

**Ergonomics in Automotive Design**  
**Prof. Sougata Karmakar**  
**Department of Design**  
**Indian Institute of Technology, Guwahati**

**Module – 03**  
**Occupant Packaging**  
**Lecture – 04**  
**Occupant Packaging :: Basics and Details**

Welcome to the course; Ergonomics in Automotive Design. Now, we are going to discuss our third module, that is Occupant Packaging.

(Refer Slide Time: 00:38)



Massive Open Online Course (MOOC),  
The Ministry of Human Resource Development (MHRD)

**Module-3:**  
**Occupant Packaging**

- Definition and importance of vehicle packaging
- Key vehicle dimensions and reference points associated with occupant packaging
- Sequence and development procedure of vehicle package

**Dr. Sougata Karmakar**  
Associate Professor  
Department of Design  
Indian Institute of Technology (IIT) Guwahati  
Guwahati, Assam-781039, INDIA  
[karmakar.sougata@gmail.com](mailto:karmakar.sougata@gmail.com)

In this module, we will discuss about three major topics. First one; definition and importance of vehicle packaging. Second; key vehicle dimensions and reference points associated with the occupant packaging. And the third topic; sequence and development procedure in vehicle packaging.

(Refer Slide Time: 00:59)



**Definition and importance of vehicle packaging**

Occupant packaging?

The term packaging was introduced in automotive industry to indicate the process of assembling vehicle components (sub-systems and systems) within the allocated/ planned 3D space or volume of the vehicle to ensure functionality and usability of the vehicle.

The **occupant packaging** is defined as the 2D or 3D representation (sketches or CAD rendered models) of occupant e.g. drivers and passengers (mostly in the form of manikins) in relation to vehicle components and layout.

So, first, we should know; what is occupant packaging. The term packaging was introduced in the automotive industry to indicate the process of assembling vehicle components; those are (sub-system or system) within the allocated or planned 3D space or volume of the vehicle to ensure functionality and usability of the vehicle.

The occupant packaging is defined as the two-dimensional or three-dimensional representation; generally, sketches or CAD rendered models of the occupants. These occupants may be drivers, passengers (mostly in the forms of manikins) in relation to the vehicle components and layout.

So, in brief; what we can mention as occupant packaging; the occupant packaging is a process of representation in two-dimensional or in three-dimensional form to indicate how the various occupants (either driver or passengers or maintenance operator) will be accommodated within the vehicle, so that they can perform their activity with ease and with comfort.

(Refer Slide Time: 02:08)

**Definition and importance of vehicle packaging**

The Society of Automotive Engineers (SAE), USA has formulated various standards and many of these form part of the legislation which covers automotive design.

SAE standards which are relevant to occupant packaging and ergonomics evaluations are listed below. The corresponding International standards (ISO) and British standards (BS) are given in parenthesis (Porter and Porter, 2002).

SAE J826	H-point (ISO 6549)
SAE J1100	Seating reference point
SAE J1100	H-point travel path
SAE J1517	Driver selected seat position
SAE J941	Eyellipse (ISO 4513/ BS AU 176)
SAE J1052	Driver and Passenger head position contours
SAE J287	Hand controls reach envelopes (ISO 4040/BS AU 199)

So, definition and importance of occupant packaging: so, there are various automotive standards, those standards are actually guiding; how to do that automatic packaging process.

So, SAE standards; which are relevant to occupant packaging and ergonomic evaluations are listed below. Apart from those SAE standards; the corresponding international standards - ISO standards, British standards are also given in parenthesis.

Now, if we look at; so, there are various standards. SAE J826 is for H-point; similarly, that is also mentioned in ISO 6549. Then SAE J1100; seating reference points. Then SAE J1100; H-point travel path. SAE J1517; that is for driver selected seat position. SAE J941 for Eyellipse. Similar standard is also mentioned in ISO that is 4513, British standards related to automotive design 176. Then SAE J1052 related to driver and passengers head position contours. Then SAE J287 that is related to hand control reach envelopes; similarly, in ISO also, similar standard is 4040 and a British standard 199.

(Refer Slide Time: 03:34)

**Definition and importance of vehicle packaging**

Design recommendations and guidelines relevant to automotive design

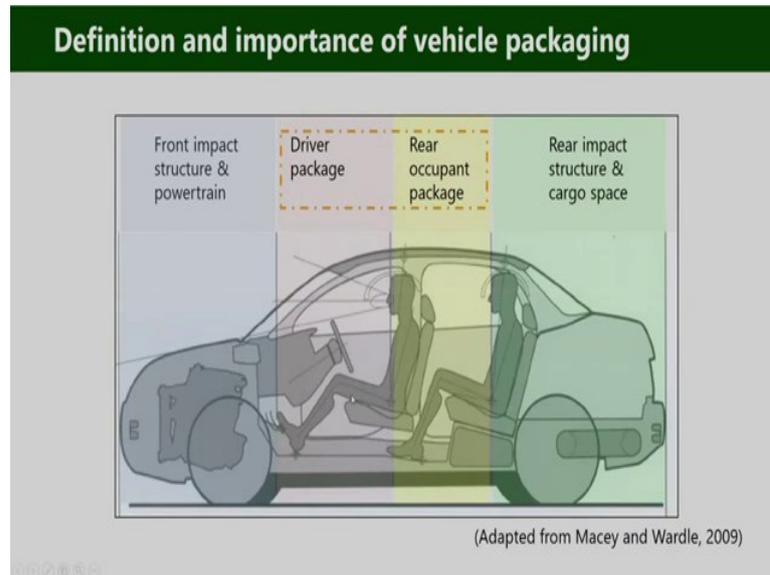
- Sanders and McCormick (1992) Displays, controls, workstation layout
- Peacock and Karwowski (1993) Occupant packaging, displays and controls, the ageing driver
- Defence Standard 00-25 Displays, controls, anthropometry, noise, vibration, workstation layout
- Pheasant (1996) Anthropometry
- Campbell *et al.* (1998) Design guidelines for in-vehicle information systems

(Adapted from Porter & Porter, 2002)

Apart from these various standards for occupant packaging; there are also other design guidelines which are relevant for automotive design. These types of guidelines are available in various literature resources, few are mentioned here; like, Sanders and McCormick (1992). This is related to displays, controls, workstation layout. Similarly, Peacock and Karwowski (1993), they have given some guidelines related to occupant packaging, display and controls, the aging of driver.

There are other guidelines or standards related to occupant packaging; this is a defence standard. Then there are also standards available for anthropometry, display controls, design guidelines for in-vehicle information system. So, apart from SAE standards, British standards and many other similar automotive standards are there, there are also various design guidelines which we can consult for automotive packaging and vehicle design.

(Refer Slide Time: 04:33)



Now, if we look at a passenger car. So, there are various compartments. We can divide these into four compartments. The first portion; front impact structure and powertrain; the second portion – where driver is sitting on the driver seat that is related to driver package; next, the backside that is rear occupant package and the last portion that is rear impact structure and cargo space. Out of these four areas, our area of interest for this occupant packaging is mainly driver package and rear occupant package; these two middle portions.

(Refer Slide Time: 05:10)

### Definition and importance of vehicle packaging

Various aspects of occupant packaging (Bhise, 2016)

- **Relative position** of the occupant with the vehicle components
  - *key reference points* (e.g., accelerator heel point [AHP], Pedal reference point [PDR], seating reference point [SgRP])
  - *manikins* (e.g., SAE J826 and J4002, HPM & HPD)
  - *occupant packaging tools* (e.g., SAE J1517, J4004, J941, J1052, J287, J1050)
  - *primary vehicle controls* (steering wheel, pedals, gear shifter etc.)
  - *some vehicle body and trim components* (e.g., seats, instrument panels, center console, door trim panels, mirrors etc.)

Now, the various aspects which we generally discuss under occupant packaging are listed here. So, one is the relative position of the occupant with vehicle components, how occupants (means, driver or passenger or maintenance persons) are positioned inside the vehicle and how they interact with the vehicle, that is defined with various aspects and those are mentioned here, like, key reference points. Like, accelerator heel point, pedal reference point, seating reference point; we will discuss in detail in subsequent slides.

Next, manikins, SAE J 826, then J4002, H-point machine, H-point devices. So, these are other aspects. Then occupant packaging tools, these are mentioned in various SAE J standards. Primary vehicle controls like steering wheel, pedals, gear shifter, how should be their location so that the driver can easily use those controls. Then some vehicle body and trim components like seats, instrument panel, centre console, door trim panels, mirror etcetera; we also discuss under occupant packaging.

(Refer Slide Time: 06:22)

**Definition and importance of vehicle packaging**

- **Reachability and operations** of various controls (steering wheel, pedals, gear shifter, knob/buttons on instrument panels of the dashboard, grab handles etc.)
- **View-field** of the occupant (eyellipses: drivers' eye locations specified in SAE standard J941, in-vehicle and external visibility by the occupant, indirect visibility through mirrors)
- **Clearance dimensions** (head, knee and lateral clearances, legroom etc.)
- **Entry-exit** (dimensions of door trim panels, stairs/ ladders etc.)
- **Storage space** (different holders and drawers/ cabinets for keeping the small sized belongings of the occupant and the trunk / boot/ dickie for keeping large sized luggage)
- **Service/ maintenance:** Keeping provisions for easy and safe maintenance and servicing (e.g., refueling, cleaning, replacing faulty components etc.)

Apart from the driver positioning and interaction with other controls, we also discussed about the reachability of the operators for various controls like steering wheels, various foot pedals, gear shifter, knob/buttons on the instrument panels. So, these are discussed under occupant packaging.

Then view-field of the occupants; eyellipse, diver's eye location specified in SAE standard J941, in-vehicle and external visibility by the occupant, that may be direct visibility through the windshield, or it may be indirect visibility using the mirror or any

other devices. Then clearance dimensions; like head clearance, knee clearance, thigh clearance, lateral clearance, different types of clearance dimensions whether those are available in the vehicle, so that driver and other occupants like passengers or maintenance person can do their job comfortably. That is also discussed under this occupant packaging. Then we study; entry/exit, that how driver or passenger is entering inside the vehicle, coming out of from the vehicle, and how they are taking seats inside the vehicle. Those aspects are discussed under this entry/exit.

