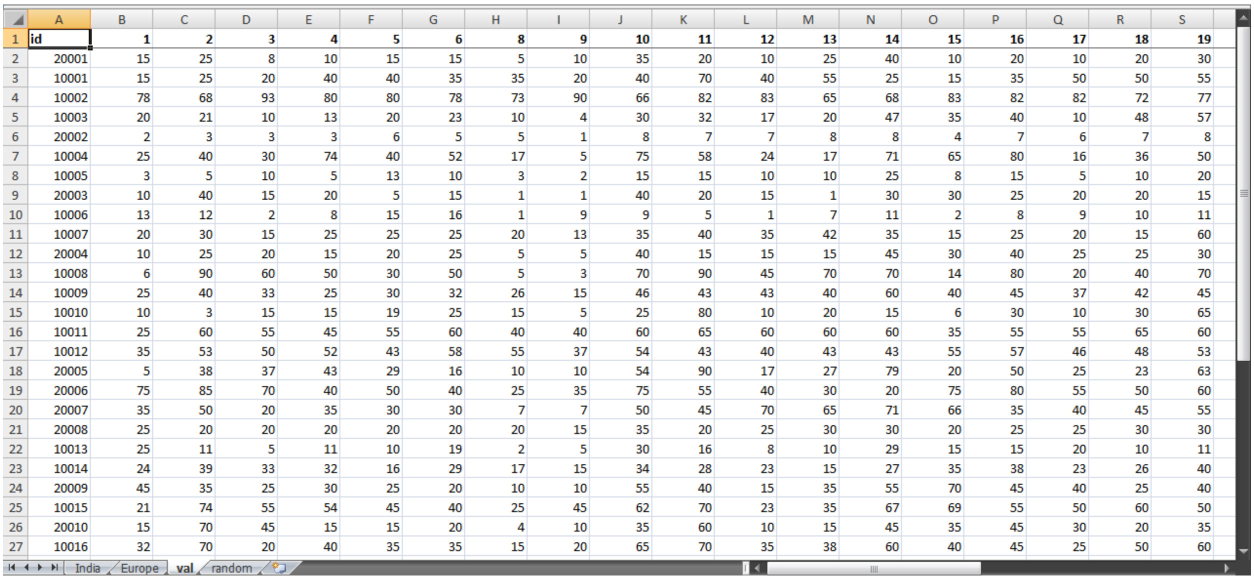
Please use the trackbar to rate the video.
Click on Accept to save changes. This can always be reviewed again.

☐ Turn off notifications

*Figure 16 - VB form (3/5) - Rating for Videos*

This was the form that was used to obtain ratings for all the videos that were shown to the participant. In Figure 16, the number shown in red colour, ‘19’ suggested the participant to load the corresponding video from the FOT systems. The scroll bar had a default value of 50 and ranged from 1 to 100. The value set in this scroll bar is displayed in the text box besides it. Once the rating for a video was set, ‘Accept’ was used to confirm it to the programme and this rating was stored at a temporary array in the programme. The ‘Next Video’ and ‘Previous Video’ buttons helped the participant to moves about the entire range of 32 videos that required rating.

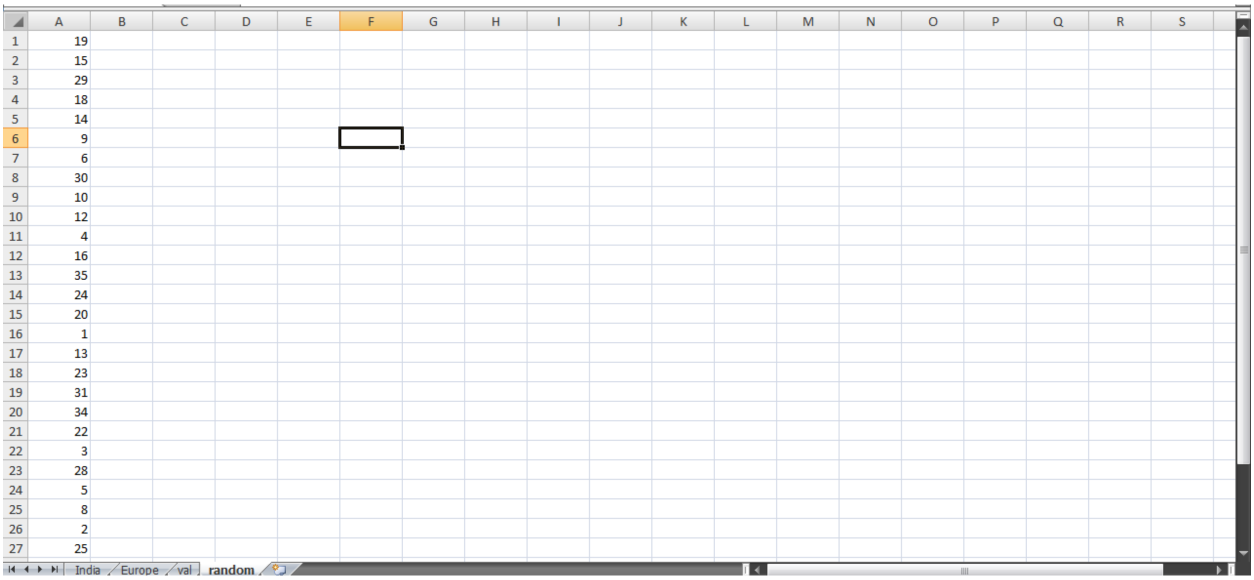
This helped a participant to return back to an earlier video and modify his already set rating. Finally after rating all the 32 videos, a confirmation was obtained from the user and the ratings were stored into the same excel file in the sheet ‘val’ as shown in Figure 17.



