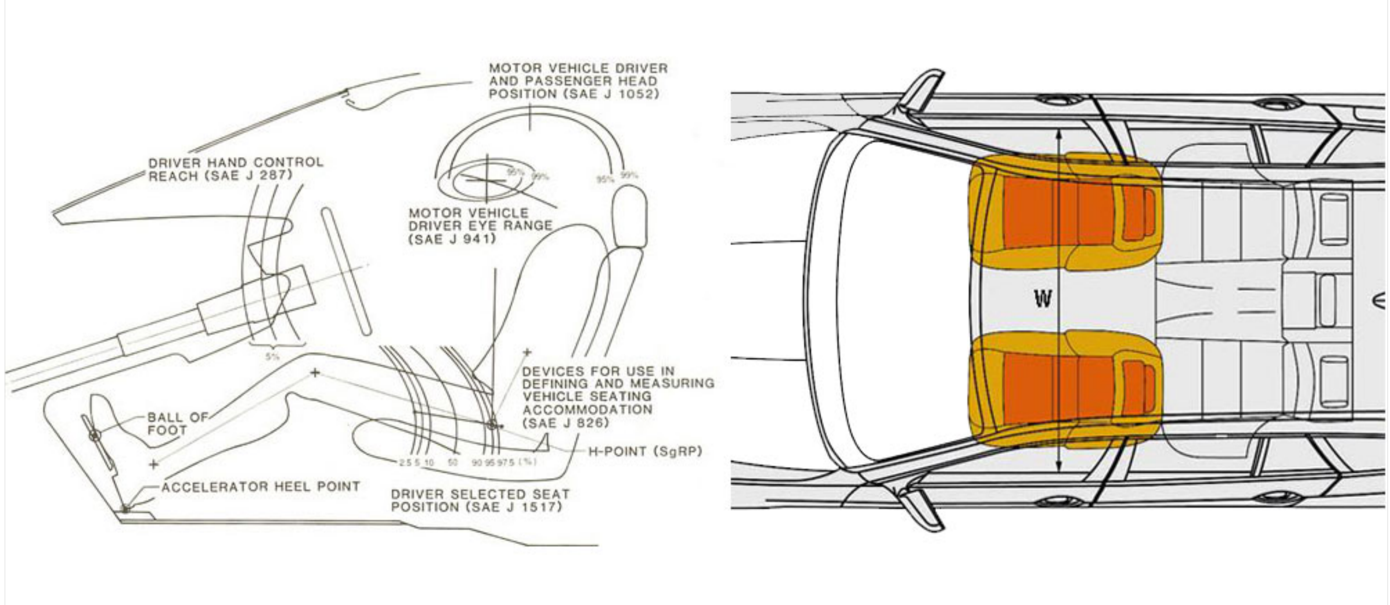
Design Course

Basic Ergonomics in Automotive Design

The Fundamentals of Human-System Interactions

by
Prof. Sougata Karmarkar
DoD, IIT Guwahati



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Introduction

The word "Ergonomics" originated from two Greek words "Ergon" means "work" and "Nomos" means "natural laws"

International Ergonomics Association (IEA) defined Ergonomics (or human factors) as the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. An ergonomist is an individual whose knowledge and skills concern the analysis of human-system interaction and the design of the system in order to optimize human well-being and overall system performance (IEA, 2000).

Aims:
This course is for a brief idea about Ergonomics/Human Factors and its application in automotive design.

Objectives:
- To provide basic concepts about Ergonomics/Human Factors and their implementation in design.
- To illustrate the application of elementary ergonomic principles in automobile design

The course is divided into the following three modules:

• **Module 1**
- Introduction to Ergonomics
- Ergonomics
- Domains of Specialization
- Applications and benefits
- Aspects of Ergonomics

• **Module 2**
- Automotive Ergonomics
- Introduction
- Spatial arrangement
- Reachability
- Strength capability
- Visual field and visual obstruction
- Seat design and seating comfort

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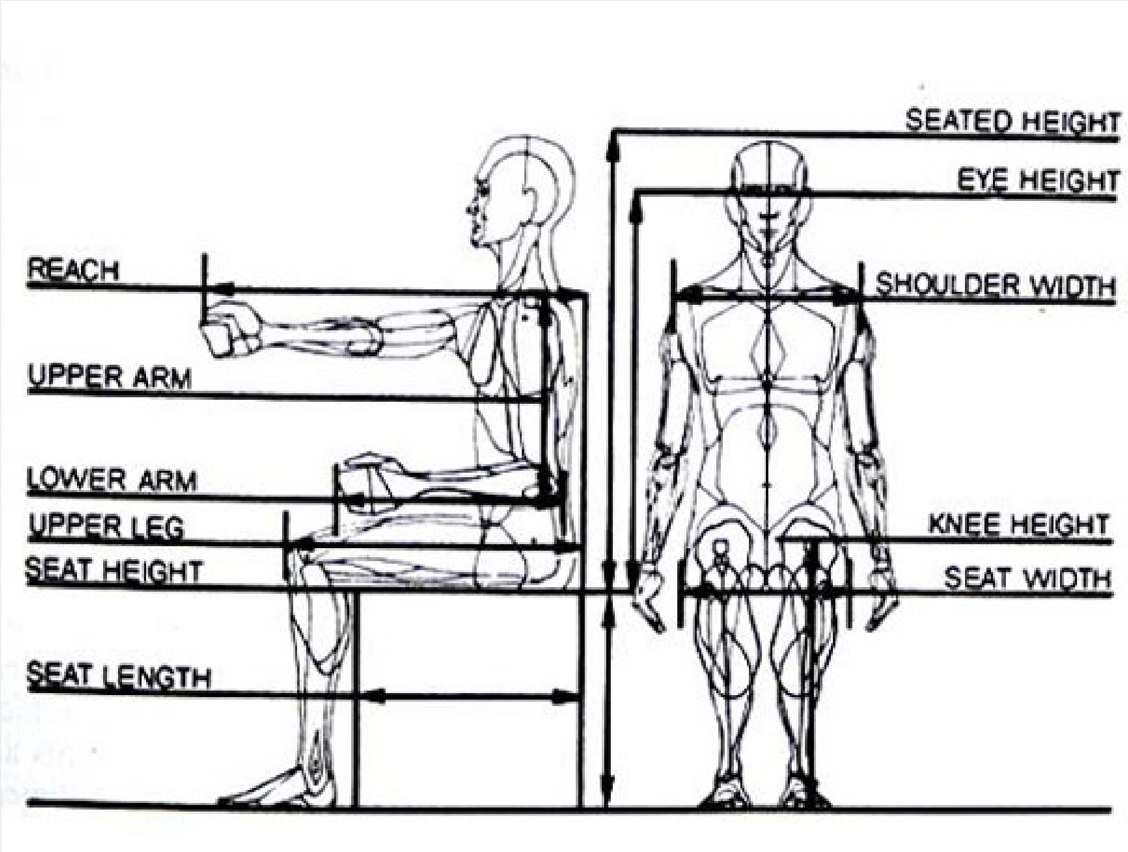
- **Module 3**

- Case studies



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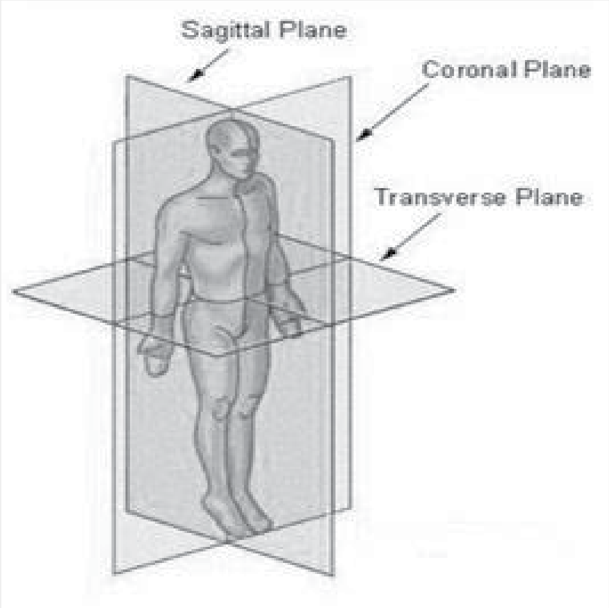
Module 1

Introduction to Ergonomics:

Introduction to Ergonomics module is divided into following:

- Ergonomics
- Domains of Specialization
- Applications and Benefits
- Aspects of Ergonomics



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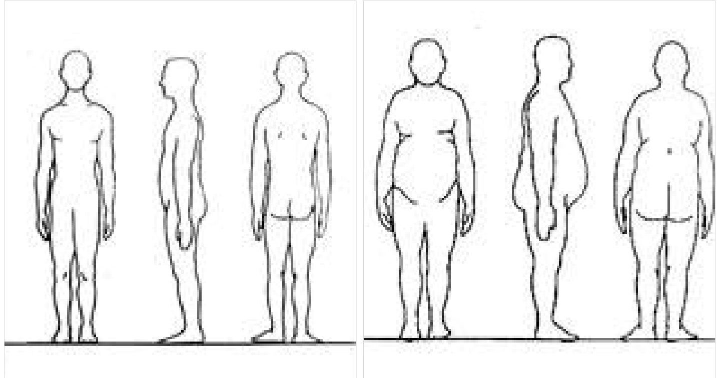
Ergonomics

Ergonomics is concerned with the health of the people and the productivity of the system. It is to get a proper fit between people and their technological tools and environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, equipment, information and the environment suit each user.