Storage space; different holders, drawers, cabinet for keeping small-sized belongings of the occupant. On the other hand, the trunk, boot or dickie for the keeping large sized luggage. So, how the storage space should be distributed in that vehicle that is also coming under occupant packaging. Then service and maintenance; keeping provisions for easy and safe maintenance for servicing. For example, refueling, cleaning, replacing faulty parts, so for that purpose also, while we are designing the vehicle or developing the vehicle concept, then these various aspects of the occupant packaging, we should need to consider, we should consider in detail, so that there should not be any problem while the users are using that vehicle.

(Refer Slide Time: 08:24)



**Definition and importance of vehicle packaging**

**Challenge in occupant packaging?**

The major challenge in occupant packaging is to accommodate the **maximum percentage** of the targeted users (drivers, passengers, maintenance or service personnel etc.) in such a manner that **they can easily and comfortably perform** all required tasks related to driving or non-driving.

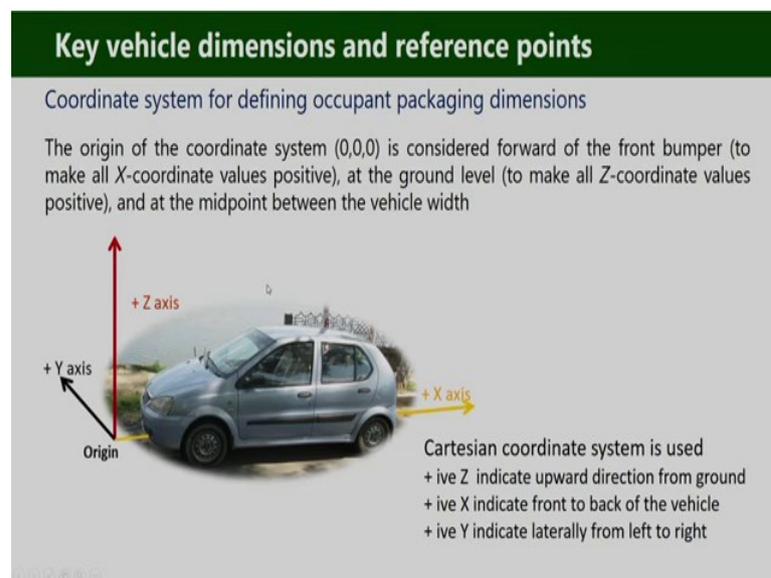
Successful automotive design is achieved by optimum compromise among various factors within the imposed constraints (typically time, cost, and legislation). Such compromises will not be achievable if the **basic ergonomics issues affecting accommodation and comfort** are not established from the very early stage of design and development (Porter and Porter, 2002).

Next, what are the challenges in occupant packaging? The major challenge in occupant packaging is to accommodate the maximum percentage of the targeted users. As we mentioned earlier, these targeted users are drivers, passengers, maintenance or service

personnel, in such a manner we have to do this, so, that they can easily and comfortably perform all the required tasks, those tasks may be related or non-related to driving. So, driving or non-driving task should be performed comfortably and easily. At the same time; we have to take care that maximum percentage of the targeted users or targeted customer should be accommodated within that vehicle.

Successful automotive design is achieved by optimum compromise among various factors within the imposed constraints. Typically, these constraints are; time, cost, and legislation. Such compromises will not be achievable if the basic ergonomic issues affecting accommodation and comfort are not established from the very beginning stage; that is the conceptual stage of the vehicle development.

(Refer Slide Time: 09:35)

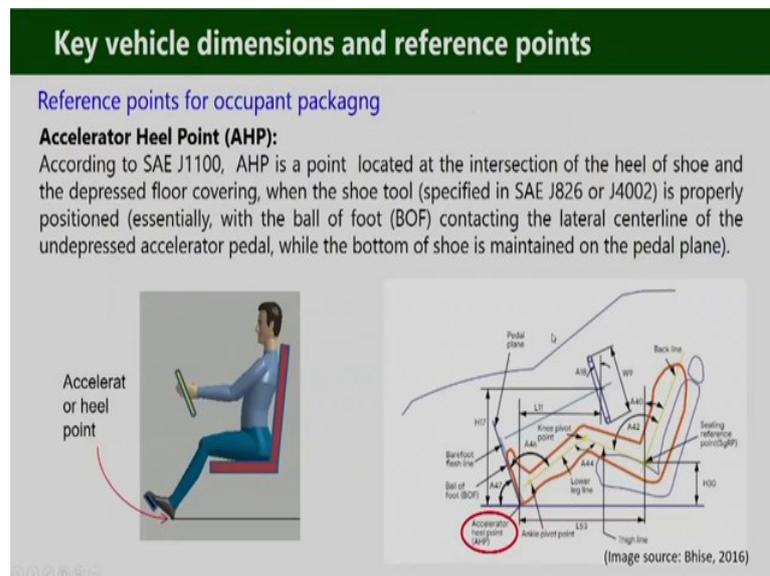


Now, while we are discussing about the occupant packaging, various dimensions, key reference points, then first; we have to understand that, how to define the vehicle in 3D space. Various dimensions, various spaces inside the vehicle, how we can define in 3D space; for that purpose, we have to take help of coordinates; Cartesian coordinate system.

The origin of the coordinate system; (X,Y,Z) that is the (0,0,0) position is considered forward of the front bumper. Here it is, you can see, at this point, this is the area where this is the origin point. So, where all (X,Y,Z), all are 0. So, this is located actually in front of the vehicle on the ground. Then, the upward direction is Z-axis, that is positive; then sidewise - from the left side to the right side, it is positive Y-axis. Similarly, from

the front to the back of the vehicle, that is the positive X-axis. Thus, what is happening when we are defining the axis in such a way, then all the dimensions, vertical dimensions from the ground upwards, it is coming in positive value. Similarly, all the dimensions in X direction that is also coming in positive value. Only, as this is the midpoint of the vehicle, so lateral dimension that may be positive and negative because in that case positive X-axis is also there, negative X-axis is also there. So, in this way, the Cartesian coordinate system is followed for defining the vehicle dimensions.

(Refer Slide Time: 11:11)

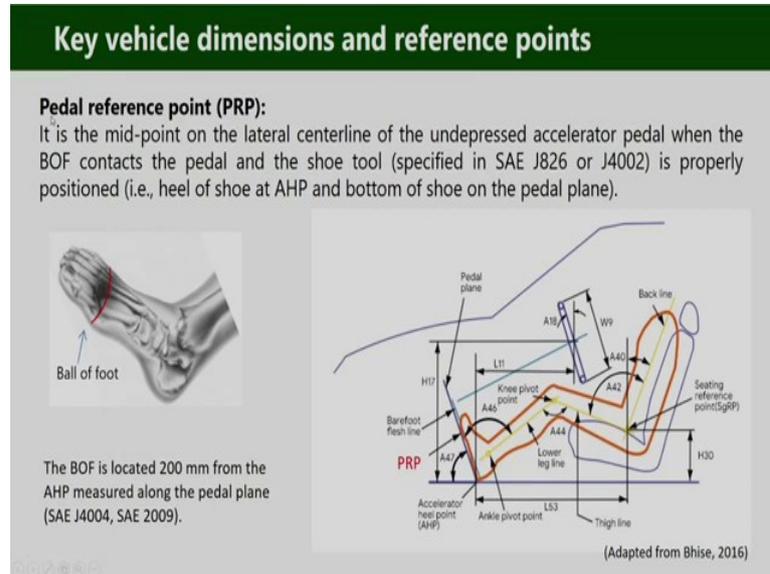


Now, we should go for defining various reference points which are used for occupant packaging. The first and the foremost important point is Accelerator Heel Point (AHP); in brief, we mention AHP. According to SAE J1100, according to this standard, AHP is a point located at the intersection of the heel of the shoe and the depressed floor covering, when the shoe tool (specified in SAE J826 or J4002) is properly positioned, that is (essentially, with the ball of foot) contacting the lateral centerline of the undepressed accelerator pedal, while the bottom of the shoe is maintained on the pedal plane.

As we read this definition; then from that, what is accelerator heel point? So, if we look at this image, accelerator heel point is a point on the vehicle floor where the heel is touching. What is the condition? When the foot is on the undepressed accelerator pedal, bottom of the shoe is parallel with the pedal plane, at that point where the heel of the

shoe is touching the vehicle floor, that particular point is referred as accelerator heel point.

(Refer Slide Time: 12:31)

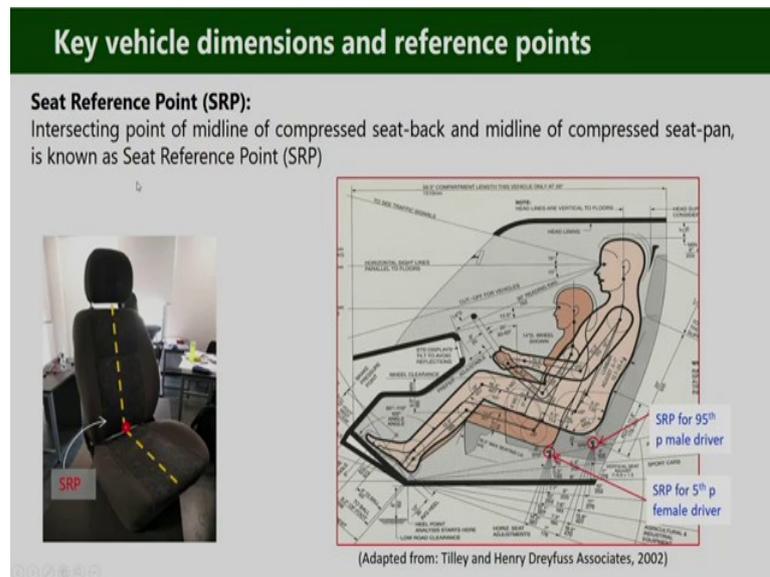


Next important reference point is a Pedal Reference Point; in abbreviated form PRP. So, it is the mid-point on the lateral centerline of the undepressed accelerator pedal when the ball of foot contacts the pedal and the shoe tool (as specified by SAE J826 standard) is properly positioned (that is the heel of the shoe at the AHP position and bottom of the shoe on the pedal plane).