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **id** | **1** | **2** | **3** | **4** | **5** | **6** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| 2 | 20001 | 15 | 25 | 8 | 10 | 15 | 15 | 5 | 10 | 35 | 20 | 10 | 25 | 40 | 10 | 20 | 10 | 20 | 30 |
| 3 | 10001 | 15 | 25 | 20 | 40 | 40 | 35 | 35 | 20 | 40 | 70 | 40 | 55 | 25 | 15 | 35 | 50 | 50 | 55 |
| 4 | 10002 | 78 | 68 | 93 | 80 | 80 | 78 | 73 | 90 | 66 | 82 | 83 | 65 | 68 | 83 | 82 | 82 | 72 | 77 |
| 5 | 10003 | 20 | 21 | 10 | 13 | 20 | 23 | 10 | 4 | 30 | 32 | 17 | 20 | 47 | 35 | 40 | 10 | 48 | 57 |
| 6 | 20002 | 2 | 3 | 3 | 3 | 6 | 5 | 5 | 1 | 8 | 7 | 7 | 8 | 8 | 4 | 7 | 6 | 7 | 8 |
| 7 | 10004 | 25 | 40 | 30 | 74 | 40 | 52 | 17 | 5 | 75 | 58 | 24 | 17 | 71 | 65 | 80 | 16 | 36 | 50 |
| 8 | 10005 | 3 | 5 | 10 | 5 | 13 | 10 | 3 | 2 | 15 | 15 | 10 | 10 | 25 | 8 | 15 | 5 | 10 | 20 |
| 9 | 20003 | 10 | 40 | 15 | 20 | 5 | 15 | 1 | 1 | 40 | 20 | 15 | 1 | 30 | 30 | 25 | 20 | 20 | 15 |
| 10 | 10006 | 13 | 12 | 2 | 8 | 15 | 16 | 1 | 9 | 9 | 5 | 1 | 7 | 11 | 2 | 8 | 9 | 10 | 11 |
| 11 | 10007 | 20 | 30 | 15 | 25 | 25 | 25 | 20 | 13 | 35 | 40 | 35 | 42 | 35 | 15 | 25 | 20 | 15 | 60 |
| 12 | 20004 | 10 | 25 | 20 | 15 | 20 | 25 | 5 | 5 | 40 | 15 | 15 | 15 | 45 | 30 | 40 | 25 | 25 | 30 |
| 13 | 10008 | 6 | 90 | 60 | 50 | 30 | 50 | 5 | 3 | 70 | 90 | 45 | 70 | 70 | 14 | 80 | 20 | 40 | 70 |
| 14 | 10009 | 25 | 40 | 33 | 25 | 30 | 32 | 26 | 15 | 46 | 43 | 43 | 40 | 60 | 40 | 45 | 37 | 42 | 45 |
| 15 | 10010 | 10 | 3 | 15 | 15 | 19 | 25 | 15 | 5 | 25 | 80 | 10 | 20 | 15 | 6 | 30 | 10 | 30 | 65 |
| 16 | 10011 | 25 | 60 | 55 | 45 | 55 | 60 | 40 | 40 | 60 | 65 | 60 | 60 | 60 | 35 | 55 | 55 | 65 | 60 |
| 17 | 10012 | 35 | 53 | 50 | 52 | 43 | 58 | 55 | 37 | 54 | 43 | 40 | 43 | 43 | 55 | 57 | 46 | 48 | 53 |
| 18 | 20005 | 5 | 38 | 37 | 43 | 29 | 16 | 10 | 10 | 54 | 90 | 17 | 27 | 79 | 20 | 50 | 25 | 23 | 63 |
| 19 | 20006 | 75 | 85 | 70 | 40 | 50 | 40 | 25 | 35 | 75 | 55 | 40 | 30 | 20 | 75 | 80 | 55 | 50 | 60 |
| 20 | 20007 | 35 | 50 | 20 | 35 | 30 | 30 | 7 | 7 | 50 | 45 | 70 | 65 | 71 | 66 | 35 | 40 | 45 | 55 |
| 21 | 20008 | 25 | 20 | 20 | 20 | 20 | 20 | 20 | 15 | 35 | 20 | 25 | 30 | 30 | 20 | 25 | 25 | 30 | 30 |
| 22 | 10013 | 25 | 11 | 5 | 11 | 10 | 19 | 2 | 5 | 30 | 16 | 8 | 10 | 29 | 15 | 15 | 20 | 10 | 11 |
| 23 | 10014 | 24 | 39 | 33 | 32 | 16 | 29 | 17 | 15 | 34 | 28 | 23 | 15 | 27 | 35 | 38 | 23 | 26 | 40 |
| 24 | 20009 | 45 | 35 | 25 | 30 | 25 | 20 | 10 | 10 | 55 | 40 | 15 | 35 | 55 | 70 | 45 | 40 | 25 | 40 |
| 25 | 10015 | 21 | 74 | 55 | 54 | 45 | 40 | 25 | 45 | 62 | 70 | 23 | 35 | 67 | 69 | 55 | 50 | 60 | 50 |
| 26 | 20010 | 15 | 70 | 45 | 15 | 15 | 20 | 4 | 10 | 35 | 60 | 10 | 15 | 45 | 35 | 45 | 30 | 20 | 35 |
| 27 | 10016 | 32 | 70 | 20 | 40 | 35 | 35 | 15 | 20 | 65 | 70 | 35 | 38 | 60 | 40 | 45 | 25 | 50 | 60 |

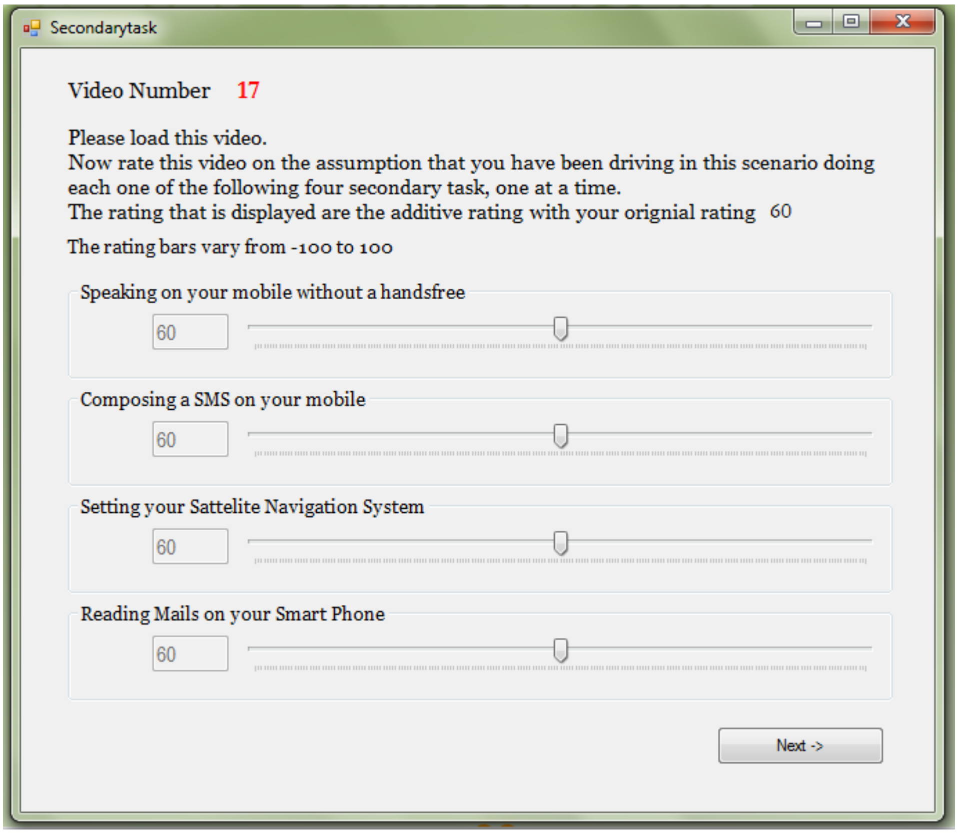
Figure 17 - Excel Sheet (3/4) - "val"

In the ratings form (Figure 16) the video number to be loaded was randomized in order to eliminate any trend formation. This was done in a very simple method. The numbers from 1-32 were randomized in the Excel Workbook ‘users’ in sheet ‘random’ (Figure 18). This column was randomized after every participant finished rating. The value in each of the cell was read into the VB programme as an array and was displayed.



| | A |
|---|---|
| 1 | 19 |
| 2 | 15 |
| 3 | 29 |
| 4 | 18 |
| 5 | 14 |
| 6 | 9 |
| 7 | 6 |
| 8 | 30 |
| 9 | 10 |
| 10 | 12 |
| 11 | 4 |
| 12 | 16 |
| 13 | 35 |
| 14 | 24 |
| 15 | 20 |
| 16 | 1 |
| 17 | 13 |
| 18 | 23 |
| 19 | 31 |
| 20 | 34 |
| 21 | 22 |
| 22 | 3 |
| 23 | 28 |
| 24 | 5 |
| 25 | 8 |
| 26 | 2 |
| 27 | 25 |

