Ergonomics in Automotive Design
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Module – 06
Lecture – 08
Vehicle Entry and Exit: Basics and Details

Welcome to course Ergonomics in Automotive Design. Now we are going to discuss our 6th module, that is Entry and Exit by drivers and passengers.

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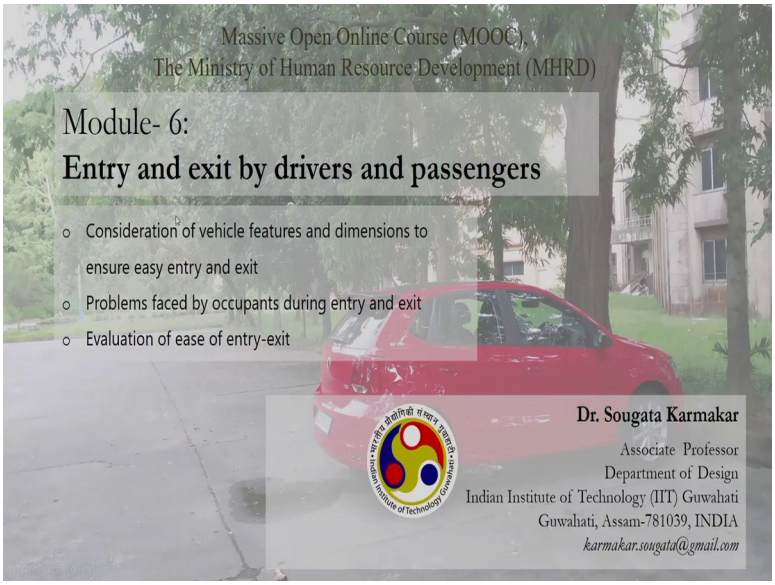

So, under this topic; we will discuss three subtopics; first one - consideration of vehicle features and dimensions to ensure easy entry and exit. Second sub-topic is problem faced by occupants during entry and exit (these occupants are both drivers as well as passengers) and evaluation of easy entry/exit, means, how we can evaluate the entry/exit process; if there is any difficulty or what type of improvement is required.

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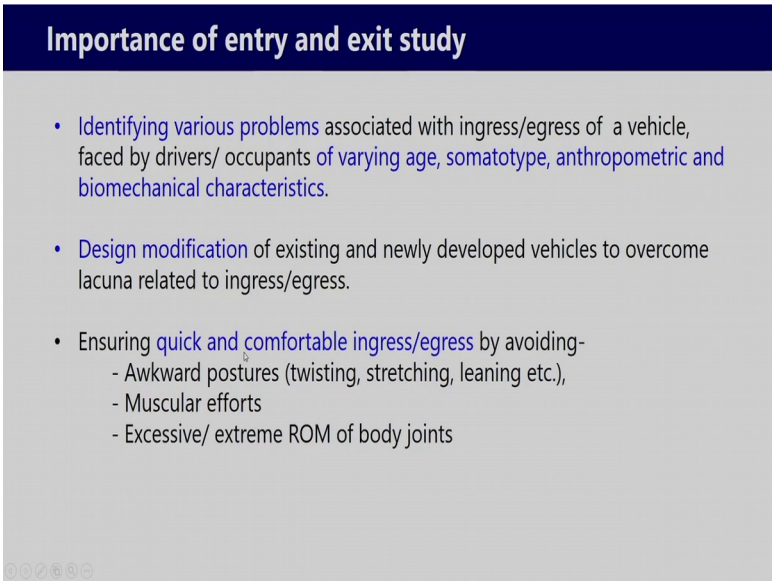

Now, first, we need to know why this entry/exit study is important in case of automotive design. Firstly, for identifying various problems associated with ingress and egress of a vehicle, faced by the drivers or occupants of varying age, somatotypes, anthropometric and biomechanical characteristics.

So, drivers and occupants may be of different types; in terms of their age, somatotypes, anthropometric characteristics, biomechanical characteristics, so, based on that, they differ in their entry/exit pattern and also, they face different types of problems during entry/exit. If we can identify those problems faced by different types of drivers or occupants, then we can go for re-designing that vehicle, or whenever we are designing a new vehicle or modifying the existing vehicle, then we can address those lacunas related to ingress/egress. Then, for ensuring quick and comfortable ingress and egress by avoiding awkward postures, like twisting, stretching, bending-forward, leaning, at the same time reducing the muscular effort for lifting the bodyweight from the seat or gradually lowering down the bodyweight where one hand is settling on the seat.

Then, avoiding excessive or extreme range of motion of body joints, during entry and exit process. So, these are the various aspects which we need to ensure during automotive design, particularly to ensure comfortable entry and exit.

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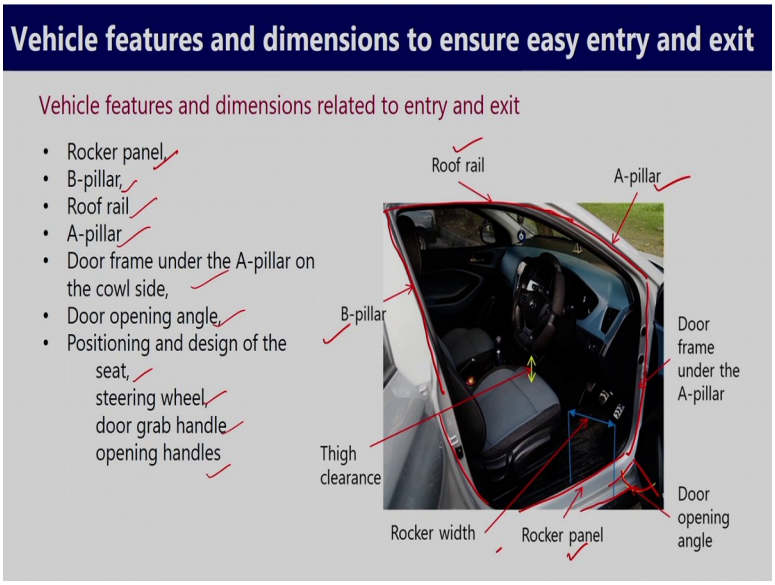

Now, while we are discussing about entry/exit, then, we should know the various design features of the vehicle, particularly associated with the door-openings and how those dimensions or design features actually affect the entry/exit by different types of drivers. So, first, if we look at this image, where different markings are there. So, if we start from the rocker panel. So, first, this bottom part, this one is the rocker panel, then, rocker panel is constituting the bottom part of the door opening.