So, if we look at this image, then we understand that PRP is this particular point where ball of foot is touching the mid-line of the accelerator and the heel is touching at the accelerator heel point. So, while the driver is keeping his foot on the pedal plane, then the contact point of the ball of foot at the accelerator that is called as the PRP, pedal reference point.

Now, what is the Ball of foot? Ball of foot is this particular area, it is located about 200 millimetres from the accelerator heel point, measured along the pedal plane. From the pedal, from the AHP if we go along this pedal plane then at around 200 millimetres distance, we will get the ball of foot. So, ball of foot is actually the area of the feet through which we press the accelerator, brake or these types of controls, where these metatarsal bone and phalanges bones are there, this junction point is known as the ball of foot.

(Refer Slide Time: 14:00)



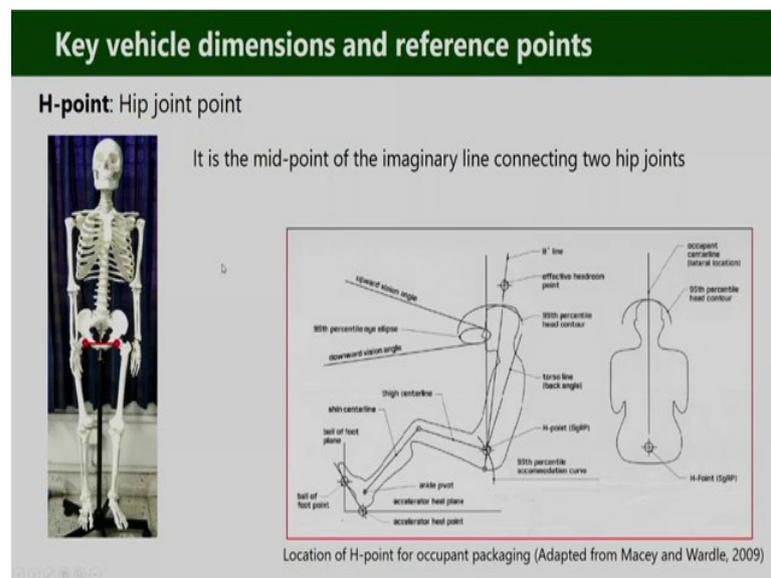
Now, the next reference point is the Seat Reference Point (SRP). This seat reference point is the intersecting point of the mid-line of the compressed seat-back and the compressed seat-pan. So, in this image you can see, this is the point which is defined as the seat reference point, means, this is the intersecting point of the compressed seat-back and the mid-line of the compressed seat-pan because the property of the cushion or the material of the seat is different.

So, that is why we have to consider the compressed seat-back, mid-line of the compressed seat-back, and the mid-line of the compressed seat-pan. These two lines where they are intersecting that particular point is known as SRP. So, SRP for a particular seat is fixed in relation to that seat but while the seat is moving to accommodate different types of driver, while the seat is moving along the seat track, then the SRP position also varies in relation to the vehicle, but in relation to the seat its position is fixed.

Now, if we look at this image, so while the 5<sup>th</sup> percentile female driver or female manikin is positioned on the seat, keeping their leg on the accelerator, it is touching the accelerator heel point, similarly, 95<sup>th</sup> percentile manikin, male manikin is also positioned with the same, similar driving posture. Then what is happening? As per their requirement, they will adjust the seat forward and backwards. So, 5<sup>th</sup> percentile female will adjust, move the seat forward, whereas, the 95<sup>th</sup> percentile male driver will move the

seat backward. As the seat is moving forward and backward, so accordingly the SRP position will also vary. So, in this image, this is the SRP position for 5th percentile female manikin; on the other hand, this is the SRP position for 95th percentile male manikin. So, position of the SRP is varying as per the seat adjustment.

(Refer Slide Time: 15:58)



Now, the next important reference point is the H-point, that is hip joint point. Now, what is hip joint point? If we look at this skull, then we will understand, so there are two hip joints. So, one is right hip joint; another is left hip joint. The midpoint of these two hip joints, these positions is known as H-point. So, how we can define; what is the H-point. So, H-point, if we connect the two hip joints with an imaginary line the midpoint of that line is known as H-point.

Now, from this image, if we see from the side view, then it is coming at the side of the hip joint. So, this is the H-point. On the other hand, while we are looking at the manikin from the front view or back view, then it is coming in the middle of the hip joints. Although, these points are at the centre of this imaginary line, but from the side view it appears like it is at the side, but its actual position is at the middle of the two hip joints.

(Refer Slide Time: 17:05)

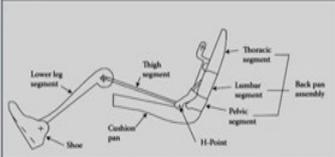
### Key vehicle dimensions and reference points

#### H-point manikin

SAE standard J826 specified H-point machine (HPM)  
SAE standard J4002 specified in or H-point device (HPD)

HPM and HPD are three-dimensional fixtures for representing

- Lower-limb dimension of 95th percentile legs
- Weight of 50th percentile (76 kg) &
- Torso contour of 50th percentile of U.S. male



H-point device- SAE J826 (Adapted from: Bhise, 2016)



ASPECT manikin- Modified H-point manikin with an articulated lumbar spine. (Reed et al., 2001)



Head Restraint Measurement Device on H-point Machine (Reed et al., 2001)

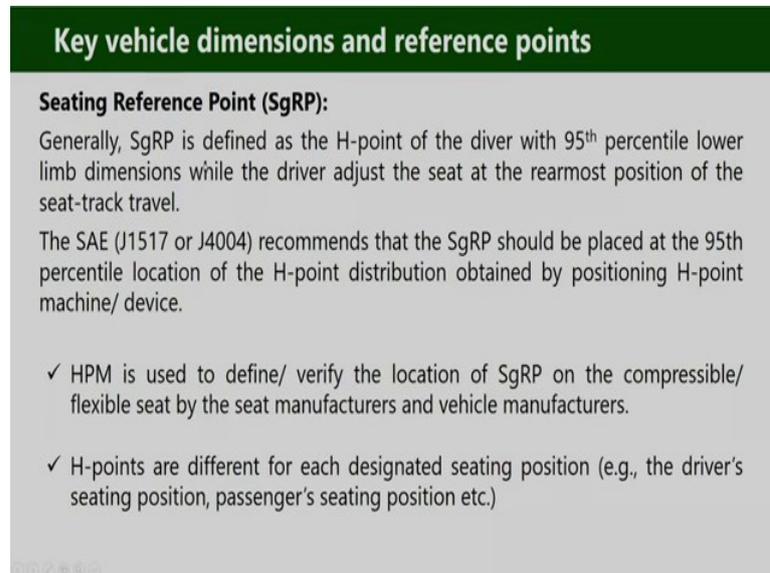
Now, H-point manikin; for defining H-points, SAE J standard 826 specified the H-point machine, so that we can easily detect the H-point in a particular seat when it is manufactured or when it is installed in a vehicle. SAE J standard J4002 specified H-point device that is called HPD. While in SAE J standard 826; it is mentioned as H-point machine. In SAE J 4002, it is mentioned as H-point device. So, this is the updated one. So, H-point machine and H-point device are actually three-dimensional fixture for the representation of lower limb dimension of 95<sup>th</sup> percentile legs, whereas, weight of 50<sup>th</sup> percentile male that is 76 kg for US population and torso contour of 5<sup>th</sup> percentile of US male. So, this H-point machine or H-point device is actually representing these anthropometric and biomechanical properties.

So, if we look at this image, then you can see, there are various segments; lumbar segment, pelvic segment, thoracic segment and this is the cushion pan, and this is thigh segment and lower leg segment, and this is the shoe portion. So, these types of devices are positioned on the automobile seat to identify where will be the location of H-point, while the shoe of the device is kept on the H-point, accelerator heel point location.

Later on, there was also modification of that H-point machine. So, the University of Michigan in their automotive research program, they developed ASPECT manikin, automobile seat and packaging evaluation. So, ASPECT manikin, its full form is automotive seat packaging evaluation and comparative tool. So, in ASPECT manikin,

they modified the H-point manikin or H-point machine with an articulated lumbar spine. Similarly, there is also further modification of that H-point machine; they added head restraint device for identifying the head location and representing the head position.

(Refer Slide Time: 19:20)



**Key vehicle dimensions and reference points**

**Seating Reference Point (SgRP):**

Generally, SgRP is defined as the H-point of the driver with 95<sup>th</sup> percentile lower limb dimensions while the driver adjust the seat at the rearmost position of the seat-track travel.

The SAE (J1517 or J4004) recommends that the SgRP should be placed at the 95<sup>th</sup> percentile location of the H-point distribution obtained by positioning H-point machine/ device.

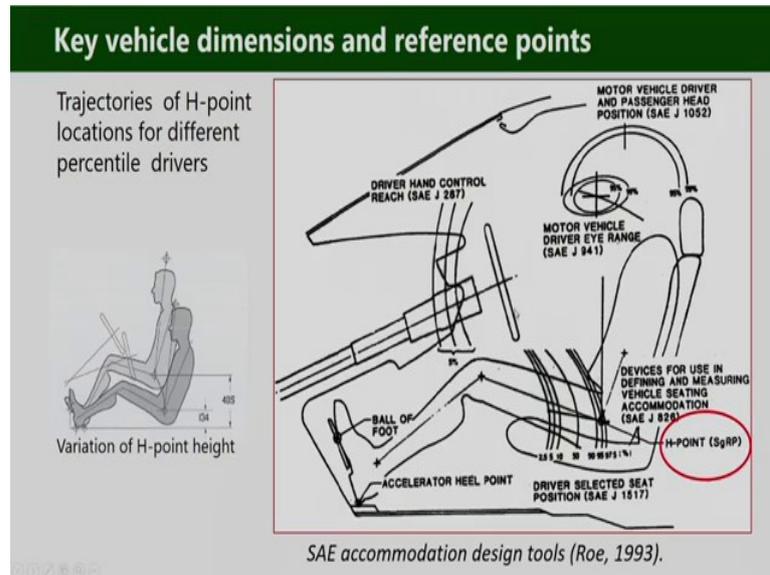
- ✓ HPM is used to define/ verify the location of SgRP on the compressible/ flexible seat by the seat manufacturers and vehicle manufacturers.
- ✓ H-points are different for each designated seating position (e.g., the driver's seating position, passenger's seating position etc.)