Figure 18 - Excel Sheet (3/4) - "random"



Secondarytask

Video Number 17

Please load this video.
Now rate this video on the assumption that you have been driving in this scenario doing each one of the following four secondary task, one at a time.
The rating that is displayed are the additive rating with your orignial rating 60

The rating bars vary from -100 to 100

Speaking on your mobile without a handsfree: 60

Composing a SMS on your mobile: 60

Setting your Sattelite Navigation System: 60

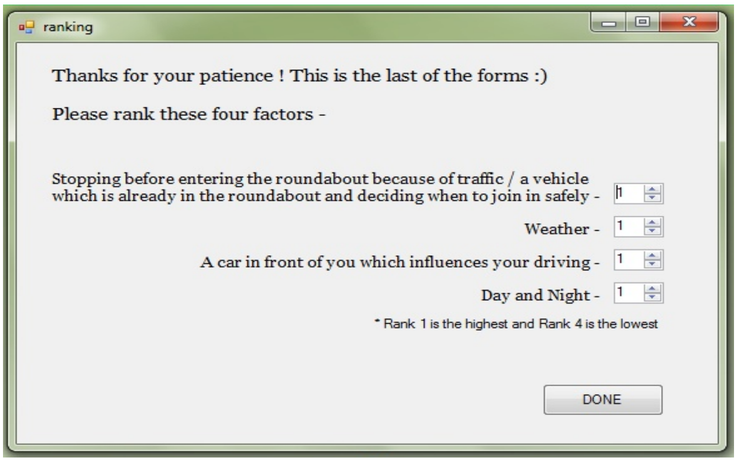
Reading Mails on your Smart Phone: 60

*Figure 19 - VB form (4/5) - Rating for Secondary Task*

On completing the ratings for all the 32 videos, the video that was rated to be the most demanding i.e. the one with the highest value, was then carried over to the form shown in the Figure 19. The rating that was already set for this video was carried over from the previous form and displayed in each of the text boxes for each of the four secondary tasks.

The participant was then advised to affect this rating assuming that he/she was driving in the same scenario but now doing a secondary task. The slider shown besides each of the text boxes ranged from -100 to 100 with a default value of ‘0’. This was an additive scale and the value in the text box besides the scroll bar displayed the net value of the value from the scale and the initial value set for the video.

On clicking ‘Next’, the values from each of the four secondary tasks were stored in the same Excel Workbook in sheet ‘val’ (Figure 18) corresponding to the participant ID.



Thanks for your patience ! This is the last of the forms :)

Please rank these four factors -

Stopping before entering the roundabout because of traffic / a vehicle which is already in the roundabout and deciding when to join in safely - 1

Weather - 1

A car in front of you which influences your driving - 1

Day and Night - 1

* Rank 1 is the highest and Rank 4 is the lowest

*Figure 20 - VB form (5/5) - Ranking the four factors*

Finally, Figure 20 was the last of the forms that showed up to the participant. The participant was instructed to rate the four factors amongst themselves (Rank 1 being the most important). This was later used for “Spearman’s Correlation Test”.

Spearman’s Test was used to confirm the correlation between the subjective ratings and the subjective rankings given by the participants. This ensured that the participants rated the video for the factors that formed the mathematical model.

### 2.2.5 Data handling

The values stored in Excel were used for analysis and creation of the mathematical model. The data had to be processed to make them comparable in the first place (Field, 2005)–

1. The data was initially normalized. Each of the participants’ maximum and minimum values was used to normalize the data between 1 and 100. In this way the ratings from different participants were made comparable.
2. As already mentioned, there were a total of 16 combinations and 2 videos were chosen for each of the combination leading to 32 videos. The normalized ratings of similar scenarios were then averaged to form final 16 ratings per participant.
3. Kendal’s Rank Correlation was used to verify the acceptance of ratings amongst the participants. This test evaluates the degree of similarity in ranking between different participants for the same set of objects (videos in this case). This was carried out to find if all the participants agreed in the degree of demand for each scenario amongst them.
4. SPSS was used to perform univariate anova inorder to analyse the significance of each of the factors. Further, the model was fit and validated in SPSS.

## 2.3 Mathematical model of primary task demand

The data obtained from participants was converted to comparable form and tested for concordance as discussed in section 2.2.5. The data being linear in nature, a linear fit was used to form the mathematical model.

GLMFIT – Generalized Linear Regression was used in Matlab to fit a model to the data. The model created will be of the form –

$$\mathbf{TaskDemand} = \boldsymbol{\beta}_\mathbf{0} + (\boldsymbol{\beta}_\mathbf{1} \times Weather) + (\boldsymbol{\beta}_\mathbf{2} \times Stopandgo) + (\boldsymbol{\beta}_\mathbf{3} \times Timeofday) + (\boldsymbol{\beta}_\mathbf{4} \times Car\ in\ front).$$

In the above equation $\beta_0$ is a constant and $\beta_1$, $\beta_2$, $\beta_3$ and $\beta_4$ are the regression weights for the four factors. To achieve this model, regression was performed by giving the following as input.

1. In the above equation, the expression on the LHS, 'Task Demand' refers to the values that were obtained from the participants.
2. The values for each of the four factors, 'Weather', 'Stop and go', 'Time of day' and 'Car in front' are derived from Table 4 as follows (Table 5) –
    - Weather – Good relates to 1 and Bad to 0
    - Stop and go – Yes relates to 1 and No to 0
    - Time of day – Day relates to 1 and Night to 0
    - Car in front – Yes relates to 1 and No to 0

3. Giving the values of ‘Task Demand’, and the four factors, ‘Weather’, ‘Stop and go’, ‘Time of day’ and ‘Car in front’ as input to GLMFIT, the values for the regression weights were found. The model is later discussed in detail in this document.

*Table 5 - Input for Regression*

| | Weather | Stop Go | Time of Day | Car in Front |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 0 | 0 |
| 3 | 0 | 1 | 0 | 0 |
| 4 | 1 | 1 | 0 | 0 |
| 5 | 0 | 0 | 1 | 0 |
| 6 | 1 | 0 | 1 | 0 |
| 7 | 0 | 1 | 1 | 0 |
| 8 | 1 | 1 | 1 | 0 |
| 9 | 0 | 0 | 0 | 1 |
| 10 | 1 | 0 | 0 | 1 |
| 11 | 0 | 1 | 0 | 1 |
| 12 | 1 | 1 | 0 | 1 |
| 13 | 0 | 0 | 1 | 1 |
| 14 | 1 | 0 | 1 | 1 |
| 15 | 0 | 1 | 1 | 1 |
| 16 | 1 | 1 | 1 | 1 |