Simply expressed we can say that Ergonomics is fitting the task to the person rather than fitting the person to the task.



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Domains of Specialization

According to international Ergonomics Association (IEA) ergonomics can be broadly classified into:
• Physical Ergonomics
• Cognitive Ergonomics
• Organizational Ergonomics

Physical Ergonomics:
It is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they related to physical activity. Relevant topics may include working postures, material handling, repetitive movements, work related musculoskeletal disorders, workplace layout, health and safety.

Cognitive Ergonomics:
A proper fit of a product to a user does not end with physical interfaces. Cognitive/perceptual ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. Relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system and Human computer interaction design.

Organizational Ergonomics:
It is concerned with the optimization of socio technical systems, including their organizational structures, policies, and processes. Relevant topics include communication, crew resource management, work design, design of working times, teamwork, community ergonomics, cooperative work, new work programs, virtual organizations, telework, and quality management.

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Applications and Benefits

Applications:
Ergonomics continues to be successfully applied in the fields of workplace design, occupational health, safety, product design, aerospace engineering, mechanical engineering, health care, IT sectors, transportation, training, nuclear power plant, virtual environments, industrial design and so on.

Benefits:
Application of ergonomic principles in various fields provides better man-machine interaction, healthy and comfortable working environments, and enhancement of human performance and efficiency and thus ultimately leads to an overall improvement of system's (man-machine-environment) productivity with reduction of error and accidents.

Key benefits of application of ergonomics are listed below:

- Human fatigue and error can be reduced.
- Increase productivity and safety.
- Increase work quality.
- Decrease risk of accidents.
- Improve people's attitudes.
- More user satisfaction.
- Less absenteeism.
- Reduced lost time, etc.

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Aspects of Ergonomics

Study of compatibility issues for proper man-machine interface is very important in ergonomics. Here, focus is generally made on user's requirement, user's characteristics and user's capabilities/limitations for user friendly design. Human compatibility with machine/instrument/work elements are discussed in terms of anthropometric, biomechanical, physiological and cognitive/psychological aspects.

Anthropometry:
Anthropometry is the subject which deals with the measurements of the human external body dimensions in static and dynamic conditions. Anthropometric data is used for product and workplace design.

Anthropometry is of two types:
- Static Anthropometry
- Dynamic Anthropometry

Static Anthropometry:
External human body dimensional measurement taken when a man is placed in a rigid static position i.e. standing, sitting, or other adopted postures.

Dynamic Anthropometry:
The dimensional measurement of human body with various movements taken into consideration in different adopted postures which the work context demands are termed dynamic anthropometry.

To understand anthropometry, knowledge of body planes and somato-types are essential. These imaginary planes (fig. 1) are used for the identification of relationship between the position of things and postural configuration and for description of any location.

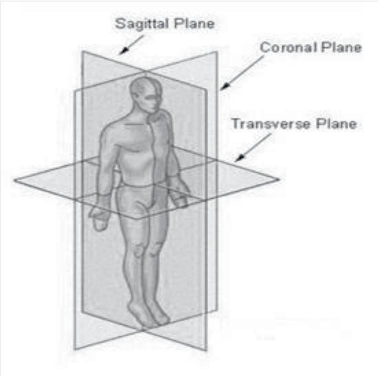

Fig 1. Body Planes
(Image Source: http://images.wikia.com/athletics/images/1/13/Body_planes.jpg)

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Somatotypes:

The human body types are classified according to the contents of fat in the body. These are ectomorphs, mesomorphs and endomorphs.

- **Ectomorphs:**
- **Mesomorphs:**
- **Endomorphs:**

- **Ectomorphs:**

Due to low fat storage, the full body appears to be skinny, lean and thin (fig 2). Abnormal postures are adopted by the people of this category while working, standing, and sitting.

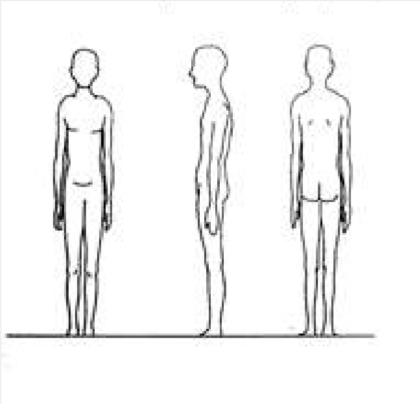

Fig. 2. Ectomorphs (Adopted from Chakrabarti, 1997)

- **Mesomorphs:**

This type of body contains less fat but is well balanced and firm; usually referred to as muscular (fig. 3). Movements are well coordinated in all the limbs and in the body as a whole.

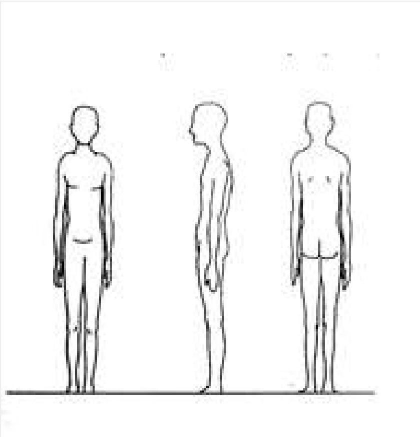

Fig. 3. Mesomorphs (Adopted from Chakrabarti, 1997)

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• **Endomorphs:**
This body type has increased fat storage, a wide waist and a large bone structure, usually referred to as fat (fig. 4).

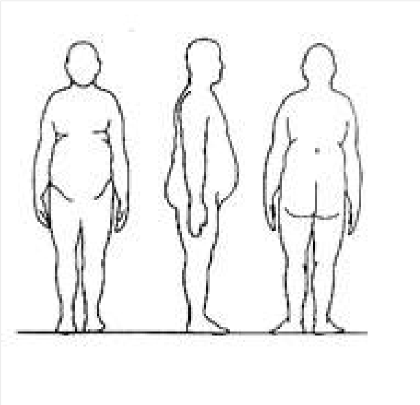

Fig. 4. Ectomorphs (Adopted from Chakrabarti, 1997)

Measuring Procedures:
Direct and indirect measuring techniques are followed to collect anthropometry data. In direct measuremen method, body dimensions are measured with standard anthropometric tools/kits. In indirect measurements method relies on stealing photographs and pictures. Presently, 3D Laser Body Scanner is used for getting detailed data.

For the larger survey and sample size, statistical treatment of anthropometric data is done to get the standard measurements for whole population. An extremely useful statistic for designers is the percentile.

Percentiles are the statistical values of a distribution of variables transferred into a hundred scale. The population is divided into 100 percentage categories, ranked from least to highest, with respect to some specific types of body measurement. The first percentile of any height indicates that 99 percent of the population would have-heights of greater dimensions than that. Similarly, 95th percentile height would indicate that only 5 percent of the study population would have greater height and 95 percent of the study population would have the same or less height. The 50th percentile, or median, is one kind of average which divides the whole population into two similar halves.

Biomechanics:
Biomechanics is the study of the structure and function of biological systems by means of the methods of mechanics.

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It is the application of mechanical principles to biological systems of human-beings (fig. 5).

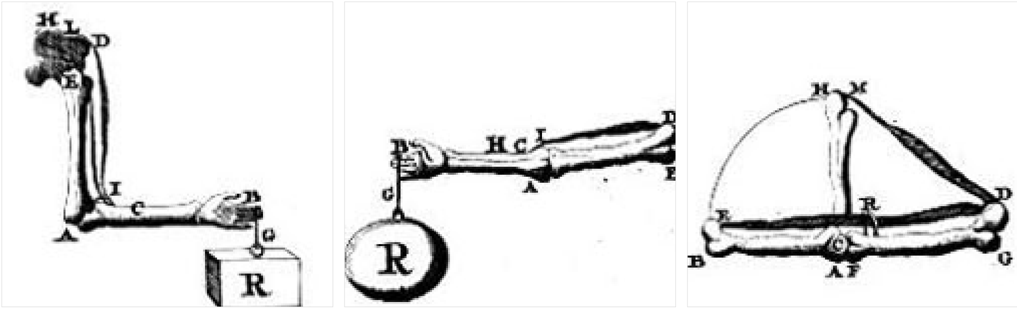

Fig. 5. Mechanical analysis of human body
(Image Source: http://upload.wikimedia.org/wikipedia)

Factors to be considered in Biomechanics:
• Newton's three laws of motion can be used to solve most biomechanical problems.

• **Force:**
Forces are key to understand mechanics. A force is any influence that causes a free body to undergo a change in speed, a change in direction, or a change in shape. The unit of force is kgms-2. Force can be internal or external when we consider biomechanical problems. We generally consider the body is acting within the environment.