Now, another reference point used in defining automotive packaging that is called Seating Reference Point (SgRP). Generally, the seating reference point is defined as the H-point of the driver of 95<sup>th</sup> percentile lower limb dimension, while the driver adjusts the seat at the rearmost position of the seat-track travel.

The SAE J1517 or J4004 recommends that the SgRP, means, seating reference point should be placed at the 95<sup>th</sup> percentile location of the H-point distribution, obtained by positioning H-point machine. So, in brief, what is seating reference point? So, seating reference point, while the 95<sup>th</sup> percentile driver is keeping their leg on the accelerator heel point and adjusting the seat as per their requirement, at that time, whatever will be the position of the H-point that is called as the SgRP.

H-point machine is used to define or verify the location of SgRP on the compressible seat, by the seat manufacturer and vehicle manufacturers. H-points are different for each designated seating position. For driver seat, it is different from the passenger seat, so based on the type of seat, whether this is a driver seat or co-passenger seat or the passengers of the rear seat, based on that the H-point location will also vary.

(Refer Slide Time: 20:47)

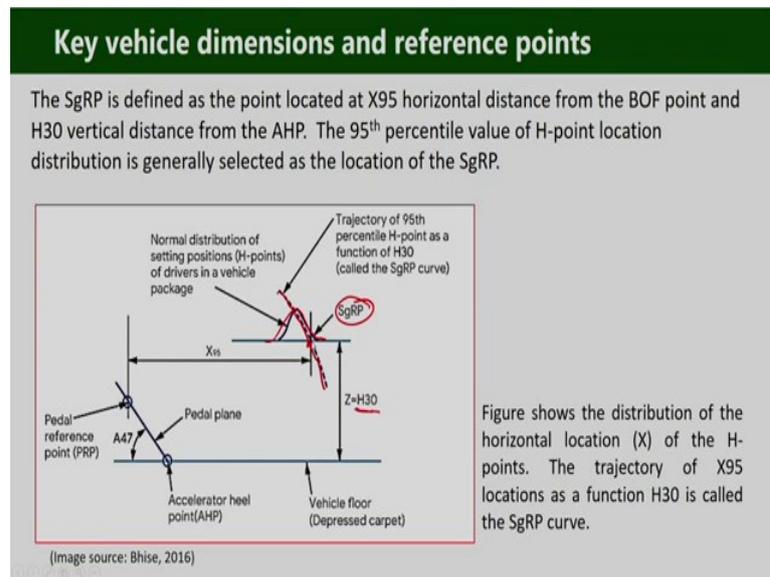


Now, if we look at this image, then while manikins of different percentile, starting from 2.5<sup>th</sup> percentile to 97.5<sup>th</sup> percentile or 5<sup>th</sup> percentile to 95<sup>th</sup> percentile, manikins are being positioned on the occupant seat, then while the seat adjustment is happening, based on this H-point machine or H-point manikin, then what is happening? The trajectories of the H-points are different as represented here.

So, this type of trajectories is there. Out of this trajectory, this is the H-point or SgRP. So, how these trajectories are happening? So, while that H-point position is almost fixed and while the driver is adjusting the seat height, accordingly the H-point movement is happening. So, the path of the H-point movement is mentioned as the H-point trajectory. So, these are the H-point trajectories for different percentile manikins.

Out of this trajectory, from this one, if we go for the 95<sup>th</sup> percentile trajectory, then this particular location is, that is the H-point (SgRP). So, how is this SgRP different? It is the function; we are going to the next slide; where we will see how these H-point is defined.

(Refer Slide Time: 22:11)



Now, similar to that one, the SgRP is defined as the point located at X95 horizontal distance from the ball of foot point and H30 vertical distance from the accelerator heel point. So, this particular point is designated as the SgRP. So, what is SgRP? So, this is actually, an intersection point of the X95 distance from the pedal reference point to the 95<sup>th</sup> percentile trajectory and the vertical seat height, which is designated as 'Z' distance that is H30.

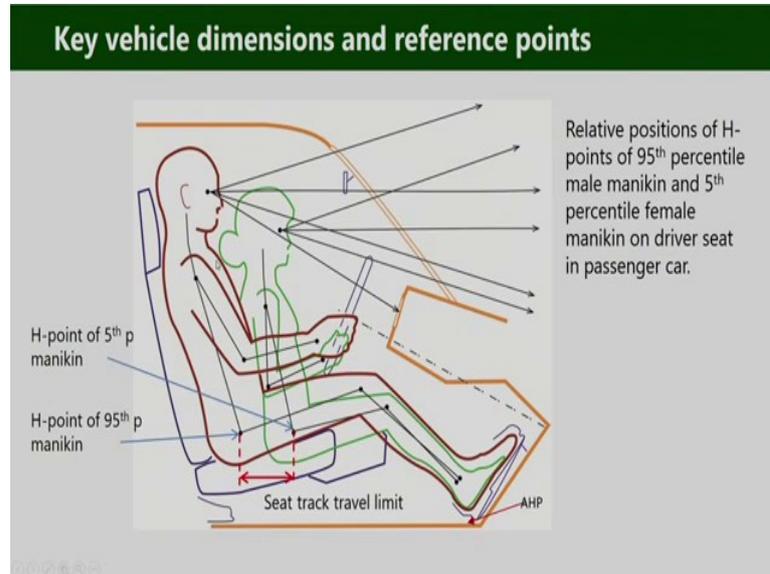
So, in this particular figure, it shows the distribution of the horizontal location of 'X' of the H-points. So, X distance from the pedal reference point or from the accelerator heel point. If we position for different percentile manikin, then we will get this type of normal distribution curve. Means, while the X distance is presented as the function of 'Z' height (that is the H30) then we are getting this type of normal distribution curve, means, all the drivers with different body dimension or anthropometric variability,

so, their H-point will be within this area, means, their H-point will follow this type of normal distribution pattern. Out of that normal distribution pattern, if we particularly consider this trajectory, that is for 95<sup>th</sup> percentile manikin or 95<sup>th</sup> percentile driver, then this particular location, where the X95 distance is intersecting with the 'Z' height, that is the H30, that particular point is referred as a seating reference point, SgRP.

So, trajectory of the 95<sup>th</sup> percentile H-point as a function of H30, that particular point is called SgRP curve, and on that SgRP curve, this intersecting point, as I mentioned, that

X95 distance intersecting with the 'Z' height, that is the H30, that particular intersecting point is known as seating reference point, SgRP.

(Refer Slide Time: 24:16)



Now, if we look at this image, so if 95<sup>th</sup> percentile or male manikin or the manikin with a larger body dimension and this green one, that is the 5<sup>th</sup> percentile female with smaller body dimension are positioned on the driver seat, then we can see, where is the H-point location. This is the H-point location for the 5<sup>th</sup> percentile female manikin, and this is the H-point location of the 95<sup>th</sup> percentile male manikin.

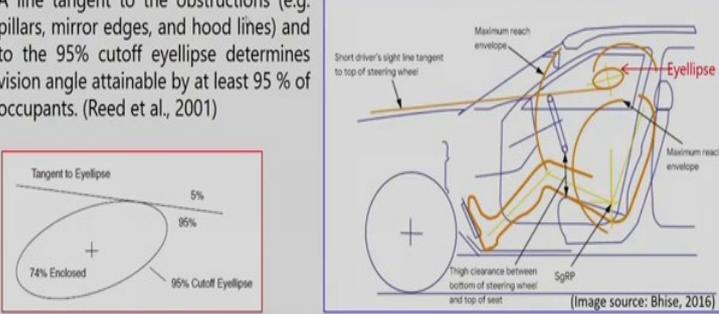
So, while we are deciding that how much should be the seat track travel limit, then we have to consider, so that that seat track travel limit should be sufficient enough, so, that both 5<sup>th</sup> percentile female manikin, at the same time 95<sup>th</sup> percentile male manikin, they can adjust the seat forward and backward as per their requirement. So, in this image, relative position of H-points of 95<sup>th</sup> percentile male manikin and 5<sup>th</sup> percentile female manikin on the driver seat has been represented.

(Refer Slide Time: 25:17)

### Key vehicle dimensions and reference points

**Eyellipse (or eyellipsoid in three dimensions):**  
A graphical representation of approximation of the occupant eye location distribution as a multidimensional normal density Distribution.

A line tangent to the obstructions (e.g. pillars, mirror edges, and hood lines) and to the 95% cutoff eyellipse determines vision angle attainable by at least 95 % of occupants. (Reed et al., 2001)



The diagram consists of two parts. The left part, titled 'Illustration of eyellipse concepts (Reed et al., 2001)', shows an eyellipse (a 2D normal distribution) with a horizontal line tangent to its upper boundary. The area above the line is labeled '5%' and the area below is '95%'. A smaller area within the ellipse is labeled '74% Enclosed' and the outer boundary is '95% Cutoff Eyellipse'. The right part, titled 'Representation of eye locations of driver using eyellipse', shows a side view of a driver in a vehicle seat. A yellow eyellipse is drawn around the driver's eye area. A horizontal line is tangent to the top of the steering wheel, labeled 'Short driver's sight line tangent to top of steering wheel'. Other labels include 'Maximum reach envelope' for the driver's reach, 'High clearance between bottom of steering wheel and top of seat', and 'SgRP' (Seat Reference Point). The source is cited as '(Image source: Bhise, 2016)'.

Illustration of eyellipse concepts (Reed et al., 2001). Representation of eye locations of driver using eyellipse

Now, after discussing about various key reference points, like accelerator heel point, seating reference point, pedal reference point, we are moving to discuss about eyellipse or eyellipsoidal shape in the three-dimensions.