# 3 Results

## 3.1 Primary Task Demand over the populations

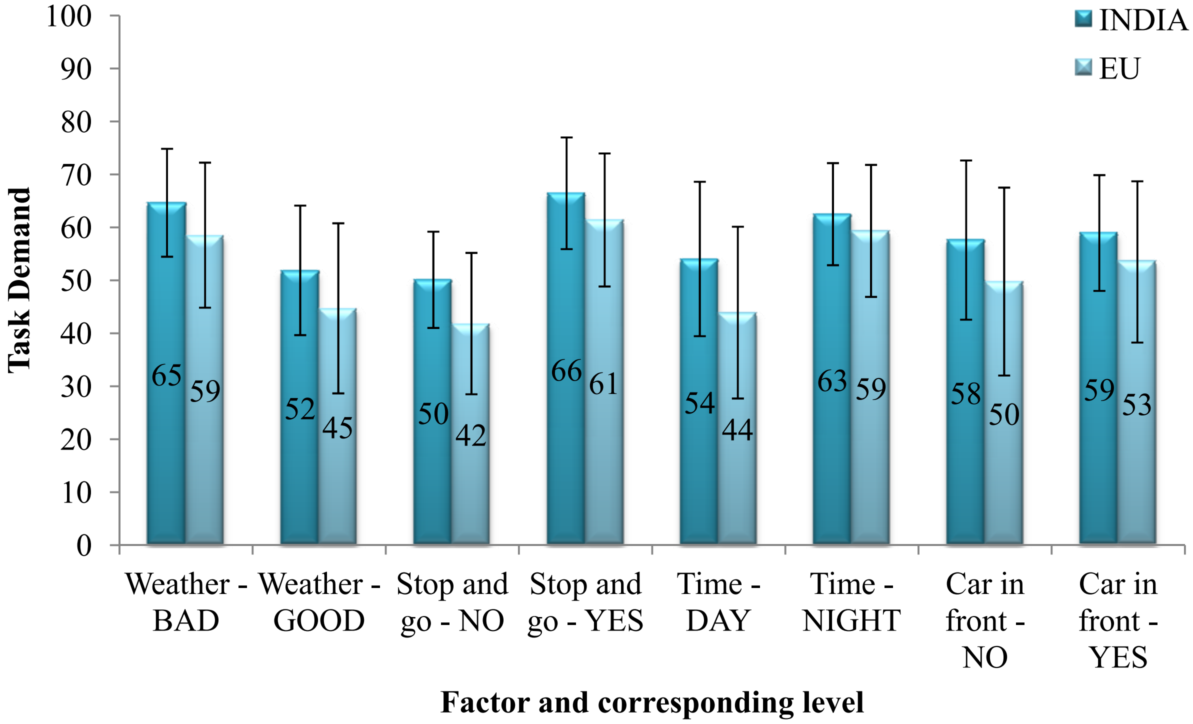


*Figure 21 – Factor comparison – Single level (Indians Vs Europeans)*

Figure 21 shows the average of primary task demand as rated separately by populations over each level of the four factors considered.

- As agreed by both the population, the highest rated scenario is the one with the presence of the factor ‘Stop and Go’.
- It can also be inferred from this plot that all Indians are consistent in rating the task demand to be higher than that of the Europeans.
- Both Indians and Europeans agree on the manoeuvre with stop and go to be highly demanding
- Secondly both populations also agree with the scenario of bad weather.

The drawback of this plot is that it does not show how demanding is a factor separately is. Hence a plot has to be made which shows a difference between a factor’s presence and absence. Figure 22 shows the difference in primary task demand for the presence and absence of a factor.

## 3.2 Difference of Primary Task Demand over the Factors

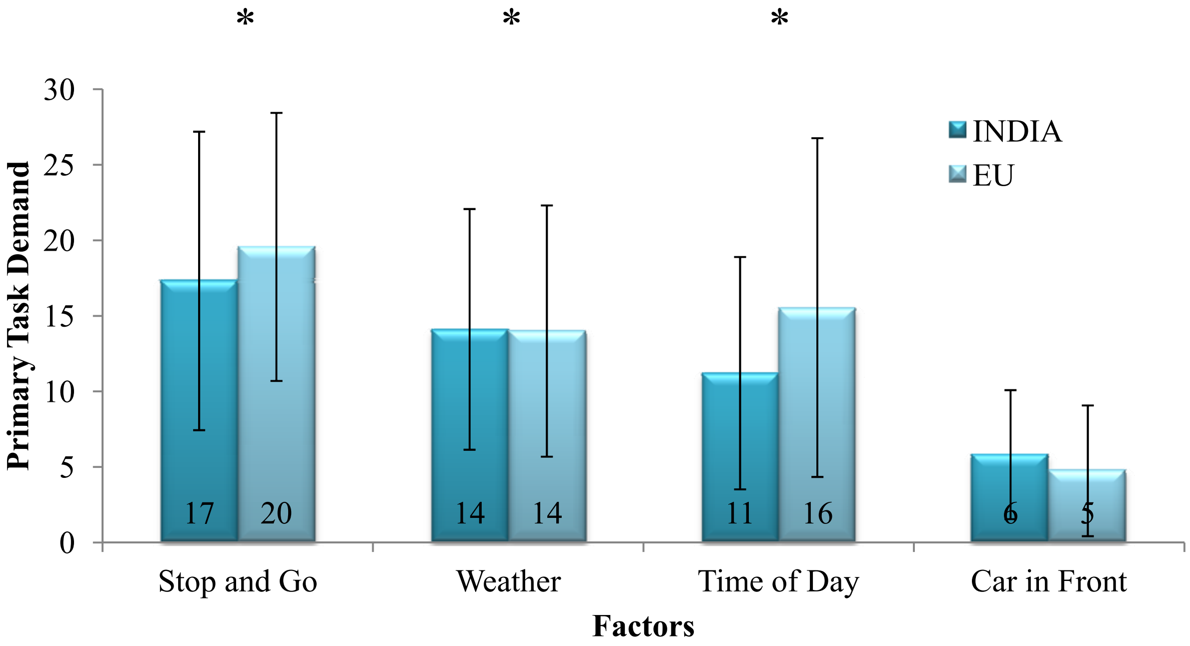


Figure 22 – Difference in Primary task demand Vs Factors

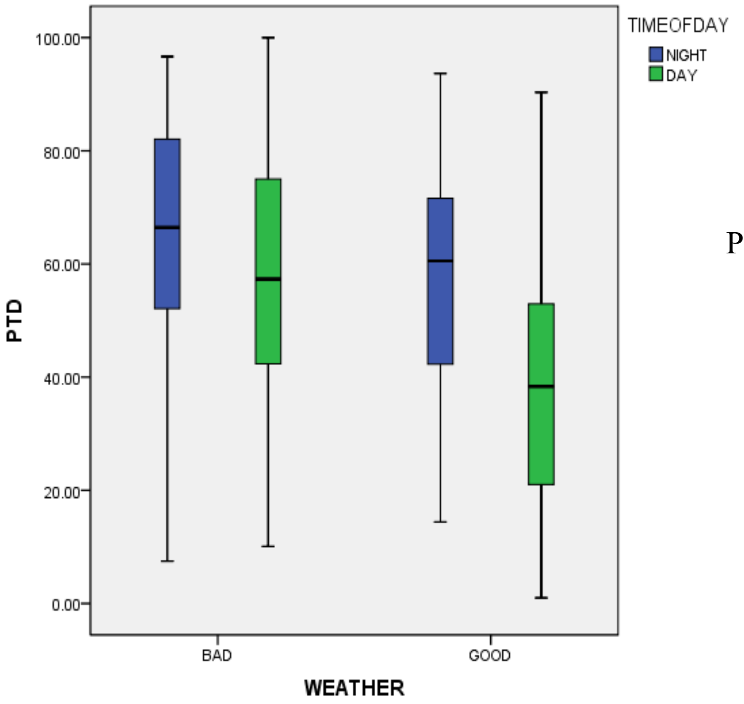
The difference between the primary task demands for each factor's within their levels is shown in Figure 22. Univariate ANOVA was conducted between each of the factors and primary task demand. The results showed that three factors stop and go, time of day and weather were statistically significant but car in front was not. Hence from here on only these three factors will be considered for further analysis and model development. This plot implies that

- Stop and go is the most demanding scenario and both the Europeans and Indians are in agreement. It is to be noted that Europeans feel this factor to be more demanding than the Indians.
- The next demanding factor is the weather for both the Indians and Europeans and there is no difference in perception of weather between the populations.
- The third factor is time of day, which mainly relates to the amount of daylight present during the trip. Europeans state that driving without daylight is more demanding than the Indians and this could be related to the big difference in daylight change between the winter and the other seasons.