Internal forces are the forces that act within the body, such as muscle forces, joint reaction forces, and load that act on the various body tissues.

To move relative to the outside world the body needs to be subjected to external forces. These are often the result of internal forces causing a change in the body conformation but can also be due to some other external forces such as gravity or other applied forces from contact with the object.

• **Joint:**
A joint is the location at which two or more bones make contact. They are constructed to allow movement and provide mechanical support, and are classified structurally and functionally. Structural classification is determined by how the bones connect to each other, while functional classification is determined by the degree of movement between the articulating bones.

Joints can also be classified according to their anatomy or their mechanical properties.

- **Simple Joint**: 2 articulation surfaces, e.g. shoulder joint, hip joint etc. (fig. 6)
- **Compound Joint:** 3 or more articulation surfaces, e.g. radio carpal joint (fig.7)
- **Complex Joint:** 2 or more articulation surfaces and an articular disc or meniscus, e.g. knee joint (fig.8)

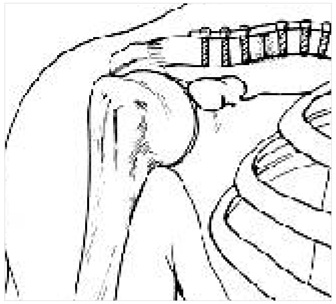

Fig.6. Shoulder joint

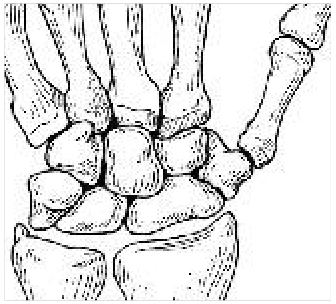

Fig.7. Radio carpal joint

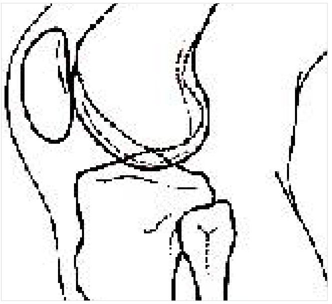

Fig.8. Knee joint

• **Range of Motion:**
Generally speaking, range of motion refers to the distance and direction a joint can move to its full potential. Each specific joint has a normal range of motion that is expressed in degrees after being measured with a goniometer (i.e., an instrument that measures angles from axis of the joint). Rage of movement for different body joints is shown in fig. 9.

Physiology:
Human physiology is the science of the mechanical, physical and biochemical functions of humans in good health, and how to apply that information in the evaluation and design of work. Various physiological aspects which are studied to evaluate work performance of human beings are as follows:

• Cardiovascular response (HR, BP, Cardiac output).
• Respiratory response (O2 uptake, CO2 out put).
• Metabolic response (Energy expenditure).
• Static & dynamic muscle loading.
• Tissue compression etc.

Increase in physiological demand for performing activity leads to physiological stress which in turn creates various health complications or disorders.

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Fig. 9. Movements of the human body (Van Cott & Kinkade, 1972)

Psychology:

Psychology in ergonomics are concerned with adapting the equipment and environment to people, based upon their psychological capacities and limitations with the objective of improving overall system performance.

The objectives of psychology in ergonomics are to optimize the effectiveness and efficiency with which human activities are conducted as well as to improve the general quality of life through "increased safety, reduced fatigue and stress, increased comfort and satisfaction.

For performing any activity, human receives various information through different sensory organs (e.g. eye, ear, nose, tongue, skin etc.), processes that information in the brain and then execute neuromuscular actions. Processing more information in a shorter duration leads to an increase in cognitive workload. Hence, in man-machine compatibility evaluation, analysis of cognitive workload is very essential.

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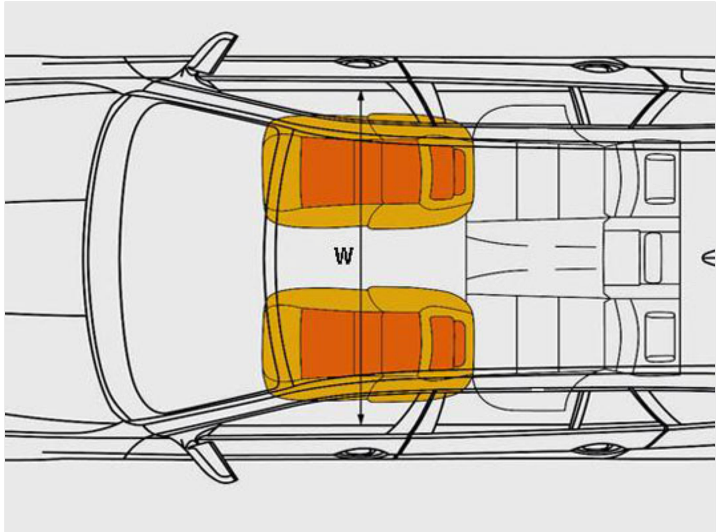
Module 2

Automotive Ergonomics:

Automotive Ergonomics Module is divided into following:

- Introduction
- Spatial Arrangement
- Reachability
- Strength Capability
- Visual Field and Visual Obstruction
- Seat Design and Seating Comfort



Introduction

Automotive ergonomics focuses on the role of human factors in the design and use of automobiles. This includes analysis of accommodation of driver and/or passengers; their comfort; vision inside and outside vehicle; control and display design; pedal behaviour, information processing and cognitive load during driving etc.

In the present module attempt will be made to discuss various physical aspect of occupant packaging for providing comfortable driving posture, clearance dimensions, proper view field, easy reach of the controls etc. to the driver.

This module highlights the following:

- Spatial accommodation
  - Seating Position
  - Leg Room
  - Head Clearance
  - Lateral Clearance
- Sitting comfort /discomfort
- Reach and limitations of human
- Visual field and Visual Obstruction

To establish the required interior space, and arranging the interior and structural components, the design methods relies on the human factors data base through years of research and practical applications.

The anthropometry for automotive design is consistent with the driver and passenger safety, comfort, convenience and accommodation. The study of human capabilities and limitations gives the measurements for designing automobiles.

Anthropometric Measurements for Automotive Ergonomics:
Automobile is designed as per the anthropometry of the targeted user population. Measurement process can be broadly classified into two categories.

Conventional Static Measurements:
The measurements taken on human body with the subjects in rigid, standardized position (fig.10). They are typically length, width, height and circumferences. These measurement includes standing height, seated height, seated eye height, upper leg length, knee height, seat length, upper and lower arm length, reach (total arm length), shoulder width, hip or seat width, weight, etc.

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These measurements are referenced to non-deflecting horizontal or vertical surfaces supporting the subject.

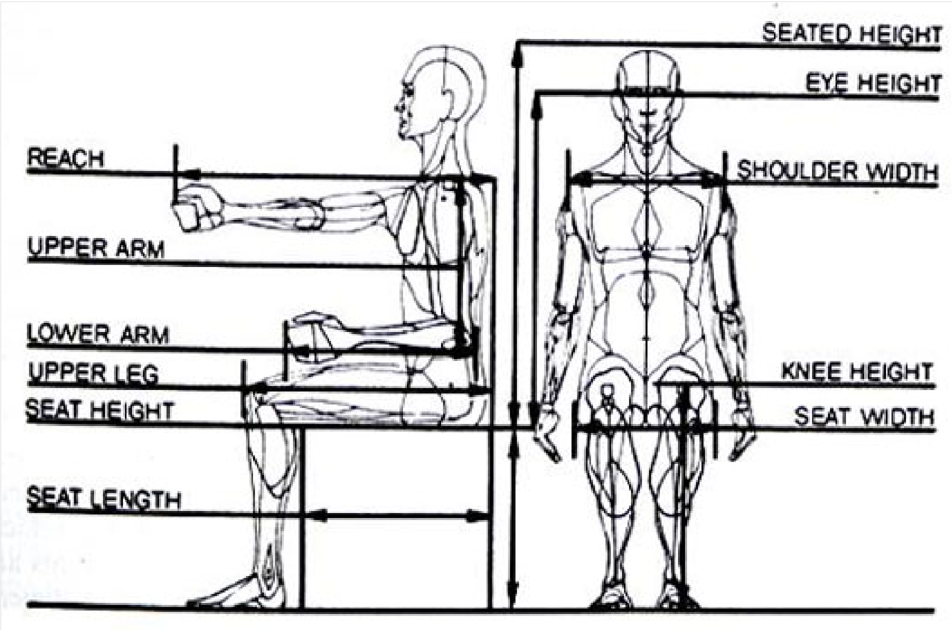

Fig 10. Conventional static measurements
(Image Source: Peacock and Karwowski, 1993)

Functional Task Oriented Measurements:
The measurements are taken with the human body dimensional co-ordinates x, y, z with respect to body land marks as reference points. at work or motion in the workspace (fig. 11). Typically they are represented in three dimensional co-ordinates x, y, z with respect to body land marks as reference points:

