Chapter 8

Visual Aspects in driving comfort
8.1 - Introduction-

Most animals have some sort of eye structure. Like humans many rely heavily on vision in day to day life, including predatory birds. The visual sense is very complex and is able to process large amount of information vary rapidly. How this is done is still not clearly understood to doctors or experts however one can imagine some of these by understanding some components like retina, visual cortex and brain centers.

One of the important tasks in front of automobile designer is to provide adequate field of view to all car users. In simplest terms, the clear view in front of the driver will help him not only to take decisions like relative distance between vehicles, respond to road turns as well as signals given by other drivers and also to stop the vehicle as soon as he/she encounters as the obstacle. For example if an animal steps on the road, the driver will not be able to avoid collision unless the animal is seen by driver at least 12m ahead of the vehicle at 50Kmph, or 31m at 80 Kmph.

In reality drivers need much longer field of view in order to anticipate, and prepare for avoiding collision. SAE J 941\textsuperscript{(56)} and SAE J 1050a\textsuperscript{(57)} describes Driver’s frontal visibility and obscuration aspects. View close to the vehicle is also important while overtaking, turning, checking relative distance with other vehicles and pedestrians while driving through cities.

The view to the rear of the vehicle, obtained mainly through the rear view mirror provides information about passing vehicles, pedestrians or objects in vehicle proximity while reversing or changing lanes. These examples set few parameters for considering the driver’s field of vision, taking account of both technical and
operational aspects of the vehicle. A complete specification of the view of road environment is obviously more complicated where the driver needs to see changes in the road alignment like (road markings), other vehicles (oncoming vehicles moving at similar or faster speeds in opposite direction), warnings or information signs placed beside the road. Many places signals or some of the road signs are mounted at high location so upward visibility also necessary.

8.2 The Driver's performance and Behavior –

Driving an automobile requires the full rage of human capabilities, including perception, decision making and motor skills. These capabilities must be performed in highly coordinated fashion often under stressful conditions.

Driver's behavior relies exclusively on visual perception of the environment as primary source of information. A critical aspect of this is driver's visual scan pattern. Drivers can not see what they have not looked at. Mourant (58) et.al. used eye movement recorder while driving the car at 80 Km/h on an expressway. The study revealed that route familiarity plays important role. Over unfamiliar routes the driver typically sampled a wide area in front of them. With increased familiarity in rout, eye movement tends to be confined to smaller details/areas.

Car drivers tend to focus on center of road, closer to car ahead of them and less time on traffic control information / signage. While following another car visual adaptation plays a major role, drivers increase or decrease speed based speed of the car ahead, many times missing the judgment about distance is required to avoid collision.

To understand driver's visibility requirements one need to understand human eye construction, optical requirements / limitations as well as constraints created by particular vehicle.
8.3 Human Eye –

Figure 8.1 Human Eye constructions

The structure of Human eye is shown in Figure 8.1. It is almost spherical, with approx 8mm diameter the inner sphere covered by transparent layer called cornea. The principle of image formation by the eyes is same as man made optical system like camera. Image forming light enters through the cornea and is refracted by the cornea. The lens helps to focus the object at retina. The opening of the iris (aperture in camera) is called pupil.

The light sensitive tissue layer of the eye is called retina. It consists of number of cellular and pigmented layers and a optical nerve fiber layer. The thickness of the retina varies between 0.05mm at foveal center to 0.6mm near the optical disc. The receptors cells are known as rods and cones based on their shapes.

Cones function at high illumination, such as during day light, and can differentiate between colours. Without cones one can not see any colour. Rods function at low level of illumination, such as night and can only differentiate between gray scales. The 6 to 7 million cones are concentrated near the center of retina called the fovea. The fovea is the area of greatest acuity. 130 million or so rods...
predominate in the peripheral parts of the retina with maximum density at about 10 to 20 degrees from the fovea. Because rods function at low level of illumination and are in primarily in the periphery of the retina. We can see a dim object more effectively if we look slightly to one side of it, rather than directly at it.

Based on neural network of human eye output of about 100 rods can combine on the way to the brain. This system creates rods very sensitive to light but poor spatial resolution. In contrast this output of fewer cones is combined, so cones have high colour as well as spatial sensitivity but they are efficient only with higher light level.

The area where the main optical nerve enters the retinal region does not have cones as well as rods hence this region can not collect visual image information. This region is called as ‘Blind spot”. The eye has number of axes. Major ones are optical and visual axis. The optical axis is defined as the line joining the centers of curvatures of refracting surfaces. The visual axis is line joining the center of the object of interest and Fovea.

![Figure 8.2 Human Eye muscles](image-url)
The eye rotates in its socket under the action of the six extra ocular muscles shown in Figure 8.2. The way these muscles are placed and operate there is no specific center of rotation but provides enormous flexibility of eye ball rotation. Two eyes provide better perception of the external world than one eye. Binocular vision improves contrast sensitivity, visual acuity and mainly helps to get information for processing the dimensional depth.

8.4 Visual Capability -

Three major optical aspects needs to be understood before moving to driver’s field of View.