The ANOVA results also showed the existence of some significant interaction between the considered factors. Hence a two box plots were plotted in SPSS statistical analysis tool to study the effect of interaction factors.

## 3.3 Interaction Factors

### 3.3.1 Weather over Time of Day



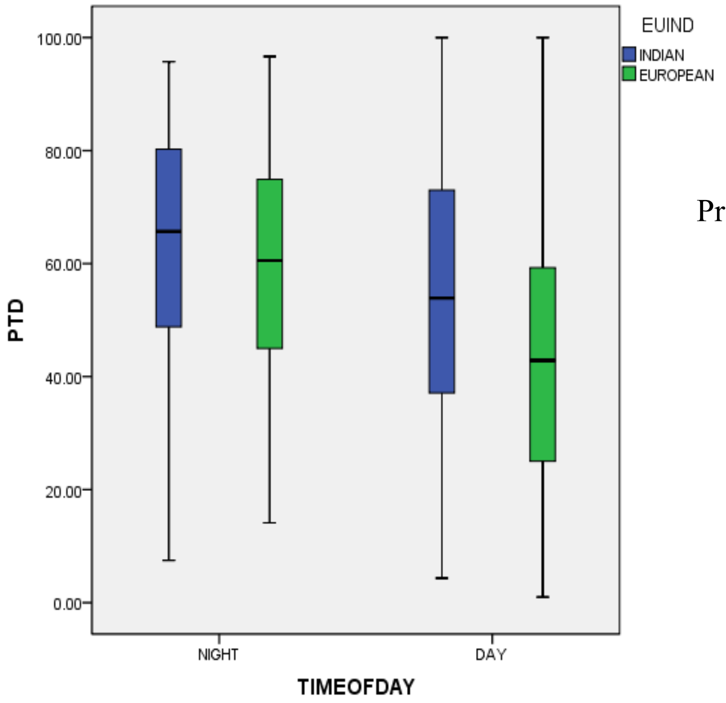
Probability – 0

*Figure 23 – Boxplot for Weather and Time of day (Interaction factor)*

This box plot shows the distribution of primary task demand against weather and time of day. It can be inferred from Figure 23 that,

- A significant difference can be noted between the means of the distribution of time of day and weather.
- When the weather is the good and there is presence of daylight, the distribution of primary task demand is low. But when the weather is good and time of day is night the distribution of primary task demand is relatively high.

### 3.3.2 Time of Day over Population



Probability – 0.02

*Figure 24 – Boxplot for population and time of day (Interaction factor)*

Figure 24 shows the distribution of primary task demand against time of day and population. It could be understood from this plot that there exists a significant difference in primary task demand during day between Indians and Europeans. The distribution of task demand for European population is significantly lesser than that of the Indians.

## 3.4 The Model

The three statistically significant factors were considered for the development of the mathematical model. Models are abstract, simplified representations of reality, often used both in science and in technology. The generalized linear model uses the linear regression and in addition to it a link function can be added to involve a variety of distributions thus linking the regression part to the mean of one of these distributions(Lindsey, 1997).

This model was created with the data from all participants. Generalized linear model in MATLAB was used to find the regression coefficients of each of the considered factors.

$$\mathbf{TaskDemand} = \boldsymbol{\beta_0} + (\boldsymbol{\beta_1} \times Weather) + (\boldsymbol{\beta_2} \times Stopandgo) + (\boldsymbol{\beta_3} \times Timeofday)$$

Where,

$\beta_0$ – constant

$\beta_1$ – regression coefficient for factor ‘Weather’

$\beta_2$ – regression coefficient for factor ‘Stop and go’

$\beta_3$ – regression coefficient for the factor ‘Time of day’

*Table 6 – Regression coefficients for different models*

| Weights | India | Europe | Overall |
|---|---|---|---|
| **$\beta_0$** | 60.71 | 56.47 | 58.59 |
| **$\beta_1$** | -12.76 | -13.81 | -13.29 |
| **$\beta_2$** | 16.35 | 19.56 | 17.96 |
| **$\beta_3$** | -8.46 | -15.44 | -11.95 |

Table 6 shows the regression coefficients of the considered factors for Indian, European and overall models respectively.

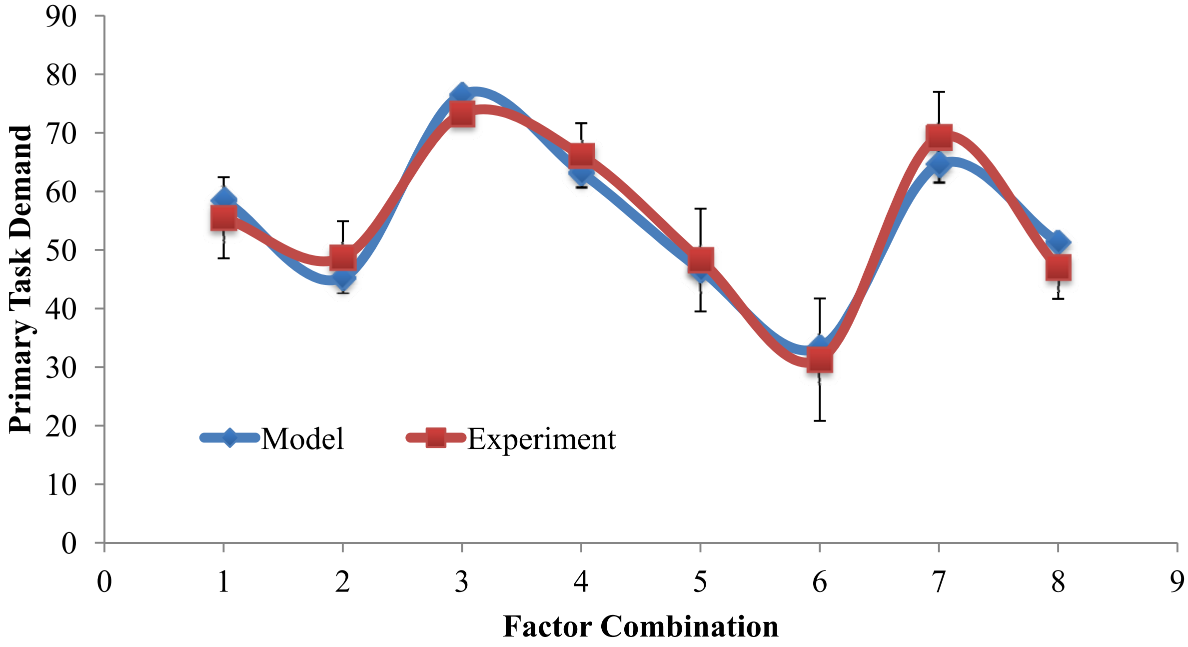


*Figure 25 – Model comparison with data from experiment*

The primary task demand estimate from of the model for each combination of factors was compared with the average of values from the experiment. It can be inferred that the model copes up with the values from the experiment for each of the combination of factors. The trend followed by the model is similar to that of the average values from participants.