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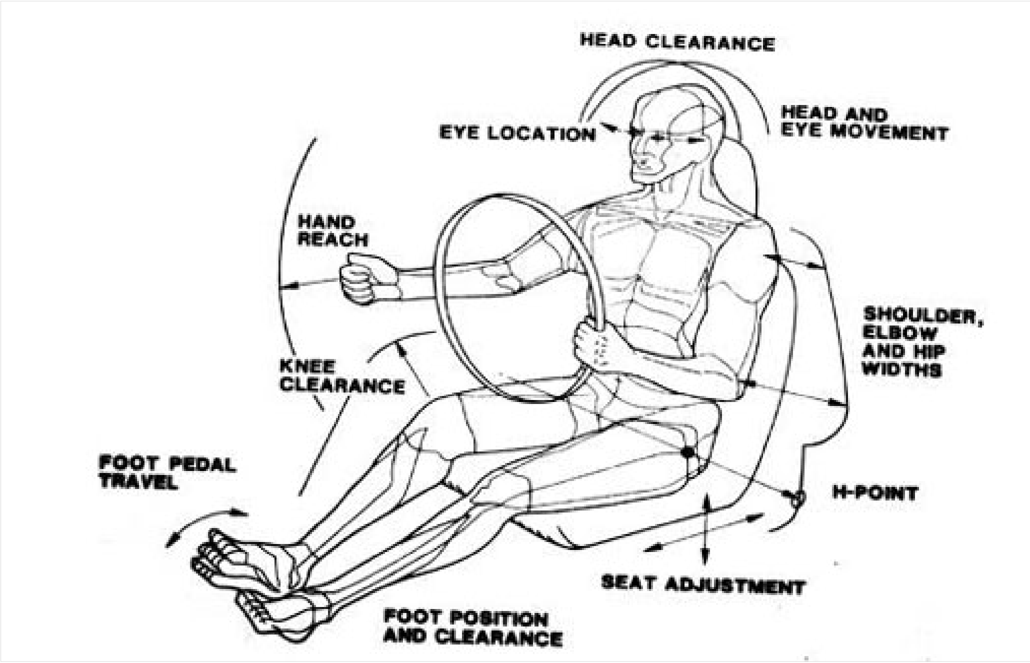

Fig 11. Functional task oriented measurements (Image Source: Peacock and Karwowski, 1993)

In automobile design, at first the position of the occupant/driver with comfortable driving posture on the seat is defined. Then all other components are arranged around the driver to provide easy reach, vision and control operations.

Few reference points e.g. H-point, BOF, AHP etc. are used as standard practice to define driver's position while SRP, NSRP and SgRP are generally used to define seat position in relation to driver.

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- H-point (Hip pivot): Mid point of the line connecting two hip joints.
- BOF (Ball of Foot): Ball joint of Foot.
- AHP (Accelerator Heel Point): position of the heel while placed on the accelerator.
- SRP (Seat Reference Point): Intersection point between midline of compressed seat back and compressed seat pan.
- NSRP (Neutral Seat Reference Point): 50th percentile person selected SRP.
- SgRP: 95th percentile person selected SRP.

These landmarks (fig.12) relate the occupant to components in the vehicle interior such as foot controls, seat and floor. For example, the foot is related to the ball of foot and accelerator heel point, where as hip, elbow and shoulder width are related to the h-point location.

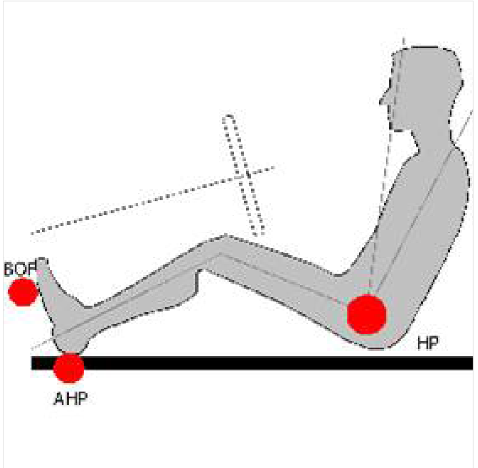

Fig. 12 Landmarks for measurements.

To accommodate wide range of target population, 5th and 95th percentile anthropometric data are used in general.

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Seat Track Travel Limit:
Seat track travel limit is decided in such a way so that individuals with smaller body dimensions as well as larger body dimensions can seat comfortably on the seat and can access all the controls including accelerator, break and clutch. Seat track travel limits in forward-backward and upward-down ward direction are decided as per operational requirement.

Fig. 13 depicts forward-backward movement of the seat as per the different percentile driver selected seat position (SAE- J1517).

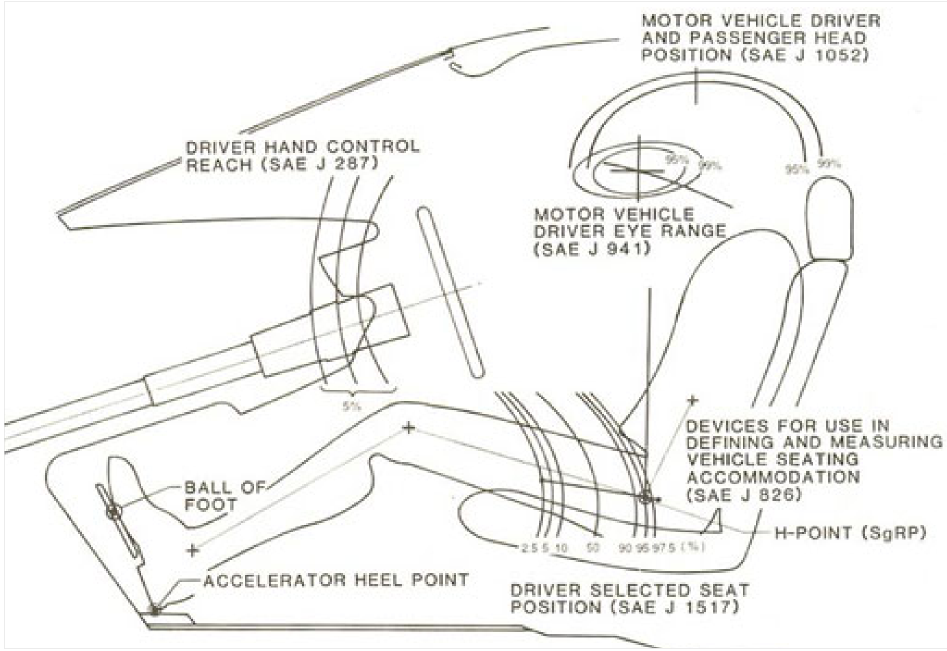

Fig. 13. SAE recommended occupant packaging
(Image Source: Peacock and Karwowski, 1993)

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Spatial Arrangement

After defining the position of the driver on the seat, all other interior and structural components inside the vehicle are arranged accordingly with the intention to provide sufficient clearance dimensions around him/her. This process relies on a human factor database. Larger anthropometric data (95th percentile value) are generally considered for this purpose.

Spatial arrangement includes the positioning of the driver's seat and passenger's seat in the allocated space on the side, and the arrangement of various controls/components according to seating arrangements.

In this module leg room, headroom and lateral space are to be described in brief.

Legroom:
The sufficient space for keeping the legs of the driver/passenger in a comfortable position in an automobile. Proper legroom enables drivers to access structural components with ease. There should not be any obstacle to keep feet comfortable and at the same time for accessing controls like pedals (brake/accelerator/clutch).

Measurement of horizontal distance between H-Point and AHP is useful for this purpose. Care should be taken to ensure that any parts of the lower body like thighs/knees should not touch with steering wheel or dashboard or any other component.

Headroom:
The height. It is the vertical clearance space above the head of the driver/passenger in an automobile. A minimum 5.0 cm head clearance for jolt in a vehicle is recommended (Galer 1987, Woodson et al. 1992). In vehicular workstations, available head clearance must be sufficient for wearing and removing the helmet in a seated posture.

Lateral Space:
Lateral space is the space pertaining to the side of driver/passenger. Lateral space is important for physical or psychological comfort.

Conventionally, 95th percentile bi-deltoid breadth of the population with an additional allowance of 10% on each side can be considered adequate for lateral clearance during normal sitting side by side (fig. 14).

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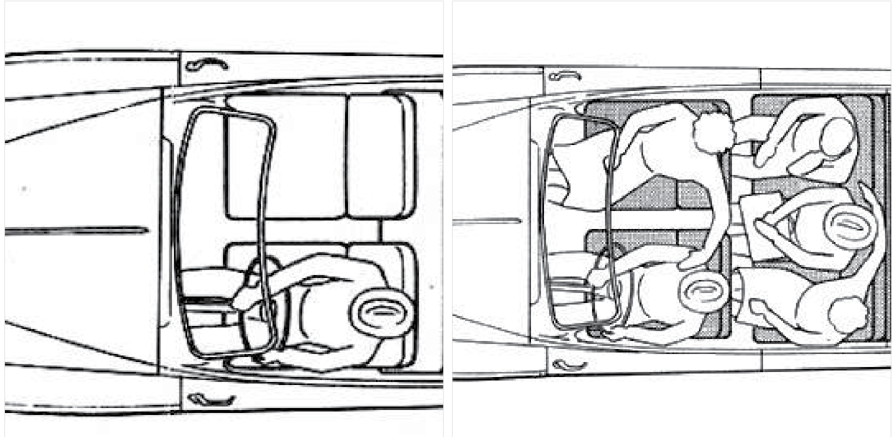

Fig. 14. Lateral clearance for sitting side by side

Dimensional Consideration of Lateral Space:
The overall distance between the inner part of doors "W" is the output of manipulated anthropometric data of lateral between two seats, and the distance from seat's edge to the door. spaces required for comfort (Fig. 15). This 'W' is composed of the width of seats and distance.