8.4.1 Visual Accommodation-

Accommodation refers to the ability of the lens of the eye to focus the light rays on the retina. For seeing the objects at far distance as well as at short distance, the ciliary muscles contracts and also causes relaxation in the suspender ligament. This allows the lens to become more rounded, thickening at center increasing the power of the lens. While focusing from closer to far objects the process is reversed. As there is phase lag of this muscle operation based on the instructions from the brain for about 0.3 to 0.9 sec while focusing infinity to near by cluster, there will be blurred image during this period.

Focal point and distance of the object from eye are expressed in diopters (D). One diopter is equal to 1/ target distance in meter. The greater the value in diopters, the closure is the focal point. e.g. 1D= 1; 2D= 0.5m; 3D= 0.33m and 0D = infinity. Continuous change distance of object to be focused will operate these muscles frequently and will lead to optical fatigue or discomfort.
To avoid such fatigue designer need to position instrument cluster behind the steering wheel and select font size such that driver need not change his /her focal distance frequently while driving.

8.4.2 Visual Adaptation –

Another set of muscles adjust the aperture in front of lens by enlarging or contracting the pupil to adjust available versus required luminance of light. This helps eye to allow to control incidence light entering along with the image. As these muscles also has some phase lag due to instructions from brain to operate, sudden flash of light (opposite car head lamp flash) as well as entering in dark areas (in tunnel) causes temporary blind effect. Continuous change in pupil size also leads to optical fatigue and discomfort.

8.4.3 Visual Acuity –

Acuity is the ability to discriminate fine details and depends largely on the accommodation of the eye. Rods are sensitive to luminance where as cones are sensitive to colour. In retinal region of human eye there is complex population mix of these optical sensitive elements, some times due to contrast or past
knowledge objects seen and understood could have wrong interpretation. For e.g. some time the eye and brain together picks C as O or jumbles in similar looking objects. Visual acuity plays major role in reading, and traffic signage or display reading.

8.5 Driver’s front Visibility –

Driver front visibility is dependent to windscreen glass size, Glass position with reference to driver’s eye point, dashboard and top roof header position with reference to eye point. Generally dash board position will govern lower visibility which shows how much road will be visible ahead of the car bumper. This is sensitive while car parking how ever in normal driving situation not as sensitive because driver look at object (either another vehicle or person) in front of the car and not the road.

Windscreen glass top header will define driver’s upward visibility. This angle is sensitive when the driver is looking at signal lights or signage. Driver’s vision measured in plan view provides relation of the car with reference to road sides, vehicles in vicinity as well as vehicles overtaking the car. For right angular junctions it also provides information about vehicles coming form these roads.

While discussion with drivers it was evident that this visibility is sensitive to driving comfort. Windscreen glass sides are pasted on structural members called “A” pillar. This member provides torsion rigidity to body and plays significant role in frontal as well as roll over crashes. Since bigger the member section better is the body rigidity, many vehicles have thick ‘A” pillars.

At the waist level junction of the “A” pillar a triangular shape pocket evident in most of the cars. This is due to side door glasses channel to pillar connection geometry. Most of the vehicles are this triangle and used to mount the side view
mirror. If the triangle is big specially in mono volume cars few provide quarter glass. For many vehicles obstruction due to "A" pillar either blocks the driver vision to vehicles coming from side lanes or adds excess neck movement to compensate such obstruction.

![Figure 8.4 Frontal Visibility](image)

The driver's view is three dimensional and so needs to be defined in geometrical terms. In order to get visibility sight lines one needs to know where driver's eyes are in space. A survey of the car drivers found that the heights of car driver's eyes above the road surface ranged from 0.87m- 1.28m. With seat travel in longitudinal direction shows cluster of eye point locations is given in SAE J945(14). Eye-ellipse has been developed as drafting tool to define the range of eye positions within the driver population. As there are two eyes one can get three dimensional ellipsoid as cluster of eyes for 5th to 95th percentile drivers.

For all vehicles to have structural rigidity driver's cage or body is generated with structural pillars. In common automobile terms, pillars supporting front windscreen are called "A" pillars. In plan view pillars from windscreen to rear fixed glass or tail gate are named "B, C, D" depending their location from 'A' pillar. e.g. pillar supporting rear door will be called 'B' pillar. Frontal visibility is blocked by position and size of "A" pillar. If driver's do not rotate the neck to enlarge their visual field, this pillar can block vision for a two wheeler or pedestrian coming
from right angle lanes. To avoid this blockage driver's change their head position in fore-aft as well as rotate the neck frequently.

To avoid large and frequent movement of the head one can compare position and size of “A” pillar and its blockage and try to compare with perceived comfort rating.

8.6 Drivers “A” pillar obscuration drafting template as per SAE J945

In this procedure P1, P2, Pm, V1 and V2 points are drawn with reference to ‘R’ point (Figure 8.3). In case the seat has longitudinal adjustment more than 108mm then P1, P2 and Pm are moved forward by 13mm as given in Table 8.1.