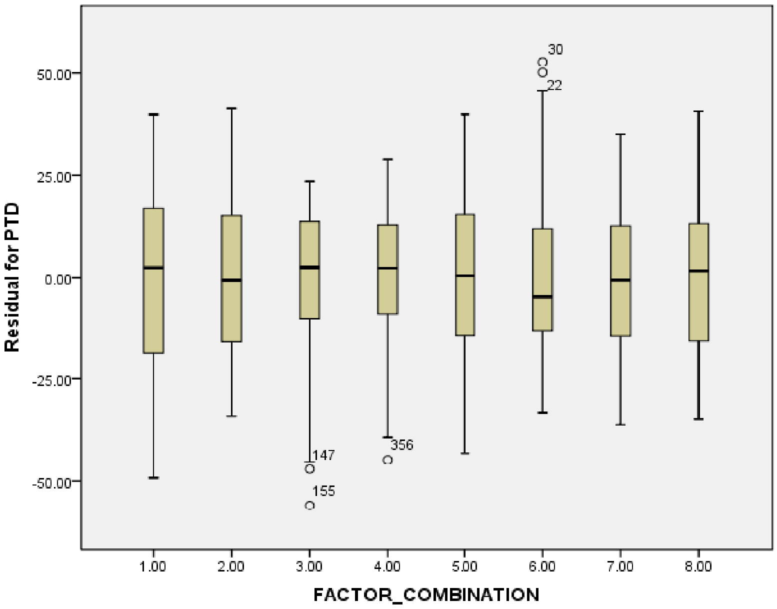


*Figure 26 – Residual plot Vs factors combination*

Figure 26 shows the boxplot for the residuals against the combination of factors. The residuals vary between ranges of -50 to +50. There are some outliers in the residual which does not fit into the boxplot, given that the data is highly subjective. The sum of the residuals was found to be zero.

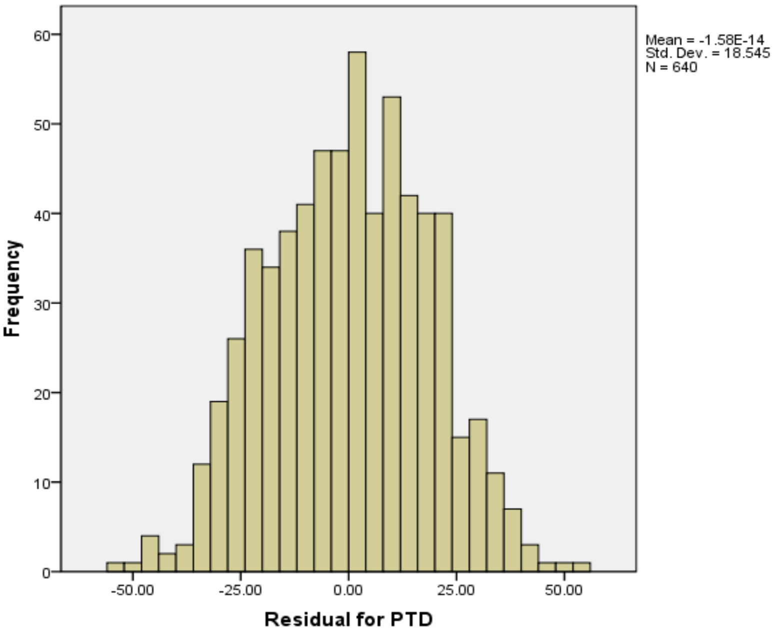


*Figure 27 – Histogram of residuals*

Figure 27 shows the histogram of residuals. The residuals follow a normal distribution with very minimal outliers and most of the values lying near the mean of the histogram.

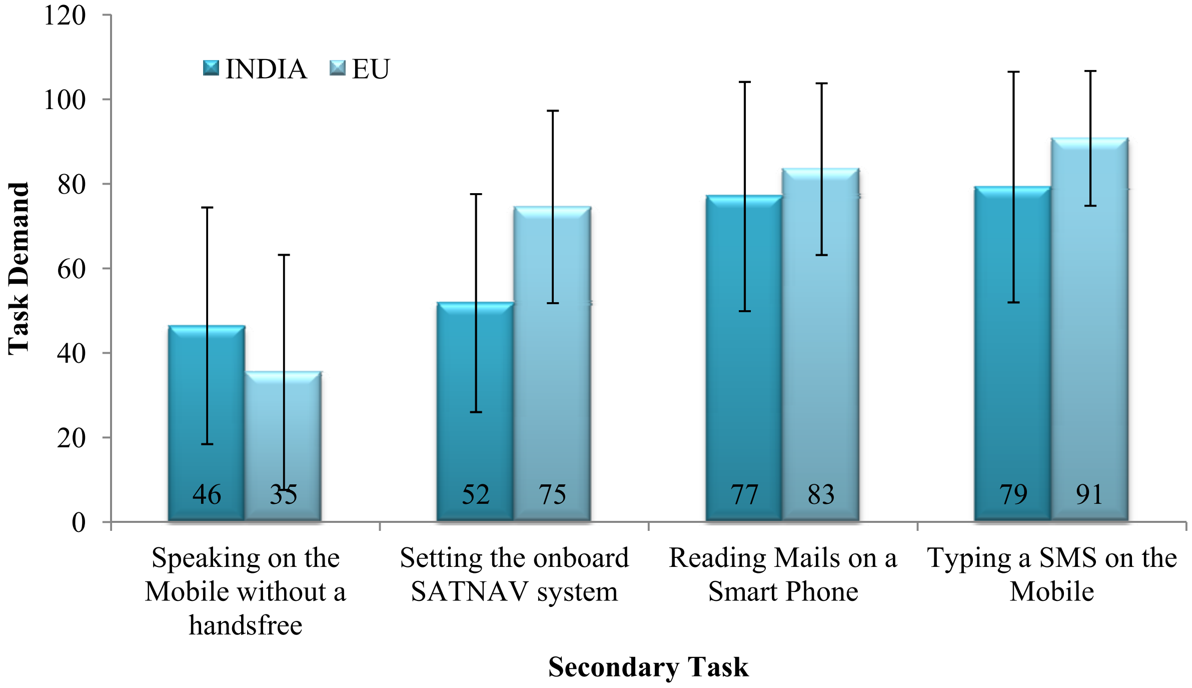


*Figure 28 – Demand of Secondary Task (subjective measure)*

Figure 28 shows the extra demand on performing a secondary task with the primary task of driving. It can be seen from this plot that,

- Indians consider reading mails from a smart phone to be the most demanding task and Europeans consider writing an SMS to be a highly demanding task.
- Setting the on-board satnav is a relatively less demanding secondary task as rated by both Indians and Europeans.
- Speaking over the phone is considered to be the least demanding secondary task by both the population.
- The reason for the long error bars is that the data is highly subjective.

# 4 Discussion

## 4.1 Why Roundabouts and why those factors?

The primary task demand as discussed depends on a lot of factors. These factors are not the same for all the scenarios. It could be said that the factors are not orthogonal, for example, a car in front of the ego vehicle is important when the driver is encountering a roundabout, whereas a car in front while overtaking is a common scenario. Hence the same factor (car in front) has different influence on the driving demand. In order to take up the work as a thesis we had to deal with a specific scenario. A lot of scenarios were brainstormed and finally roundabout was chosen.