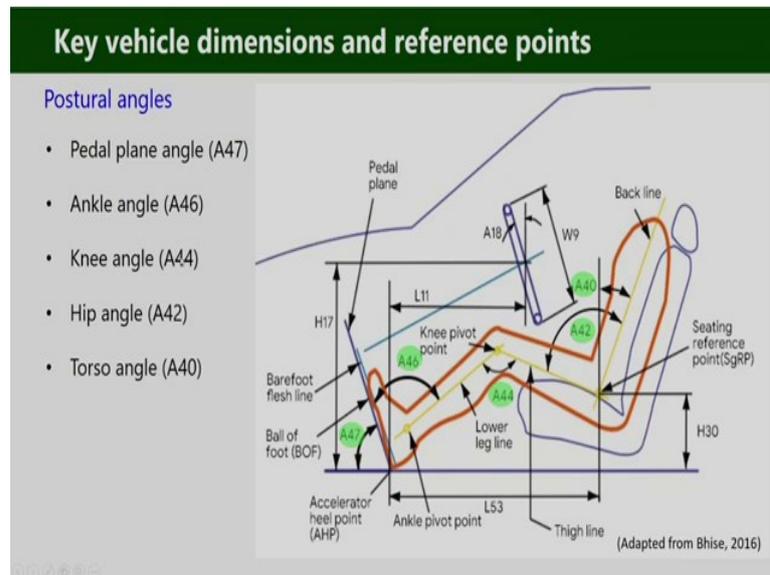
So, what is this eyellipse? If we look at this image, this is called eyellipse. So, what is this eyellipse; in that occupant packing? This is actually a graphical representation of approximation of the occupant eye location distribution as the multidimensional normal density distribution. In other words, we can mention, this is the graphical representation; two-dimensional or three-dimensional.

If it is two-dimensional, then eyellipse and three-dimensional then the eyellipsoidal shape. Within the three-dimensional shape or two-dimensional structure; all the driver's eyes will be located, within this area. So, if the drivers are the adjusting their seat as per their requirement, then locations of the eyes of those drivers, starting from 5<sup>th</sup> percentile body dimension to 95<sup>th</sup> percentile body dimension will be accommodated within this eyellipsoidal structure. Now, if we look at this image, then you can see, this is the tangent to eyellipse, which is dividing 5 percent of the population and 95 percent of the population.

Now, if we look at this sentence, a line tangent to the obstructions (such as pillars, mirror edges or hood lines) and to the 95 percent cutoff eyellipse. So, line tangent to the obstruction to the 95<sup>th</sup> percentile cutoff eyellipse determines vision angle, attainable by

the at least 95 percent of the occupants. So, this eyellipse is actually helping us to define that, if we draw a tangent line, tangent line with this eyellipsoidal structure and various obstructions. This tangent line is actually dividing; through this line of vision angle, 95 percent of the driver population will be able to visualize that particular object or target.

(Refer Slide Time: 27:25)



Now, apart from various key reference points, eyellipses; there are various postural angles which are also defined in SAE standards. These postural angles are also important for defining occupant packaging. So, these important postural angles are; pedal plane angle, ankle angle, knee angle, hip angle and torso angle.

So, first pedal plane angle; so that is denoted as A47 in SAE standard. So, this pedal plane angle is the angle with the depressed floor, and the pedal plane means accelerator plane. Similarly, this angle A46, it is known as the ankle angle, this is the angle between the pedal plane of the bottom of the foot and the shank line or the mid-line of the lower leg. So, this is known as the ankle angle. The third angle is designated as A44 in SAE standards; this is called knee angle. So, this is the angle between the thigh line and the shank line or the lower limb line.

Next angle is the A42, that is the trunk angle, angle between the thigh line and the torso line. Then another important angle is the A40, that is the torso angle. So, torso angle is the angle of the mid-line of the torso with the vertical axis or with the vertical line, how is the angle of the torso. So, that is defined as the A40, means, torso angle.

So, these are the various angles, while we are talking about the posture of the driver in that, inside the vehicle space, while they are positioned on the driver seat, then we need to analyze these angles to understand, whether the posture is comfortable or not.

(Refer Slide Time: 29:20)

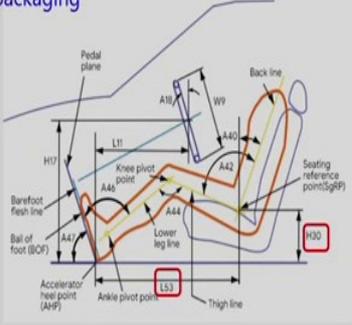
**Key vehicle dimensions and reference points**

Few Key dimensions relevant to occupant packaging

**H30 Dimension:** It is the vertical height of the SgRP from AHP.

H30 for class A vehicles (passenger cars and light trucks): 127 and 405 mm and for class B vehicles (medium and heavy trucks): >350 mm

**L53 Dimension:** It is the horizontal distance of the SgRP from the AHP.



(Adapted from Bhise, 2016)

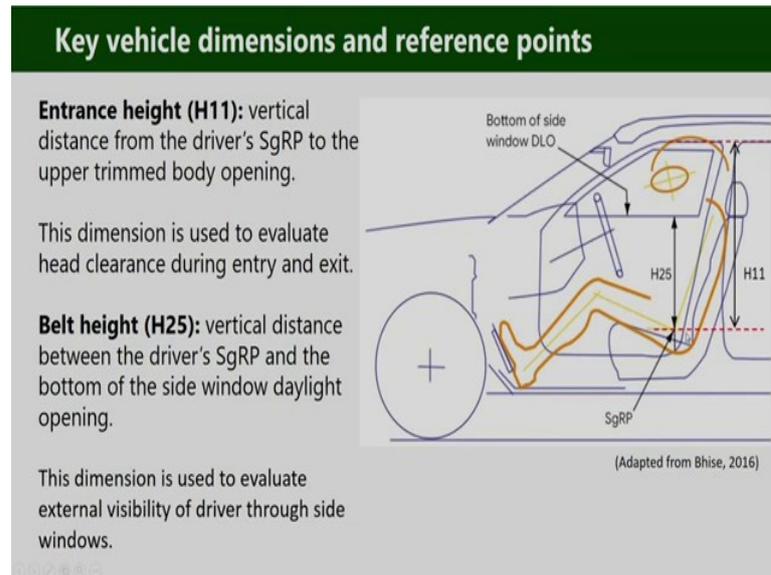
Lower values of H30 leads to lower roof height (measured from the vehicle floor) and will require longer horizontal space (dimension L53) to accommodate the driver.

Now, few other key dimensions which are also important for occupant packaging. So, one such dimension is H30 dimension; it is the vertical height of the SgRP from the accelerator heel point. This is the H30 dimension; this is the accelerator heel point, so vertical height of this particular point from the floor position, means, that is the accelerator heel point to the SgRP, seating reference point. This vertical height of the seating reference point is defined as the H30. On the other hand, the horizontal distance along the X-axis from the accelerator heel point to the SgRP, seating reference point, that is the H-point of the 95<sup>th</sup> percentile manikin, that is designated as L53, that is the horizontal distance of the SgRP.

Now, if H30 dimension, means, this vertical dimension is higher, it means, the vertical space requirement for the vehicle will also be high, at the same time if H30 is higher, then automatically the L53 will be low, means, the horizontal space requirement will be less, but the vertical space requirement will be high. On the other hand, if H30 is low, then vertical space requirement will be low, but in that case, horizontal space requirement will be more, means, along the X-axis, the space requirement will be more to accommodate the drivers.

Now, H30 for class A vehicles, like passenger cars and light trucks, it is generally 127 to 405 millimetres. On the other hand, for class B vehicles, like medium and heavy trucks, so, it is generally, more than 350 millimetres, from the accelerator heel point. Other two important dimensions related to occupant packaging are entrance height, designated as H11 and belt height H25.

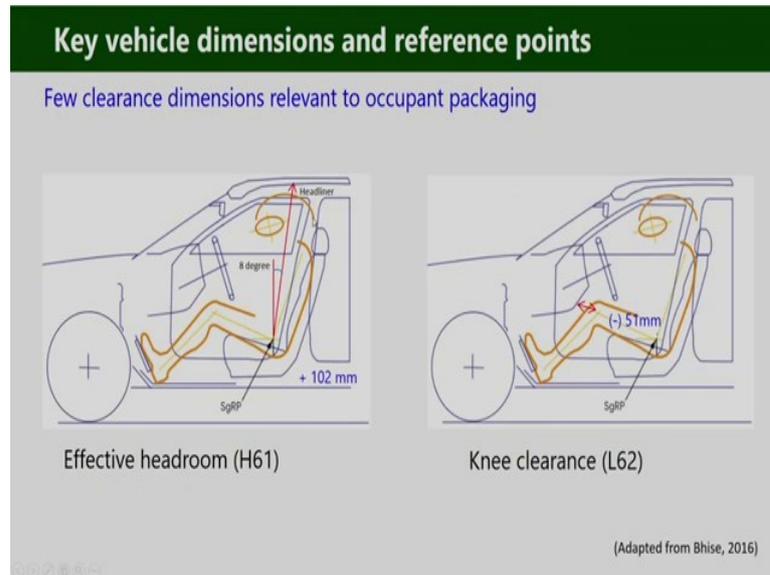
(Refer Slide Time: 31:25)



The entrance height; if we look at this image, the entrance height is the vertical distance from the seating reference point (SgRP level) to the trimmed body opening. So, starting from SgRP to the trimmed upper body opening of the door panel. So, this vertical height is known as entrance height. And this height is very important as it is used for evaluating head clearance during entry and exit.

On the other hand, belt height is the vertical distance between the drivers, seating reference point and the bottom line of the daylight opening, at this side window. So, this vertical distance from the seating reference point to the bottom line of the side window which is known as bottom of the side window daylight opening, this vertical distance is called H25 or belt height. This dimension is important to evaluate the driver's external visibility through the side window.