<table>
<thead>
<tr>
<th>no</th>
<th>Longitudinal Seat Adjustment (mm)</th>
<th>Adjustment (5x)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>108-120</td>
<td>-13mm</td>
</tr>
<tr>
<td>2</td>
<td>121-132</td>
<td>-22mm</td>
</tr>
<tr>
<td>3</td>
<td>133-145</td>
<td>-31mm</td>
</tr>
<tr>
<td>4</td>
<td>146-158</td>
<td>-42mm</td>
</tr>
<tr>
<td>5</td>
<td>158 onward</td>
<td>-48mm</td>
</tr>
</tbody>
</table>

Table 8.1 Eye ellipse adjustment for seat travel

In case seat backrest is positioned other than 25 degree then second adjustment needs to be done as per Table 8.2.

<table>
<thead>
<tr>
<th>Seat Back angle (degree)</th>
<th>Adjustment (5x)</th>
<th>Adjustment (6z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>-44mm</td>
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<tr>
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<tr>
<td>24</td>
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<td>3mm</td>
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<td>0mm</td>
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<tr>
<td>26</td>
<td>9mm</td>
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<tr>
<td>28</td>
<td>26mm</td>
<td>-8mm</td>
</tr>
<tr>
<td>30</td>
<td>43mm</td>
<td>-14mm</td>
</tr>
</tbody>
</table>

Table 8.2 Eye ellipse adjustment for seat backrest movement

From point Pm draw lines in side view 2° above and 5° below the horizontal in a forward direction, at the intersection of the latter lines with “A” post, construct a horizontal section. The section should include all non transparent parts. Locate the point P on the equilateral triangular template (sides 65mm) and rotate the
template such that parallel lines from point E1 and E2 intersects the section outermost points.

Angle intercepted between inner line of inner most edge of bottom section (section A) and line of intersection of outer most point of upper section will give angle of obscurcation.

![Figure 8.5 Frontal Obscuration Angles](image)

The forward field of view is usually considered adequate if object in front is visible to at least one eye (ambinocular view) even though some parts are obscured for other eye.

8.7 Eye location -
Eye point usually represents the mid point between the two eyes, although other vision origin -points may also be used. Two eyes, often known as E- points, are located at an inter-papillary width of 65 mm ad rotate about a neck point (or P-Point), about 98mm to the rear of the mid point, between the eyes to simulate head turn in the horizontal plane.

EEC 71/127 specifies that the eye points should be at a height of 635 mm vertically above the vehicle R-point or H-point (which is located by the procedure
of ISO 6549). This establishes the seat at the rearmost and lowest position, which also represents 95th percentile driver's seating position.

**8.8 Data Collection –**

Using SAE J945 “A” pillar obstruction angle for 10 cars was measured. At the same point clear visibility angle between Left to Right pillar was measured. The data is shown in Figure 8.6 and 8.7.

![Figure 8.6 Frontal Visibility – from Drivers Seat](image)

<table>
<thead>
<tr>
<th>CAR</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
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<tr>
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<td>64</td>
<td>76.3</td>
<td>77.4</td>
<td>76</td>
<td>75.7</td>
<td>62.2</td>
<td>62.3</td>
<td>57</td>
<td>65</td>
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<td>A plr LH obscuration</td>
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<td>5.4</td>
<td>4.6</td>
<td>4.4</td>
<td>4.5</td>
<td>4.5</td>
<td>5.8</td>
<td>5.3</td>
<td>5.3</td>
<td>5.5</td>
</tr>
<tr>
<td>A plr RH obscuration</td>
<td>6.2</td>
<td>6.3</td>
<td>5.9</td>
<td>5.8</td>
<td>5.2</td>
<td>5.7</td>
<td>5.1</td>
<td>6.5</td>
<td>5.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Total obscuration</td>
<td>12.2</td>
<td>11.7</td>
<td>10.5</td>
<td>10.2</td>
<td>9.7</td>
<td>10.2</td>
<td>10.9</td>
<td>11.8</td>
<td>11</td>
<td>11.6</td>
</tr>
</tbody>
</table>

**Figure 8.7 Frontal Visibility Angles**

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159
8.9 Conclusions -

Based on the above conclusions can be derived,

1) Car “D” has best frontal visibility followed by Car “C, E and F”. Better visibility is either due to wider windscreen widths or /and its position with reference to eye point.

2) Car “I” has worst frontal visibility through windscreen.

3) Car “E and G” has least frontal obscuration due to driver side windscreen pillar whereas Car “C, D, E and F” have least co-driver side frontal obstruction due to windscreen pillar

4) For overall frontal obscuration car “E” scores best and car “A” scores least.

5) Figure 10.9 shows similar data for visibility through rear glass. For this attribute car “F” scores best and car “H” scores worst. While discussing with test engineers’ rear visibility through rear glass is not so sensitive to comfort rating unless it is drastically low during normal driving. It is sensitive only while reversing the car.

6) As per various drivers interviews in day to day Indian city traffic frontal visibility with least obscuration matters a lot for perceived comfort.