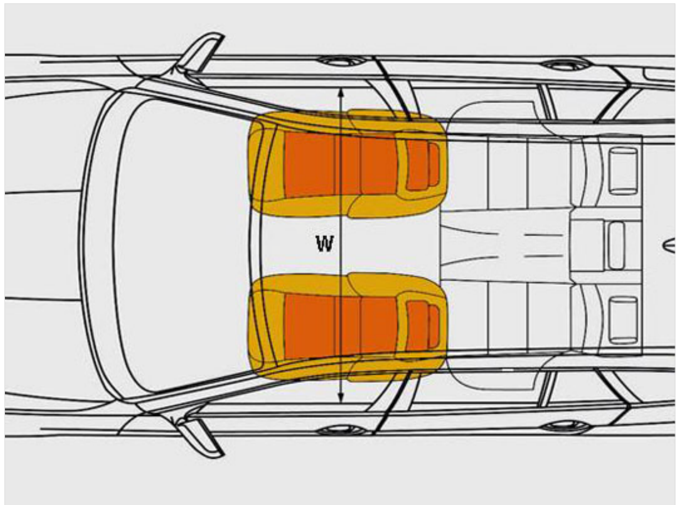

Fig. 15 Top view of a car to show lateral spaces for the front seats.

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Reachability

Reach and Limitation of Human:

In many work situations, individuals perform their activity within a specified 3D space of fixed location which is sometimes referred to as 'work-space envelope' (Sanders and McCormick 1993). This envelope preferably should be circumscribed by the functional arm reach of the operator and most of the things they need to handle should be arranged within this envelope.

In fig. 16 describe human capabilities and limits in terms of reach on horizontal work-surface with their measurements.

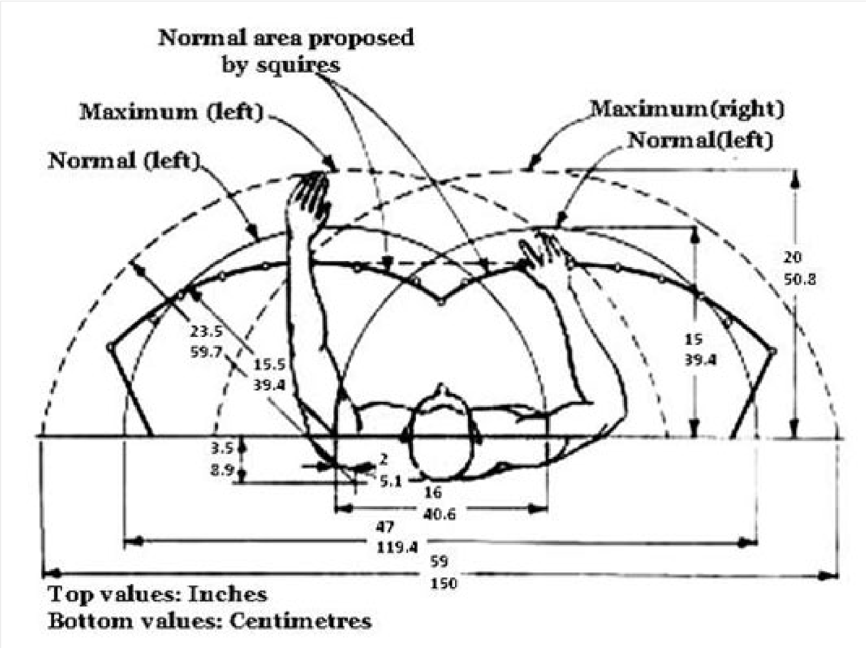

Fig. 16. Normal and maximum horizontal reach areas (Image Source: Sanders and McCormick 1993)

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Normal and maximum horizontal arm reach do not correlate with reach capabilities in actual vehicle workstations. Factors such as seat position, seat deflection, shoulder articulation, and lean allowed by slack in a shoulder harness (if one is worn) affect a driver's reach capabilities.

Forward arm reach of the driver according to anthropometry and seat track travel as described in SAE J287 shown in fig. 17.

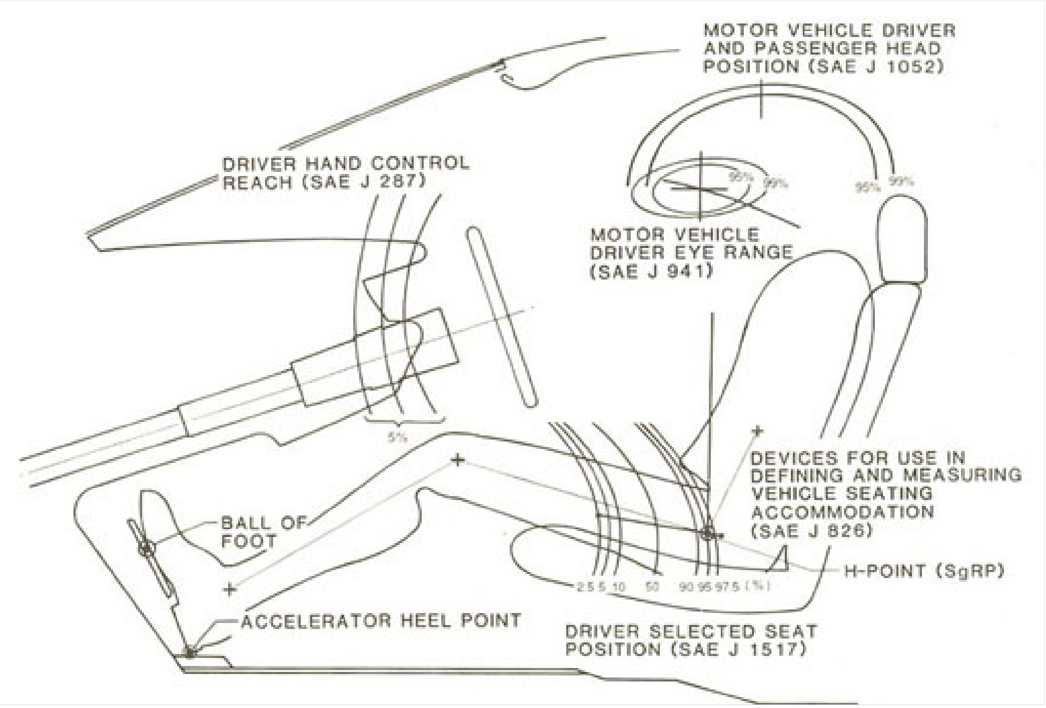

Fig. 17. SAE recommended occupant packaging (Image Source: Peacock and Karwowski,1993)

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Strength Capability

Strength for Control Operation:
Strength is one type of human performance limiting factor and concerns the application of force in the operation of controls and in other physical tasks. Often, limitation of strength imposes a one-way constraint and it is sufficient to determine the level of force that is acceptable for a weak limiting user.

The capabilities of the human body are considered to make the operational components of the vehicle while driving. For example, force is required for the ease of operation of clutch, steering, opening and closing of doors etc.

Actuating force limits for some important tractor controls for Indian male agricultural workers (CIAE, Bhopal, 2009) are given below:

Brake Pedal:
- 5th p Rt leg strength (male)=261 N.
- Maximum actuating force for break operation should be less than 260 N.

Clutch Pedal:
- 5th p Lt leg strength (male)=247 N.
- Frequently operated compared to the brake pedal.
- 50% of 5th p Lt leg strength (male)= 123.5 N.
- Maximum actuating force for Clutch operation should be less than 124 N.

Accelerator Pedal:
- 5th p Rt foot strength (male)=163 N.
- Continuously operated, 30% of 5th p Rt foot strength (male)=49 N (upper limit).
- Maximum actuating force for accelerator operation should be less than 49 N.
- Weight of leg = 9%= .09 of body wt., part of this wt. is supported by heel.
- Lower limit of force exertion for accelerator= 54.7kg x9.81x.09x0.5=24N.

Steering Wheel:
- 5th p torque strength with both hands, sitting (male)=36 Nm (force 171 N with lever arm of 0.21 m).
- Frequently operated, 30% of 5th p = 51 N.
- Maximum actuating force for steering wheel operation should be less than 51 N.

Gear Selection/ Speed Selection Lever:
- 5th p Rt hand push strength = 49 N, limiting force for operation.
- Maximum actuating force for gear operation should be less than 49 N.

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Visual Field and Visual Obstruction

Limits of Visual Field:
Driver can turn both eyes and head to gain a wider field of view and moreover can make use of peripheral vision to see objects or movements even without turning eyes.