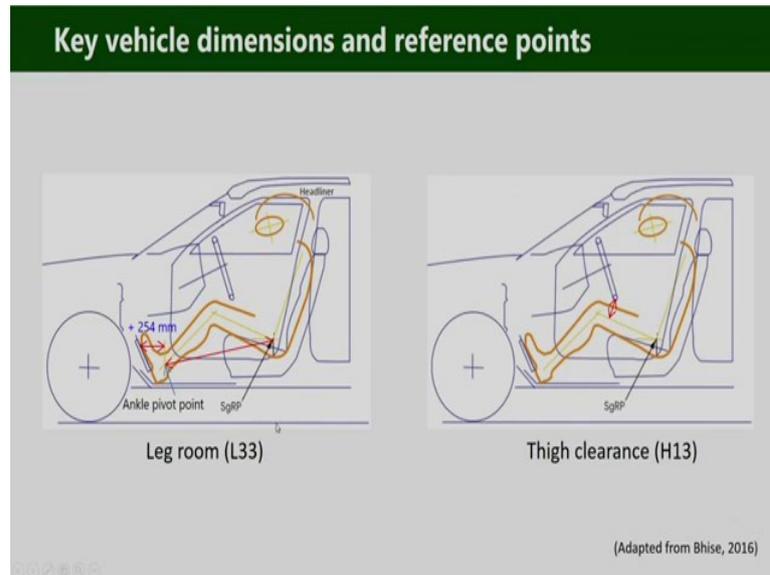
(Refer Slide Time: 32:24)



Now, we are going to discuss a few clearance dimensions, which are used for automotive packaging. So, first one is; effective headroom denoted as H61. This effective headroom is measured at 8-degree angle with the vertical line. From seating reference point, at 8-degree angle, if we measure the distance from the seating reference point up to the headliner, this vertical distance is called effective headroom. This effective headroom is very much important while we are thinking about head clearance.

Another dimension is knee clearance; that is designated as L62, it is this distance from the knee pivot point to the dashboard, and this is measured in (XZ) plane. After measuring this distance, we deduct (minus) 51 millimetre, to compensate the distance from knee pivot point to the surface of the knee. So, first; we measure the distance from the knee pivot point to the dashboard, then we deduct minus 51 to compensate this distance, from knee pivot point to knee surface.

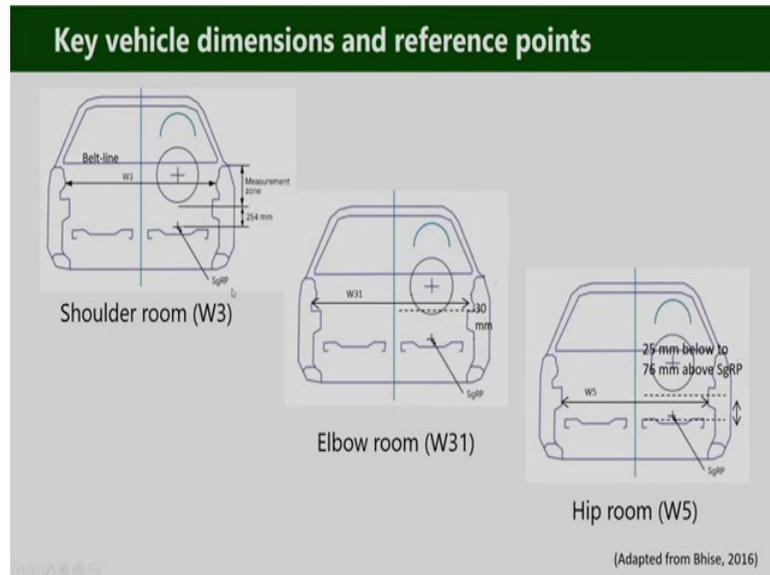
(Refer Slide Time: 33:48)



Next, legroom: legroom is measured as the distance from the seating reference point to the ankle pivot point plus the distance from the ankle pivot point to the ball of foot. So, for this purpose, 254 millimeter is added with this distance. That distance is; from seating reference point to ankle pivot point plus 254 millimetres. So, this is legroom.

Next one is the; thigh clearance. Thigh clearance is measured as a distance from the thigh mid-line to the steering wheel bottom portion. So, this vertical distance is thigh clearance, and it is also very useful dimension, it is needed to check and ensure that the driver's thigh does not touch with the steering wheel.

(Refer Slide Time: 34:40)

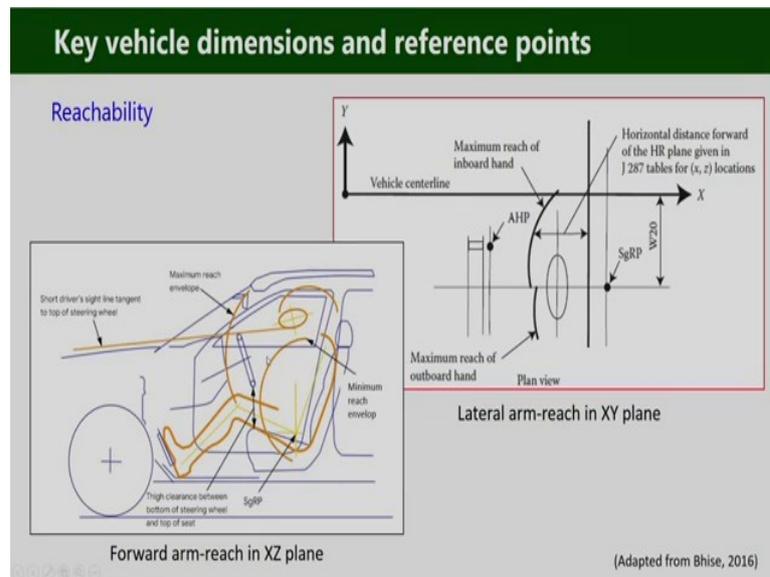


Now, some other dimensions related to width. So, the first one is the shoulder room; it is designated as W3. So, this shoulder room is measured in the measuring zone, that measuring zone is starting from the 254 millimeter above the seating reference point to beltline. So, in this measurement zone; how much is the horizontal or lateral space available, the minimum car width within this region, that is measured as the W3 or shoulder room.

Next is the elbow room. Elbow room is measured from the 30 millimetres upward, the elbow wrist. So, this is the elbow wrist portion, from that elbow wrist, if we measure the 30 millimetres above; how much is the minimum cross-car width, that is measured as W31 or elbow room. So, how much space is available for the accommodation of the drivers and co-passenger elbow.

Next is the hip room. Hip room is measured from the measurement zone, this is also the cross-car width or lateral space inside the car between these two-door panels. So, this distance is measured from 25 millimeter below (of the SgRP) to 76 millimeter above of the SgRP. Within this region; how much lateral space is available, that is measured as the hip-width.

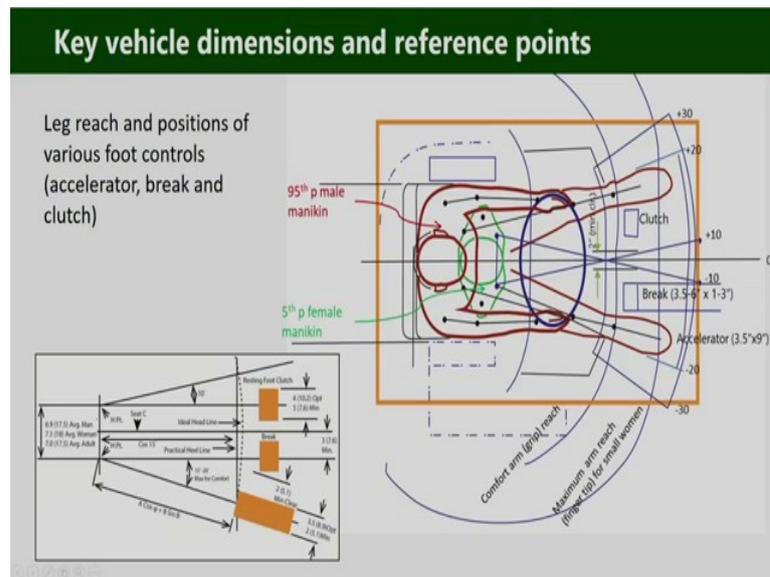
(Refer Slide Time: 36:11)



Now, reachability, while the driver is seated on the driver seat, then whether they can operate various controls or they can reach the various controls, for that purpose, reachability is studied. So, here is, this is the car, for the minimum reach envelope, where the drivers can comfortably reach, where we should position the gearbox for gear operation, and this is the extended arm-reach, where is the maximum reach envelop, this is mentioned as the maximum reach envelope. So, this type of reach envelopes are also studied for positioning various controls and displays, so that drivers can easily operate those controls and display with comfortable reach or extended arm-reach. Now, if we look at this image.

So, this is actually the top view. So, this is the SgRP position, and this is the maximum reach for the out-board hand, while driver is on the driver seat, and this is the maximum reach for the in-board hand. So, this image is actually for US vehicle, but in Indian scenario it will be opposite. So, this side will be the in-board hand, and this side will be the out-board hand. So, this is the representation, that how much area can be horizontally accessed with the maximum reach; for the in-board hand, this is the for the out-board hand.

(Refer Slide Time: 37:38)



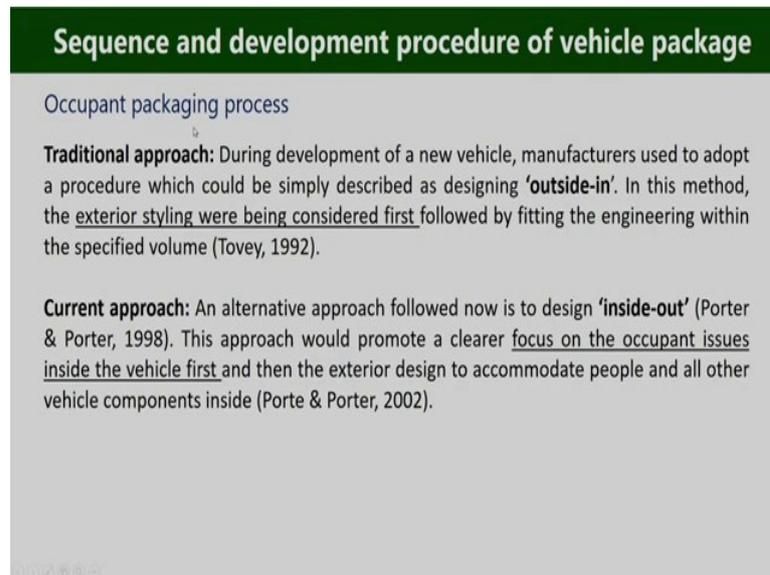
Now, apart from the hand reach, we also need to consider about the leg reach. So, while 95<sup>th</sup> percentile or 5<sup>th</sup> percentile driver is seated on the driver seat, this is their location, position of the H-point, hip joint point, and while they are keeping the leg on the accelerator. So, if we look at this area, this is the heel line. So, this is the position of the heel, these two. Now, this is the centerline, 0 degrees, and this plus 10 degrees and minus 10 degrees, this is the overlapping area for both the legs. So, for this leg; this leg can be comfortably moved from this minus 30 degree to plus 10 degrees, for this right leg. Similarly, for the left leg; plus 30 degrees to minus 10 degrees. So, this overlapping area is the plus minus 10 degrees.