Roundabouts are scenarios which neither requires a lot of driving demand nor really less, since there is a necessity for the driver to steer around it. Also number accidents occur in the roundabouts, inspite of the claimed fact that roundabouts are safer than intersections. A lot of these roundabout accidents are proven to be of distraction. In this thesis the main area of focus is the environment around the vehicle and how the task demand of the driver is affected by his environment.

Many methods had been adopted to measure the driver's task demand with respect to the environment. One such method is by looking at the road geometry(Green, Lin, & Bagian, 1994) and here an equation estimates the driver's workload.

$$Q = 0.4A + 0.3B + 0.2C + 0.1D$$

where,

Q – Workload

A – Sight Distance Factor

B – Curvature Factor

C – Lane Restriction Factor

D – Road Width Factor

This method suggests that the environment (road geometry) of the driver affects the driver's workload. Here in our thesis it can be stated that the environment is looked upon on a broader perspective as the driver not only looks on the road but everything in front of him. Amongst the various factors influencing safe travel in a roundabout, only the factors that could be visualised from the FOT database was included for the thesis work (Section 1.9).

The SeMiFOT database did not have any information about the driving demand of the trips. In order to coin a relationship between the environmental variables and the driving demand, some information on the driving demand was necessary. To obtain this data, such an experiment was conducted. The experimental setup consisted of a simple dual screen PC where the participant just clicks the suggested video number to view them. They were given full freedom on time and were not rushed. Care was taken so as to not influence or bias the results from the participants. Hence each of the participants was given a small presentation of what is expected from them. This data is then handled and is assumed to be the suggested primary task demand.

## 4.2 Secondary Task

The SeMiFOT database did not possess any information on the secondary tasks either. Hence a separate module was designed in the conducted experiment to get the input for four types of secondary tasks. The input form had a modified rating scale and the participants were asked to rate on how extra demanding the secondary task is. This was mainly done to study the difference in task demand with the presence of a secondary task. This secondary task estimates were taken from the participants for the video which has the highest demand from the experiment.

## 4.3 Discussion of Results

Section 3 shows a list of results obtained. This section will give more information on the justification of the obtained results.

The rating by the participants for the factor 'car in front' did not affect the primary task demand on a big scale. This was also validated with statistical analysis and hence it's been proved that this factor 'car in front' is statistically insignificant. It can be stated that the presence or absence of a car in front of the ego vehicle does not affect the driver's task demand.

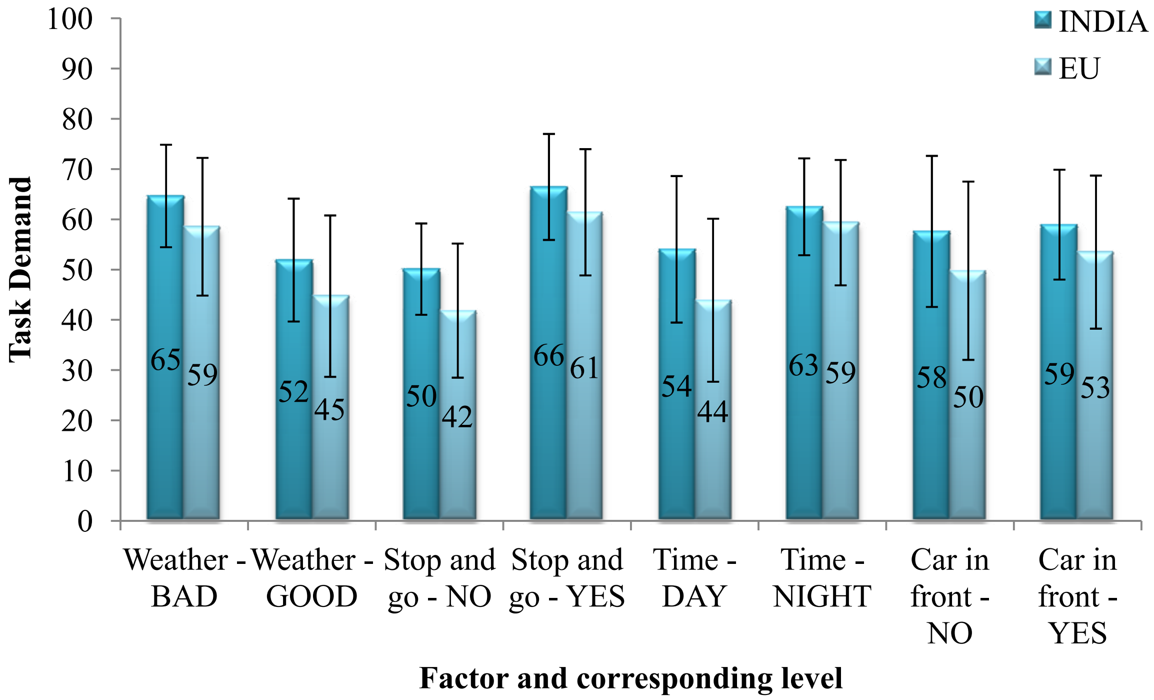


*Figure 29 - Factor comparison amongst populations*

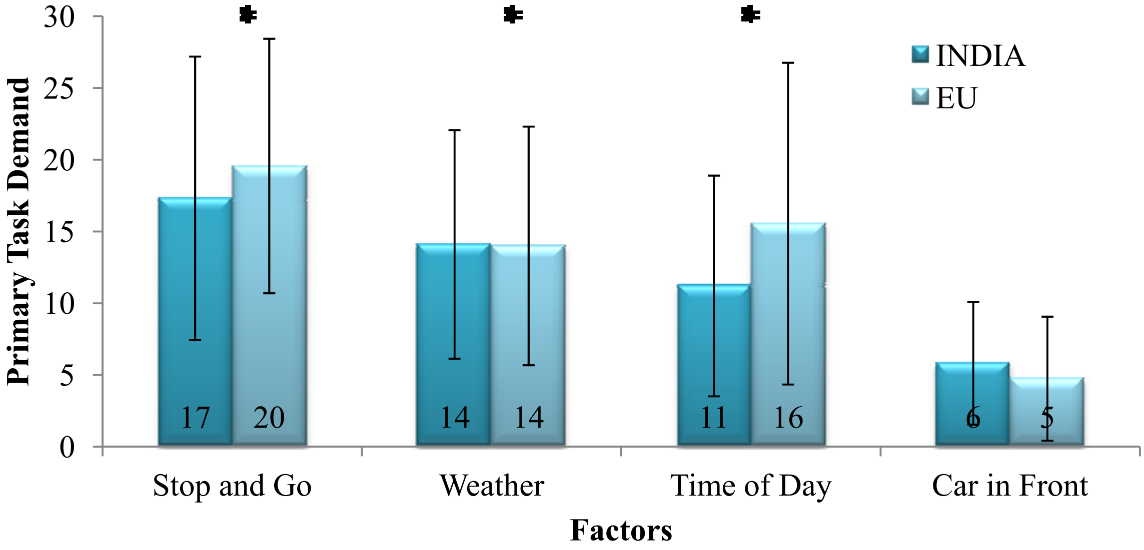


*Figure 30 - Primary Task Demand vs Single Factors*

Figure 29 shows that the rating by Indian population is high for all the considered factors and factor combinations than the European population. This can be regarded to the difference in the culture of driving between the two populations. Driving in India needs more attention than driving in Europe as there is a big difference in the driving behaviour between the cultures. A driver while driving in India expects anything to happen and hence he is always on a higher driving demand. This driving behaviour of Indians has made them to rate the videos to be highly demanding than that of the Europeans.