In the horizontal plane, the binocular field of view extends some 120 degrees, as in figure given below (fig. 18). Vision is sharp only over a fairly small area directly ahead. So, eyes need to be turned to focus on objects outside the foveal area. According to SAE J985 eyes generally only turn by about 30 degrees before the head is turned, which can comfortably give a further 45 degrees view to either side.

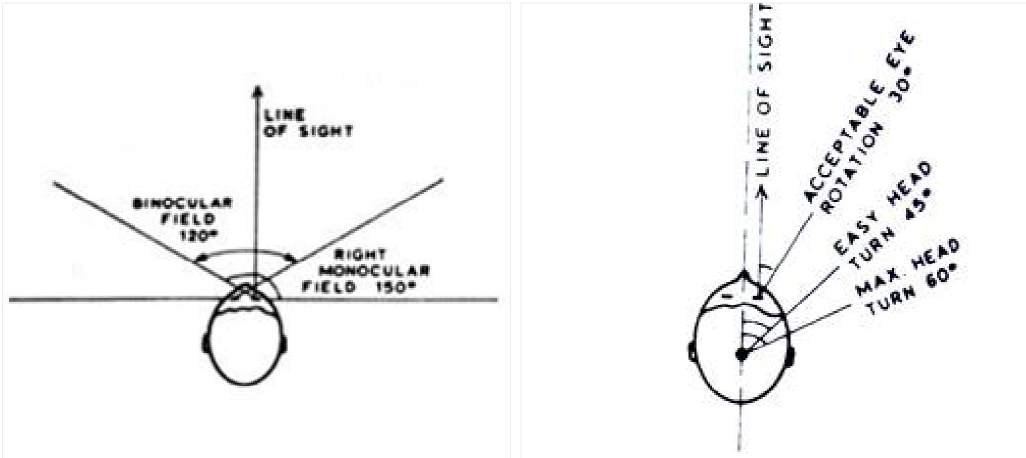

Fig. 18. Binocular field view in horizontal plane (Image Source: Peacock and Karwowski, 1993)

In the vertical plane eye movement (fig. 19) is comfortable within 15 degrees above or below the horizontal, although the eye can see upto 45 degrees upward or 65 degrees downward if necessary.

On the other hand, the head can easily incline 30 degrees upward or downward. Thus, by movement of head and eye, the driver can have an extended direct field view. The driver has to concentrate on the direct view, that is on the road. So glancing away from the road for a short period is possible. Mirror and other instruments should be close to the driver so that the driver does not require a much head and eye turn to have a look.

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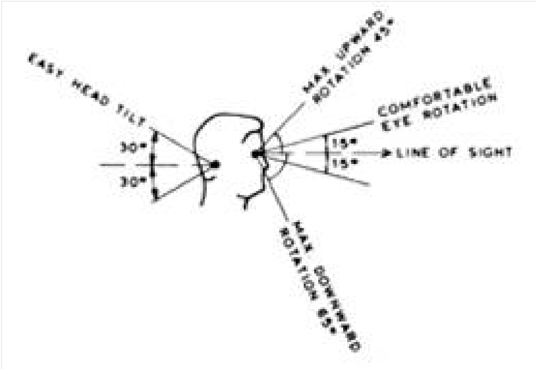

Fig. 19. Vertical views of the human eye (Image Source: Peacock and Karwowski, 1993).

Driver's Eye Location:
Variation of eye positions inside the vehicle for any driving population is considerable due to variations of seat locations and variable anthropometry of the drivers. In order to address this problem, the SAE J941 'Eyellipse' concept was developed as a drafting tool to define the range of eye positions within the driving population. It is based on the position of eyes of drivers in space. The distribution of eye position in space closely approximated an ellipsoid.

During automobile design, care should be taken to provide maximum view all around either through direct vision or with the help of devices like mirror or camera. It is also important to ensure minimum visual obstruction either by vehicle components or by the driver's own body parts. This is particularly important for allowing an unobstructed view of the displays on the dashboard.

Internal and External View from Driver Seat:
The vision is a crucial factor in the driving task as most of the information received by the driver comes through the visual sense. The clear view of the road (front and rear) enables the driver a safe drive (fig. 20). Poor visibility conditions are stressful for the drivers and result in a significantly increased risk of accidents.

• Visual Needs:
The view ahead through the windshield has to be sufficient and clear for the driver. It enables driver to stop in emergency and necessary conditions. Similarly, rear and side views are important for maintaining speed, taking turn, exerting break or during parking.

On the road driver need much longer view to anticipate and prepare for avoiding actions. Views close to the vehicle is equally important when turning left or right and maintain proper distance to avoid accidents. Fig. 16 shows the view inside the vehicle, forward and side views through glasses and rear view through mirror.

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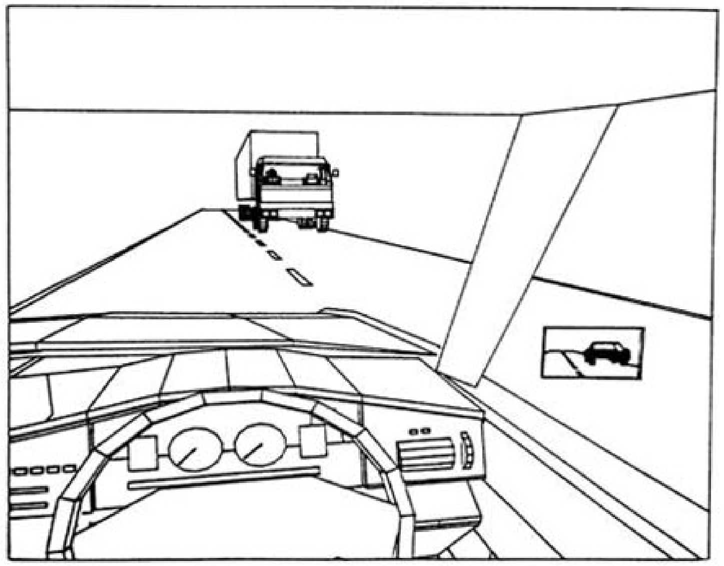

Fig. 20. View during driving (Image Source: Peacock and Karwowski, 1993).

Specifying the Field of View:

• **Direct View:**

The views observed by the driver directly through eyes are considered as direct views (fig. 21). The visual field of human eye is complex, limited by anatomical and optical factors. However, it can be represented by sightlines drawn from the eye to all the points which can be seen, collectively defining the visible field of view.

The view of driver can be represented in two dimensional geometry by considering an imaginary sight line (Horizon) passing through the driver's eye.

The viewing angle above the horizon can be considered for traffic signals and signs.

The downwards view can be considered for road. Height of the dashboard and curvature of the bonnet are the two determining factors for downward view through front windshield. Upper edge of the dashboard should be at least 15 degrees below the horizontal eye line of driver with the smallest (5th percentile) sitting eye height.

The far-distance view is based on the horizon, the sightline passing through the driver's eye.

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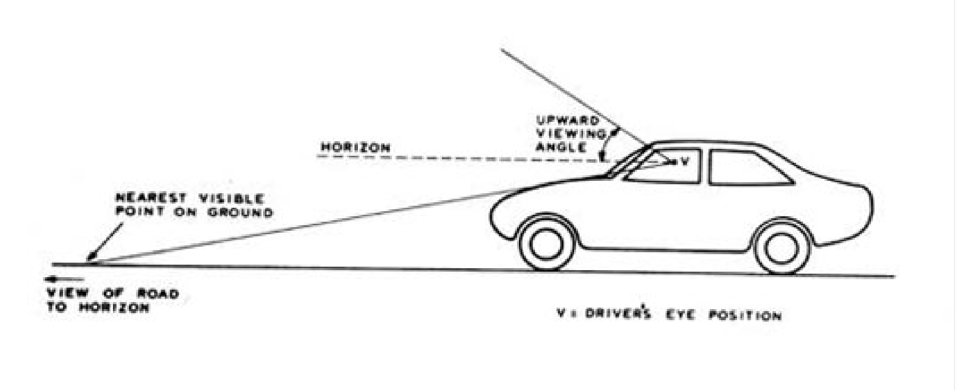

Fig. 21 Driver's forward field view (Image Source: Peacock and Karwowski, 1993)

• **Indirect View:**
The views to the rear of the vehicle are mainly obtained through the mirrors (fig. 22). This view provides information on passing vehicles, and vehicles close to the rear when the driver proposes to change lanes.

The reflected view of mirror can be represented in the same way as in direct view with the viewing angles.

The view of an image is bounded by the frame of mirror.

The image boundaries can be determined by the mirror dimensions, locations of the mirror with respect to driver's eye and optical characteristics of mirror. By adjusting the mirror the field of view of rear can be adjusted.