Now, while the driver is keeping their foot on the clutch, so clutch should be positioned within; for the right leg, this is within 20 degrees from the centerline; whereas, the brake will be positioned at this area, and clutch at this position. Between this clutch and brake, minimum clearance should be 2 inches, and here it is also mentioned; how should be the dimension of the brake, so, it should be 3.5 to 6 inches into 1 to 3 inches, for accelerator it should be, width should be 3.5 inches and its height will be 9 inch.

So, in this image also, it is shown that comfortable handgrip reach, and the maximum handgrip reach. So, positioning of the various foot controls is also important. So, it should be positioned within this guideline, so, that drivers can easily operate those controls with their, left or right leg; brake or accelerator with the right leg, whereas, the

clutch with the left leg. If we look at this image, so various dimensions are mentioned, and these are the hip joint points, these are the H-point location for various drivers, and these are the relative positions of accelerator, brake and clutch and also those dimensions are mentioned.

(Refer Slide Time: 39:52)



**Sequence and development procedure of vehicle package**

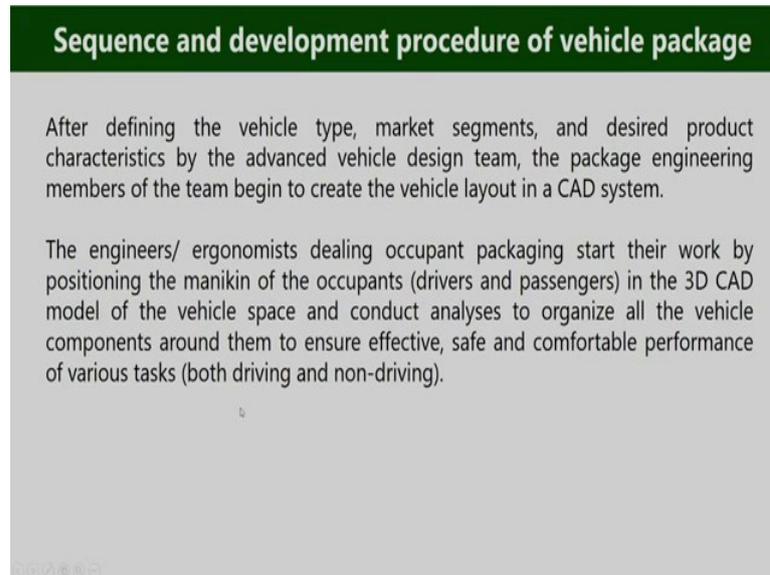
Occupant packaging process

**Traditional approach:** During development of a new vehicle, manufacturers used to adopt a procedure which could be simply described as designing 'outside-in'. In this method, the exterior styling were being considered first followed by fitting the engineering within the specified volume (Tovey, 1992).

**Current approach:** An alternative approach followed now is to design 'inside-out' (Porter & Porter, 1998). This approach would promote a clearer focus on the occupant issues inside the vehicle first and then the exterior design to accommodate people and all other vehicle components inside (Porte & Porter, 2002).

Now, the occupant packaging process. So, there was traditional approach, where during the development of the new vehicle, manufacturers used to adopt the procedure, which could be simply described as design 'outside-in'. In this method, the exterior styling was considered first, followed by fitting the engineering within the specified volume. So, they start with the outside parts. So, outside styling was done first, and then within that outside structure in-side components were fitted, but the current approach is opposite, it is 'inside-out'. So, an alternative approach is being followed nowadays, that is the 'inside-out' approach. This approach would promote a clearer focus on the occupant issues inside the vehicle first, and then the exterior design to accommodate people and all other vehicle components inside.

(Refer Slide Time: 40:47)



**Sequence and development procedure of vehicle package**

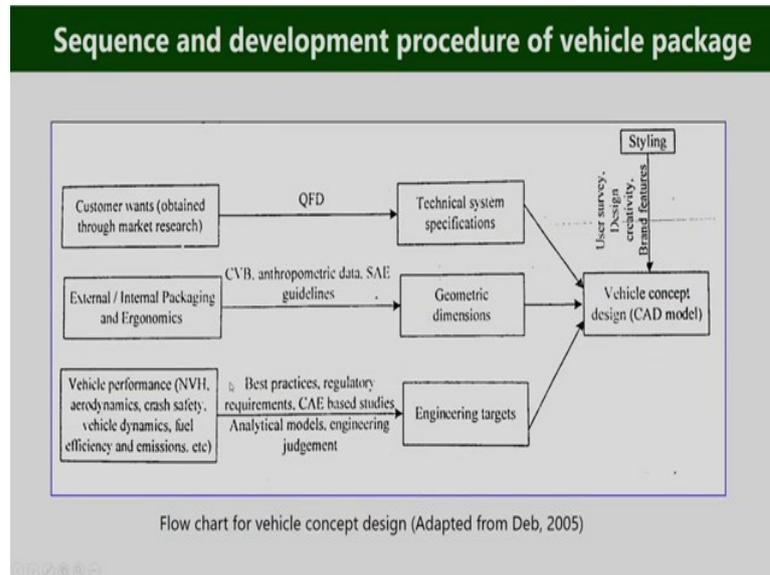
After defining the vehicle type, market segments, and desired product characteristics by the advanced vehicle design team, the package engineering members of the team begin to create the vehicle layout in a CAD system.

The engineers/ ergonomists dealing occupant packaging start their work by positioning the manikin of the occupants (drivers and passengers) in the 3D CAD model of the vehicle space and conduct analyses to organize all the vehicle components around them to ensure effective, safe and comfortable performance of various tasks (both driving and non-driving).

So, in this occupant development process, so after defining the vehicle type, market segment, and design product characteristics by the advanced vehicle team, the package engineering members of the team begins to create the vehicle layout in CAD system.

The engineers or ergonomists dealing with the occupant packaging start their work by positioning the manikin of the occupants (those are drivers, passengers) inside the 3D CAD model of the vehicle space and conduct various ergonomic analysis to organize all the vehicle components around those occupants to ensure effective, safe and comfortable performance of various tasks. These tasks may be driving or non-driving related.

(Refer Slide Time: 41:33)

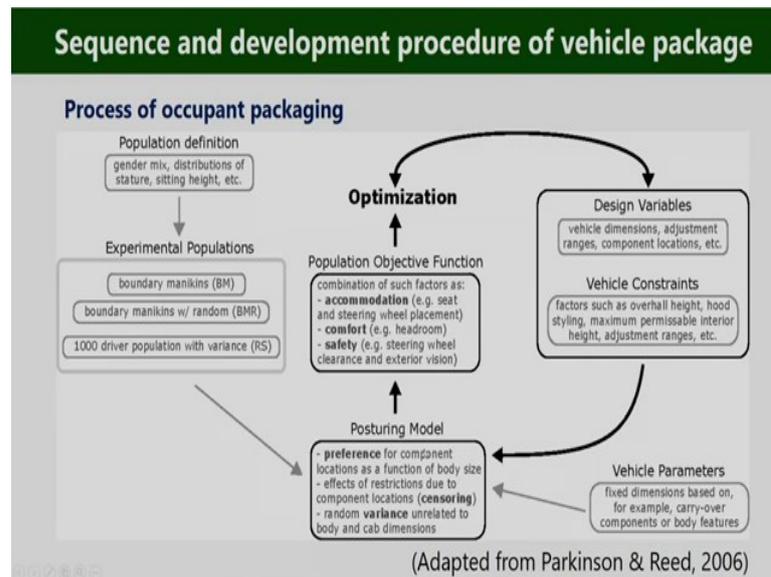


Now, if we look at this schematic diagram, then we can see, how is the design process for vehicle concept development. So, there are various aspects; one is; technical specification, geometric dimensions, another is the engineering targets.

So, technical specification is actually achieved through Quality Function Deployment (QFD) using customer wants, obtained through the market research. Then external and internal packaging and ergonomic aspects are also studied for defining the geometric dimensions. Then vehicle performance, aerodynamics, crash, safety, vehicle dynamics, fuel efficiency, so all these engineering aspects are also considered for achieving the engineering targets.

Based on these three issues; ultimately, vehicle concept is developed. And in that vehicle concept, styling is also considered based on the user survey, design creativity. So, first; defining all these aspects, then we are thinking about the styling portion to make the vehicle visually attractive, and more pleasing. So, in this way vehicle concepts are developed. In that vehicle concept development, this middle phase is related to occupant packaging.

(Refer Slide Time: 42:49)



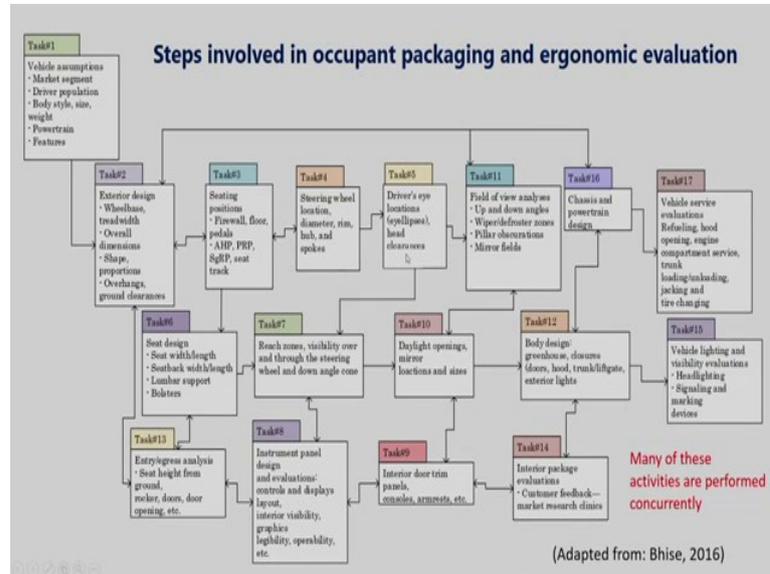
Now, how this occupant packaging is done? So, as reported by Parkinson and Reed in 2006, this is also one schematic diagram to represent the occupant packaging process. So, first; we need to define the population, their gender, means, who are the targeted audience. Their socio-economic condition, sitting height, their anthropometric and biomechanical characteristics. After that; experimental population, boundary manikin, boundary manikin with randomness. So, these are the experimental procedure.