Figure 30 also shows that the European population has rated the factor ‘stop & go’ to be highly demanding than that of the Indian population. This can be attributed to the amount of traffic that both the population is exposed to. The Indian population is exposed to more traffic than the European population, hence stop and go situations are more common for Indian population. This experience in traffic has made the Indian population to rate the task demand for ‘stop and go’ to be lesser than the European population.

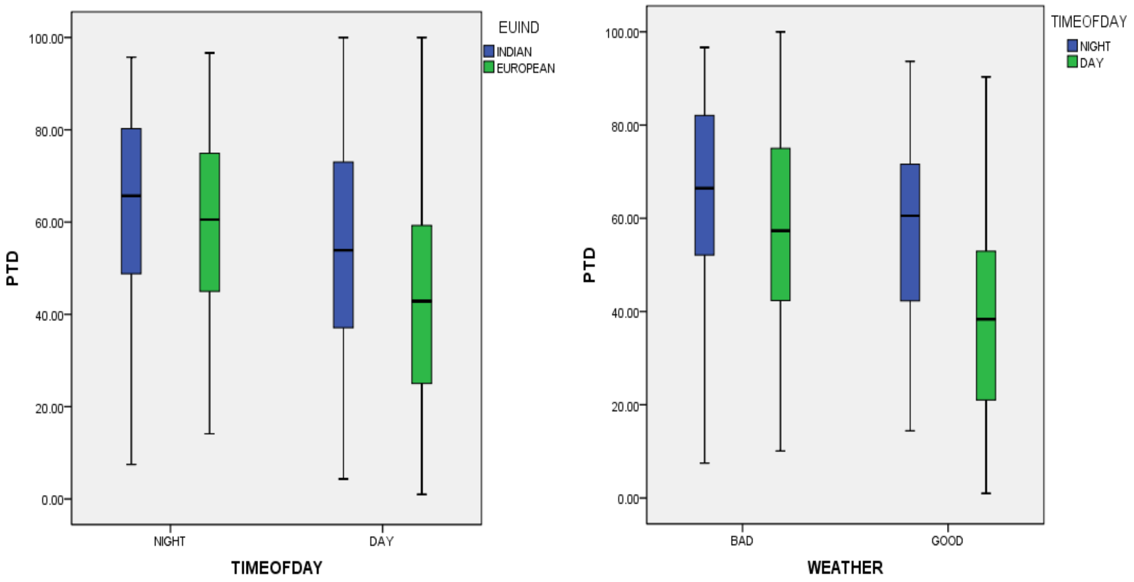


*Figure 31 - Interaction factors*

Figure 31 shows the interaction factors plot (a) for the population and time of day and plot (b) time of day and weather. Figure 31(a) states that the difference seen between night and day by the Indian population is lesser than the difference seen by the European population. Europeans feel that driving during night demands much higher task demand than daytime driving. This factor may be accounted to the variation in the length of day with respect to seasons. The whole population of Europeans are accustomed to driving in both day and night, whereas the day and night factor does not change much over seasons in India. Hence the Indian population does not feel a big difference in task demand between day and night driving

Figure 31 (b) shows the interaction between weather and time of day. As discussed before, in section 3.3.2, the probability of this interaction was very close to zero which means that there is a very high interaction between the two factors. The means of distribution of primary task demand of bad weather (day and night) and good weather (night) were almost equal. The task demand distribution for good weather during day time was clearly lesser than the others. This may mean that the task demand has a clear dependency on the visibility. When the driver has a good visibility of what is in front of him (good weather and day time) the task demand was rated to be low and when the visibility was not good (bad weather and night time) the task demand shoots up as per the rating.(Insurance Institute for Highway Safety Status Report ; Vol.43 ; No.4, 2008)

## 4.3.1 Do the participants agree with the rating?

The participants were asked to rate for the task demand and that demand was used to fit the mathematical model. The task demand was related to the considered four factors in the model. The participants were also asked to rate the four factors after they had completed the experiment. This ranking from the participants were checked for correlation with the beta[6] values of the considered factors in the mathematical model. It was seen that the rakings from the participants were completely negatively correlated with the beta values. This negative correlation is because the ranking was done in an ascending order and the beta values were fed in descending order.

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[6] The beta values are the regression weights of the model (Table 6)

# 5 Conclusions

***A simple and accurate algorithm for the detection of roundabouts from naturalistic data was created and successfully validated.***

The algorithm created can be employed for any FOT databases to capture roundabouts with high accuracy. The main advantage of this algorithm is that it confirms the presence of a roundabout with GPS co-ordinates and traces the start and end of the roundabout using the steer angle of the vehicle. This is a very simple roundabout detection system as it analyses both the vehicle and the GPS data in tandem.

***A mathematical model was created to explain the perception of primary task demand as a function of three main environmental factors.***

The model gives an estimate of the primary task demand based on the immediate surroundings of the ego vehicle. Three factors – 'Stop and Go', 'Weather' and 'Time of Day' were found to be statistically significant and hence were used to form the model. The subjective data obtained from the participants were split based on the factor levels. This was compared with the rankings obtained from the participants and was found to be in complete correlation with each other. This proved that the participants rating corresponded with the four factors that were of interest in this thesis work.

***Indian and European drivers benefitted from different models for primary task demand.***

The results and hence the model proved the existence of a cultural difference in driving. People from different regions, had different perception and expectation which affected the driving style. This difference when accounted for in the active safety systems may improve the safety levels and impress the people with improved performance. Specifically, Indian driver consistently perceived the driving situation more demanding than European drivers.

***Secondary tasks are perceived to increase the primary task demand both for Indian and European drivers***

The module created to evaluate the effect of secondary task was used to analyze the impact of secondary task on the driver. The trend of increase in primary task demand observed was the same from both the populations (Europeans and Indians). The results proved that the effect of the secondary task was the same for both populations.

## 5.1 Future Work

The model created has a large margin for improvements. The best possible use of the database was made in creation of this model. However, this method can be used in further analyses of task demand. The model can be made reliant by considering the including a simulator study. This will further enhance the model as factors from the vehicle can be added along with the environment. This could not be done in this work as the participants watched the videos and rated them and they were in no position to experience the vehicle state (eg. yaw rate) and hence their ratings will not relate to the vehicle states.

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# 7 Appendix

Participant Feedback

The feedback from the participants was collected after the experiment and they were asked about a factor which they thought was important but not considered in the thesis. There were a variety of answers and the major repetitive ones are described below –

- Many suggested that a vehicle which joins in front of the ego vehicle must also be considered since it affects the driver's decision making ability.
- They also suggested that presence of pedestrians and bicyclists in the roundabout will have different demands on the driving task.
- Some also stated that the geometry of the roundabout plays an important role in manoeuvring it and hence the task demand also has a direct dependency.
- A problem that many from India suggested was their lack of experience in driving in snow. So most of them just increased the task demand when they saw snow on road.
- People from trafficked countries said that most of the scenarios weren'tdemanding at all as there was less traffic in the roundabout. And the heading vehicle might influence the ego vehicle's driving.