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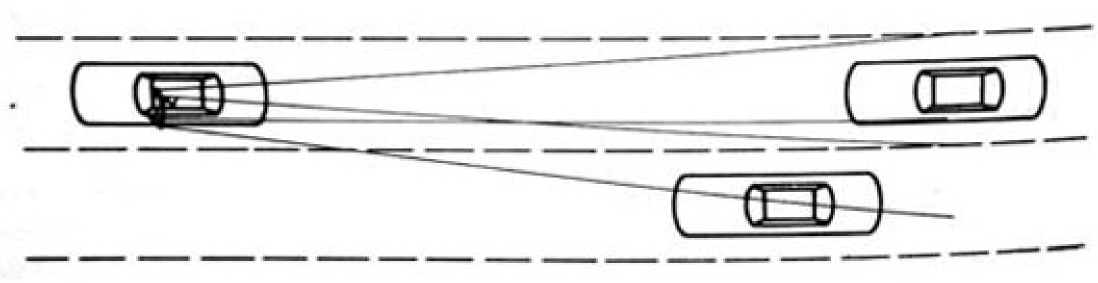

Fig. 22. Rear-ward field view in the interior and side mirror (Image Source: Peacock and Karwowski, 1993)

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Seat Design and Seating Comfort

Seating Comfort:
For occupant's comfort and health, good seat design should be applied by considering sitting postures. Static and dynamic anthropometry data are considered for proper design of a comfortable and safe seat.

Some factors to be considered for driver's seat:
• The seat should position the driver with unobstructed vision and within reach of all vehicle controls. For this purpose appropriate seat adjustment features should be there.
• Proper back support, headrest, thigh support should be provided but there should not be and obstruction/ hindrance during arm or leg movement.
• Seat must accommodate the driver's size and shape.
• Seat should be comfortable for extended period.
• Seat should provide a shape zone to the driver in a crash.

Passengers in the front and rear seats need comfortable supporting surfaces for a variety of postures unconstrained by the vehicle operation. Postural stress, vibration, muscular effort, impact and shock are the causes of backache and lower back pain in drivers. Safety should be taken into account while considering the design of seats without compromising the comfort.

Different Factors Considered for Seat Design:
Human geometry both in static and dynamic are considered for designing seats. The static geometry describes the physical size to be accommodated in the seat and dynamic geometry describes the functional position to be accommodated in the seat.

• **Body Size:**
Seats are mostly designed as per the body weight and anthropometry of the targeted user population to fit at least 90 percent of population. The 95th percentile of male and 5th percentile female anthropometric data is generally considered for accommodation on seats.

Human linkage system: Rigid human body can be specified according to the joint centre position and the angle between adjacent links. The movements and dimensions of human linkage system help to define the curvature of seats and comfortable position for sitting.

• **Position of the Body:**
Driver's seat position is dependent on the vision and reach of the driver. Clear view and comfortable sitting posture are the factors considered for designing seat. The dimensioning is mostly depends on eye, hand and foot positioning. For different body verticals, back angle adjustments are provided.

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• **Posture of the Body:**
Seats should reduce postural stress and optimize muscular effort. Postural stress occurs due to adopting one posture for long period of time, so comfortable support for many postures is essential and this can be accommodated by manipulation of anthropometric data and the linkage system.

• **Vibration and Ride Comfort:**
Vibration, shock and impacts are major factors for judgments of comfortability according to most users. Thus, the seat design also must consider the vehicle suspension system and the vibration transmitted to the seated user.

Geometric Features of Seat Design:
Seat design can be divided into accommodation and comfort. Accommodation refers to seat size and adjustments for horizontal distance from controls, height and back angle. Comfort, however refers to stiffness, contour, climate and vehicle features that promote user's comfort.

The seat height, width and back angles are based on the human anthropometry data collected from the research. It is important to provide sufficient space for physical and psychological comfort.

• Cushion's length from seat back to the waterfall line is 440-550mm is recommended (Grandjean, 1980).

• The breadth of the cushion is recommended at 480mm (Grandjean, 1980) for clothing and leg splay. The measurement is based on 95th percentile of female hip breadth and additional space for comfort since female hips are greater than male hip breadth.

• Seat back height is recommended at 509mm (Grandjean, 1980) by considering the small female, sitting shoulder height.

• Seat back breadth may be divided into lower and upper regions. The lower must accommodate a tapered shape from 432mm at the hip to 367mm at the chest (Grandjeans, 1980). 480mm is recommended for seat back breadth (Grandjean, 1980).

• Horizontal adjustments accommodate differences in leg length that are associated with seat height and preferred knee angle. Grandjean (1980) recommended a minimum of 150mm horizontal adjustment. The joint angles in automobiles are typically between 95 and 120 degrees for the hip, and 95 and 135 degrees for the knee (Rebiffe, 1969).

• Horizontal seat travel is a function of seat height and body size. Average seat travel was investigated at 148mm approx. (Schneider et al., 1979).

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• Vertical adjustments accommodate differences in sitting eye height between the fifth percentile female and 95th percentile male. A simple trigonometric relation can be established with link length and joint angles to compute the amount of seat adjustment needed in the vertical direction.

• Adjusting a flat, non-deformable surface over a range of 163mm maintains a constant eye height. Seat cushion compression and suspension deflection are no-linear functions of applied force; as a result the vertical displacement needed in a soft seat is poorly calculated from anthropometric data. Grandjean (1980) recommended a seat height between 250 and 300 mm.

• Seat back angle adjustments accommodate differences in arm length and occupant preferred hip angle. Grandjean (1980) recommended a seat cushion angle of 19 degrees with a range from 10 to 22 degrees. d on multiple joints or overall body posture (Krist 1994).

All the seat design criteria and dimensions mentioned above are for general understanding of the subject. Presently, various SAE standards are followed in automobile industries all over the world.

Both subjective and objective methods of discomfort measurements are used to analyze and rate the level of discomfort. Among the various rating scales 'Visual Analogue Discomfort Scale' or 'Verbal Numerical Rating Scale' for assessment of intensity; 'Body Map' or specific instruction for assessment of discomfort location and repeated measurement for the assessment of temporal pattern of discomfort are generally used (Van der Grinten 1991). Empirical studies of various scientists provide comfort data for quantitative estimation of sitting comfort of vehicle occupants or drivers based on single joint postural analysis (Porter and Gyi 1998, Grandjean 1980, Henry Dreyfuss Associates 1993, Rebiffe 1969) and some based on multiple joints or overall body posture (Krist 1994).

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Module 3

Case Studies:

Physical ergonomic evaluation of any vehicle workstation starts with assessing key human factor issues e.g. spatial arrangement of driver's/ passenger's seats, reachability of the occupants towards various controls (gear, accelerator, clutch, break , various knobs and switches etc.); force requirement for operating controls; comfort/ discomfort during driving or for sitting for long duration; visualization of displays/dials or controls inside vehicle; visibility towards road ahead or vision through rear view mirrors; ingress/ egress; various clearance dimensions (leg room, head room, lateral clearance etc.); environmental conditions (noise level, temperature, humidity etc.) and so on.

To evaluate anthropometric compatibility of the users (driver/passenger) with vehicle workstation components (seats, controls, displays, clearance spaces etc.), generally 5th percentile (for maximum dimensions), 50th percentile (for average dimension) and 95th percentile (for minimum dimensions) body dimensions of the targeted population are considered. As a standard practice, 5th percentile adult female, 95th percentile adult male anthropometric value and 50th percentile adult pooled (combined male and female data) data from standard database are used for evaluation purposes. For example, minimum overhead clearance inside the vehicle should be more than 95th percentile male sitting/standing height as per requirement. Similarly, minimum seat width needs to be decided based on 95th percentile sitting hip breadth of females. On the other hand, maximum reach distance towards any control should be decided according to 5th percentile female reach dimension, so that anyone from the user population can easily access that control.

From the above discussion, it is clear that different percentile body dimensions need to be considered during evaluation of different design criteria following requirements. Sometimes, it is stated that evaluation is peformed with 5th percentile female or 95th percentile male but in reality there is not a single individual whose body dimensions are of a particular percentile value. For example, if height of a person is of 70th percentile value, his leg length may be of 50th percentile value. Hence, it is better to mention that evaluation is based on 5th /50th /9th percentile body dimensions.

To find any specific percentile (say, 5th percentile) dimensions of different body parts, actually large number of individuals would be required (because for a single individual different body parts are of different percentile values). Many instances, it is impossible to recruit large number of test subjects for evaluation. To solve this problem, few individuals (male/female) are identified (from a target population) whose most of the body dimensions are close to a specific percentile (5th/95th) value and anthropometric compatibility evaluation is performed by them.

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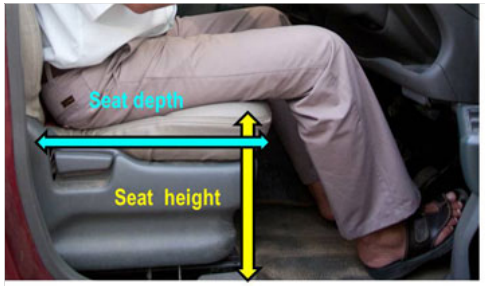
As discussed earlier that it is almost impossible to find any individual whose body dimensions of a particular percentile, various digital human modeling software are used to develop manikin/human model with specific percentile anthropometric values for ergonomic evaluation of CAD model of the vehicle in virtual environment.