Then, we go for the posture model. Performance of the component location as function of the body size, effects of restrictions due to component location. So, various posture-related issues are discussed. Then, we go for population objective function. Combination of such factors, such as accommodation, comfort, safety, all these aspects are considered.

Then, all these things are actually leading to optimization. So, optimization is also guided by design variables, vehicle dimensions, adjustment range, components location, then various vehicle constraints. So, these are actually affecting in both directions. So, these factors are affecting the optimization, and also optimization is related to these issues. So, vehicle constraint factors, such as overall height, hood styling, maximum permissible interior height. So, these issues are also affecting and determining how will be the posture of the occupants inside the vehicle. Then, vehicle parameters, like, fixed dimensions based on, for example, carry-over components of body structure, those are

also affecting the posture. So, if we go step by step, in this way, then we will be able to achieve good occupant packaging.

(Refer Slide Time: 44:34)



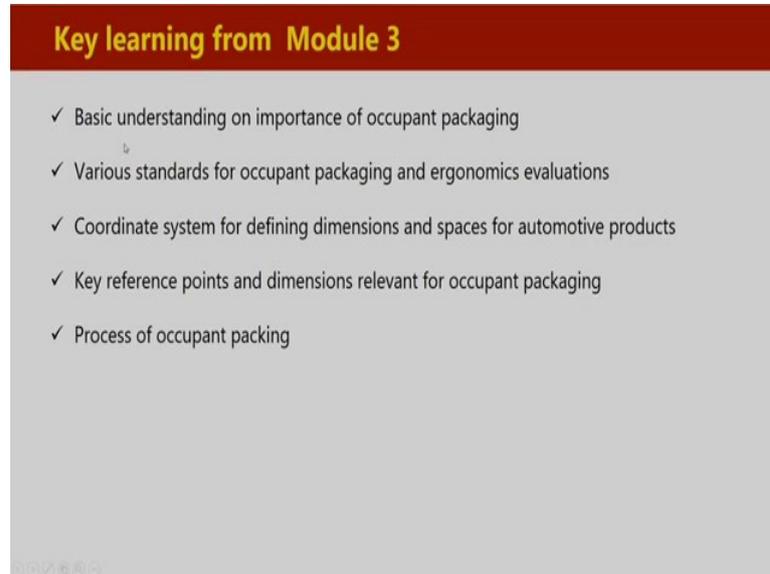
Now, Bhise, 2016, in his book, Automotive Design Process, he has given a detailed step by step process for occupant packaging. Although these steps are not one after another, these are actually happening (many of these steps are happening) concurrently or simultaneously. So, the first; it is starting with the vehicle assumption, market segment, driver population, body size, powertrain feature. So, this is the first task, and gradually one after another task is performed to ultimately get the full vehicle design.

So, as I mentioned, so, if we go for task 2; that is the exterior design. Then task 3; that is seating position based on the various reference point, various dimensions. Then task four; steering wheel location, diameter rim, various steering wheel aspect. Then task 5, then task 6; seat design; task 7; reach zone evaluation, visibility evaluation, then various ergonomic evaluations. In this way, one after another, tasks are performed to get the proper occupant packaging.

And, then we study entry/exit, instrument panel. If we look at this schematic diagram, then, we understand that always this is not a one-way direction, so sometimes it is both ways. So, one step; one task is actually related to others. So, one task is influencing another task. So, we have to perform these tasks simultaneously, to achieve the goal of

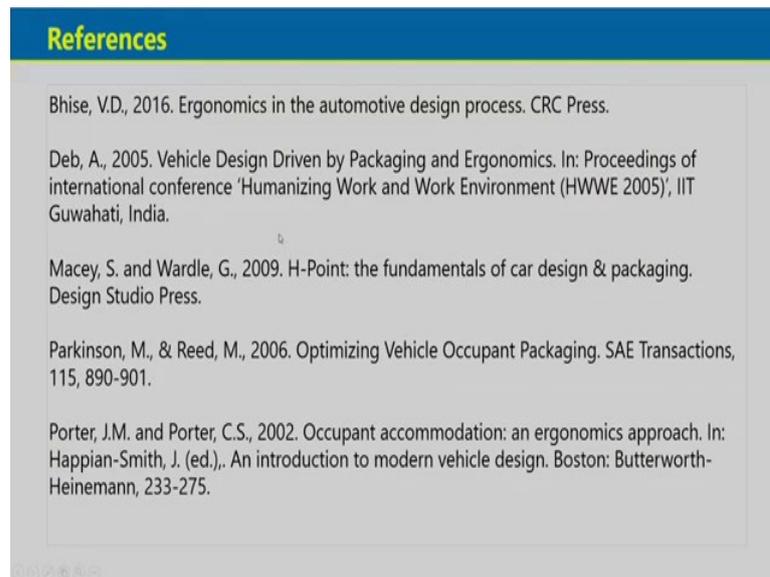
best occupant packaging, so that drivers, passengers, maintenance operator can perform their task comfortably and easily.

(Refer Slide Time: 46:20)



Now, from this module 3, what are the key learnings? So, first; basic understanding of the importance of occupant packaging, next, we also discussed various standards related to occupant packaging and ergonomic evaluation. Those are SAE standards, British standards, ISO standards. Then coordinate system for defining dimensional spaces in automotive product. We also discussed about key reference points and dimensions relevant to occupant packaging. And at last, the process of occupant packaging with schematic diagrams.

(Refer Slide Time: 46:55)



**References**

Bhise, V.D., 2016. Ergonomics in the automotive design process. CRC Press.

Deb, A., 2005. Vehicle Design Driven by Packaging and Ergonomics. In: Proceedings of international conference 'Humanizing Work and Work Environment (HWWE 2005)', IIT Guwahati, India.

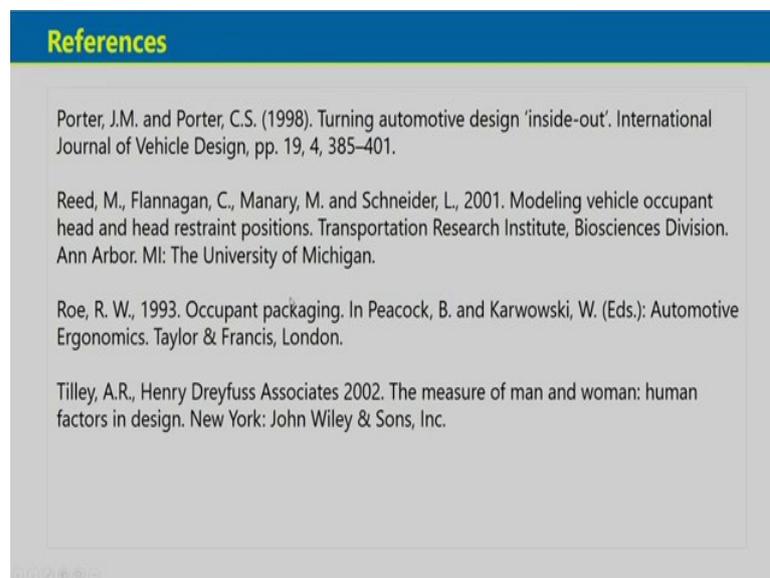
Macey, S. and Wardle, G., 2009. H-Point: the fundamentals of car design & packaging. Design Studio Press.

Parkinson, M., & Reed, M., 2006. Optimizing Vehicle Occupant Packaging. SAE Transactions, 115, 890-901.

Porter, J.M. and Porter, C.S., 2002. Occupant accommodation: an ergonomics approach. In: Happian-Smith, J. (ed.), An introduction to modern vehicle design. Boston: Butterworth-Heinemann, 233-275.

Now, these are the various references which have actually been used for this module 3 preparation.

(Refer Slide Time: 46:59)



**References**

Porter, J.M. and Porter, C.S. (1998). Turning automotive design 'inside-out'. International Journal of Vehicle Design, pp. 19, 4, 385-401.

Reed, M., Flannagan, C., Manary, M. and Schneider, L., 2001. Modeling vehicle occupant head and head restraint positions. Transportation Research Institute, Biosciences Division. Ann Arbor, MI: The University of Michigan.

Roe, R. W., 1993. Occupant packaging. In Peacock, B. and Karwowski, W. (Eds.): Automotive Ergonomics. Taylor & Francis, London.

Tilley, A.R., Henry Dreyfuss Associates 2002. The measure of man and woman: human factors in design. New York: John Wiley & Sons, Inc.

Apart from those references, I also suggest the students to go through these various online resources to get more information and objects.

(Refer Slide Time: 47:06)

**References**

Bye, V.D., 2016. Ergonomics in the automotive design process. CRC Press.

Porter, J.M. and Porter, C.S., 1998). Turning automotive design 'inside-out'. International Journal of Vehicle Design, pp. 19, 4, 385-401.

Deb, A., 2005. Vehicle Design Driven by Packaging and Ergonomics. In: Proceedings of international conference 'Humanizing Work and Work Environment (HWWF 2005)'. IIT Guwahati, India.

Reed, M., Flanagan, C., Mahary, M. and Schneider, L., 2001. Modeling vehicle occupant head and head restraint positions. Transportation Research Institute, Biosciences Division. Ann Arbor, MI: The University of Michigan.

Macey, S. and Wardle, G., 2009. H-Point: the fundamentals of car design & packaging. Design Studio Press.

Parkinson, M., & Reed, M., 2006. Optimizing Vehicle Occupant Packaging. SAE Transactions, 115, 890-901.

Porter, J.M. and Porter, C.S., 2002. Occupant accommodation: an ergonomics approach. In: Happian-Smith, J. (ed.), An introduction to modern vehicle design. Boston: Butterworth-Heinemann, 233-275.

Thank you.