Presently, vehicle manufacturers follow various standard recommended dimensions for their design. Standards provided by Society of Automotive Engineers (SAE Standards) are widely followed.

In the present module, one case study of ergonomic evaluation of a vehicle workstation with an individual in driver seat has been depicted to provide an idea of how a vehicle workstation can be evaluated for various human factor issues.

Note:
Standard methods of evaluation with specific percentile anthropometric values to evaluate accommodation of entire population or their comfort have not been followed in this module. Only, anthropometric compatibility and other human factor issues have been evaluated for a specific vehicle and for an individual (not for population).

• **Sitting Accommodation:**



Observation:
All the seat dimensions (seat cushion depth, width and height, backrest with and height; head rest dimensions) were found acceptable. More over due to various adjustable features of the seat one can adjust backrest angle/position of headrest, position of seat etc. as per his/ her requirement.

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• **Sitting and Driving Comfort:**

Observation:
Adopted driving posture by the individual shows that angles at various body joints are in comfort range as defined by Porter and Gyi (998).

The case study of a car from ford motor was done to verify the application of ergonomics.

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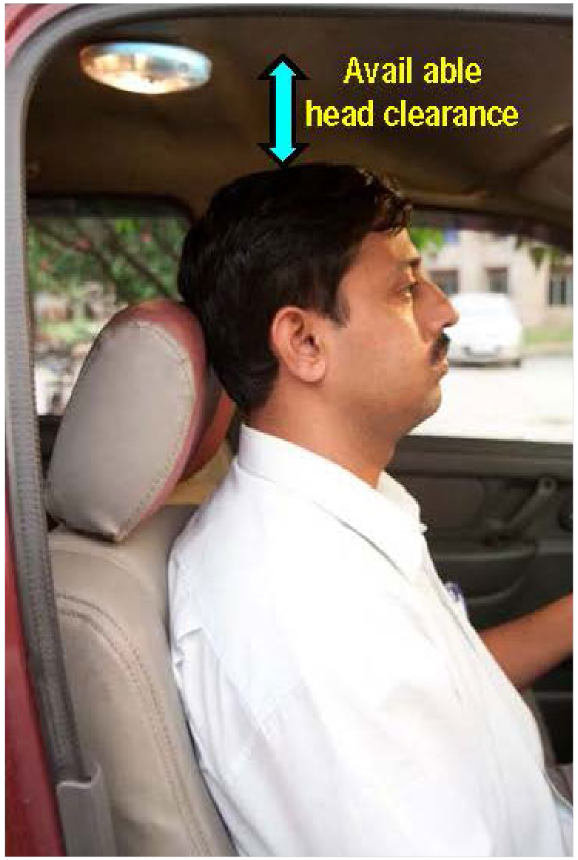
Clearanace Dimensions:
• **Headroom:**



Observation:
The headroom for the vehicle is sufficient for uses to avoid head striking with roof during jolts/ jerks.

The case study of a car from ford motor was done to verify the application of ergonomics.

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• **Leg room:**

Observation:
The legroom for the vehicle is sufficient for users for normal pedal operation.
There is no collision between:
• Seat front edge with popliteal area of lower leg,
• Thigh/knee with steering wheel/dashboard.

The case study of a car from ford motor was done to verify the application of ergonomics.

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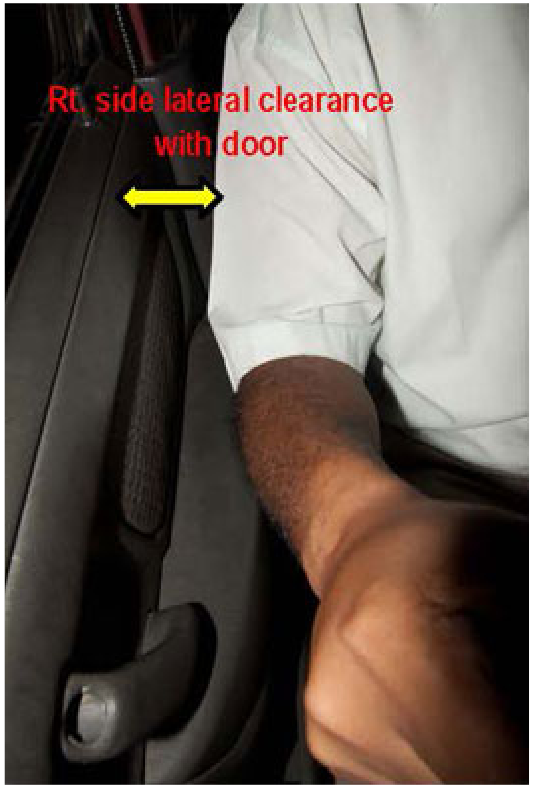
• **Lateral Clearance:**



Observation:
Left side and right side lateral clearance for the driver seat was found sufficient.

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- **Visual Field:**


Vision towards displays and controls on dashboard.


Outside front view through windshield.

Observation:
No visibility problem/ visual obstruction was found. The upper edge of the dashboard was low enough to see the road in front.

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Quiz

Assignment:

- What should be the upper edge height of the dashboard for smaller (5th percentile) driver?
  a) At the eye level
  b) At least 15 degrees below the horizontal eyeline
  c) At elbow height

- Minimum head clearance for tallest driver (95th percentile sitting height) should be
  a) 10-30 cm
  b) 5 cm
  c) 5m

- NSRP is defined as
  a) 95th percentile driver selected seat reference point
  b) 5th percentile driver selected seat reference point
  c) 50th percentile driver selected seat reference point

- Minimum seat width is decided based on
  a) Sitting hip breadth of 5th percentile female
  b)Sitting hip breadth of 95th percentile female
  c) Sitting hip breadth of 95th percentile male

- H-point is defined as
  a) Mid point of the line connecting two hip joint
  b) Heel location point
  c) Handle location point

- 'Eye Ellipse' concept of SAE is for
  a) Defining the range of eye positions within the driving population
  b) Defining visual field
  c) Defining visual obstruction

- Maximum actuating force for break operation should be
  a) 95th percentile right leg strength of female
  b) 5th percentile right leg strength of female
  c) 5th percentile right leg strength of male

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- Body type with increased fat storage, a wide waist and a large bone structure, referred as
  a) Ectomorph
  b) Endomorph
  c) Mesomorph

- Biomechanics is discussed under
  a) Cognitive ergonomics
  b) Psychology
  c) Physical ergonomics

- Drive's attention and visual information processing are studied under
  a) Physical ergonomics
  b) Cognitive ergonomics
  c) Environmental ergonomics

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References

• Charabarti, D., 1997. Indian anthropometric dimensions. Ahmedabad: National institute of design.

• Galer, I., 1987. Applied Ergonomics Handbook. 2nd ed. London: Butterworth & Co. Publishers Ltd.

• Gite, L.P., Majumdar, J., Mehta, R.C. and Khadatkar, A., 2009. Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design. CentralInstitute of Agricultural Engineering, Bhopal (ISBN: 978-81-909305-0-5).

• Grandjean, E., 1980. Fitting the Task to the Man: An Ergonomic Approach. Taylor and Francis.

• Henry Dreyfuss Associates, 1993. The measure of man and woman: human factors in design. Witney Library of Design.

• IEA (International Ergonomics Association), 2000. Definition of Ergonomics [online]. Available from: http://www.iea.cc/01_what/What is Ergonomics.html [Accessed 24 October 2011].

• Krist, R., 1994. Modellierung des Sitzkomforts: Eine experimentelle Studie. Weiden: Schuch.

• Peacock, B. and Karwowski, W., 1993. Automotive ergonomics. London: Taylor & Francis Ltd.

• Porter, M.J. and Gyi, D.E., 1998. Exploring the optimum posture for driver comfort. International Journal Vehicle Design, 19 (3), 255-266.

• Rebiffe, R., Zayana, O., and Tarriere, C., 1969. Determination des zones optimales pour l'emplacement des commandes manuelles dans l'espace de travail. Ergonomics, 12, 913 - 924.

• Sanders M.S. and McCormick, E.J., 1993. Applied Anthropometry, work-space design and seating. In: Human Factors in Engineering and Design. 7th ed. Singapore: McGraw-Hill, 415 - 455.

• Schinder, L.W., Anderson, C.K. and Olson, P.L., 1979. Driver Anthropometry and Vehicle Design Characteristics related to seat positions selected under driving and non-driving conditions. SAE Technical Paper 790384., warrendale PA: SAE, Inc.

• Van der Grinten, M.P., 1991. Test- retest reliability of a practical method for measuring body part discomfort. In: Y. Quennec and R. Daniellou, eds. Designing for everyone. Proceedings of the 11th Congress of the International Ergonomics Association. Paris: Taylor and Francis, 54-56.

• VanCott, H.P. and Kinkade, R.C., 1972. Human engineering guide in equipment design. Washington, DC: U.S. Government Printing Office.

Design Course

Basic Ergonomics in Automotive Design

The Fundamentals of Human-System Interactions
by
Prof. Sougata Karmarkar
DoD, IIT Guwahati

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