Then, there is the B-pillar, then roof rail. So, first; rocker panel, B-pillar, then roof rail, then this portion that is the A-pillar, then at the bottom of the A-pillar there is the door frame, this portion. So, all these portions are actually constituting the door-openings, and these dimensions have significant role in the ease of entry/exit. So, various vehicle components which are associated, as we already mentioned, rocker panel, B- pillar, roof rail, A-pillar, door frame under A-pillar, then door opening angle, that is also important, it is little bit shown in this figure. So, the angle between the rocker panel and the lower edge of the door-opening; door panel.

So, that angle is also important for the ease or comfortable entry or moving the feet by the passengers and as well as the drivers. Then, positioning and design of the seats, steering wheel, door grab handle, opening handles. So, these other components which are not directly associated with the door opening, but these are also influencing the entry/exit process.

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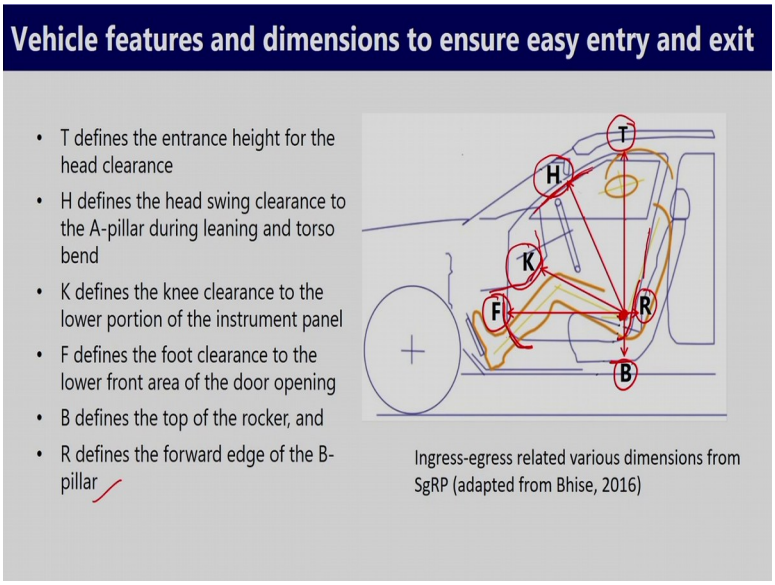

Now, if we look at this particular image, where the driver seat is shown, at the same time door opening is also visible here. So, it is indicating the ingress/egress related various dimensions from the seating reference point. If we consider this is a seating reference point, from seating reference point; these are the various dimensions which are associated with the entry/exit process.

So, first, if we consider this one 'T'; so, 'T' is the vertical clearance dimension, which is from the seating reference point to the roof rail. So, this height is actually ensuring that how much head bending or neck bending is required during entry by the or exit by the driver. So, this is actually related to head clearance. Next, another dimension is the 'H'; this 'H' dimension is the distance from the seating reference point to the A-pillar. So, this is also important because it defines the head swing clearance to the A-pillar during leaning and torso bending. So, while the driver is going inside; they need to bend their torso and neck and then enter. So, these dimensions; how much is the distance from the seating reference point to the A-pillar, this distance actually matters for the ease of entry or exit from the vehicle.

The next dimension is the 'K; dimension; it is related to knee clearance dimension. So, this is a distance from the seating reference point to the dashboard or the steering wheel hub. So, these distances are actually indicating that; how much space is available, so that, there should be sufficient knee clearance while the driver is sitting on the seat and

adjusting the seat; the knee should not touch with the lower edge of the steering wheel column or the instrument panel. Then; the next important dimension is the ‘F’; it is the distance between the seating reference point to the forward edge of the door opening. So, ‘F’ defines the foot clearance to the lower front area of the door opening. So, this dimension is also important; this corner is very important because while the drivers are keeping their leg from outside to inside of the vehicle, they need to cross this area, and there is possibility of hitting their feet with this corner.

So, how is the design of the corner and what is the dimension of it? These two important variables are actually deciding that; how much there is the chance of collision between the driver’s feet and this door opening. Next; another dimension is the ‘B’ dimension, it defines the top of the rocker panel, that, how is the height from the rocker panel to the seating reference point. So, if this height, means, how much is the height of the SgRP from the rocker panel surface. So, this is also deciding that, how the driver can sit on the seat, can enter the vehicle and sit on the driving seat. Another dimension is the ‘R,’ that defines the forward edge of the B-pillar; that, how is the distance of the seating reference from the forward edge; this is the B-pillar forward edge.

So, the forward edge of the B pillar and the seating reference point; how is the distance between these two dimensions, that is defined by the ‘R.’ So, these various dimensions related to door opening are actually defining that. If these dimensions are larger in size or bigger in size, then what will happen? Drivers will be able to go inside the vehicle easily, at the same time during their egress; they will be able to come out easily, without much effort and without hitting any of the body parts with the vehicle components.

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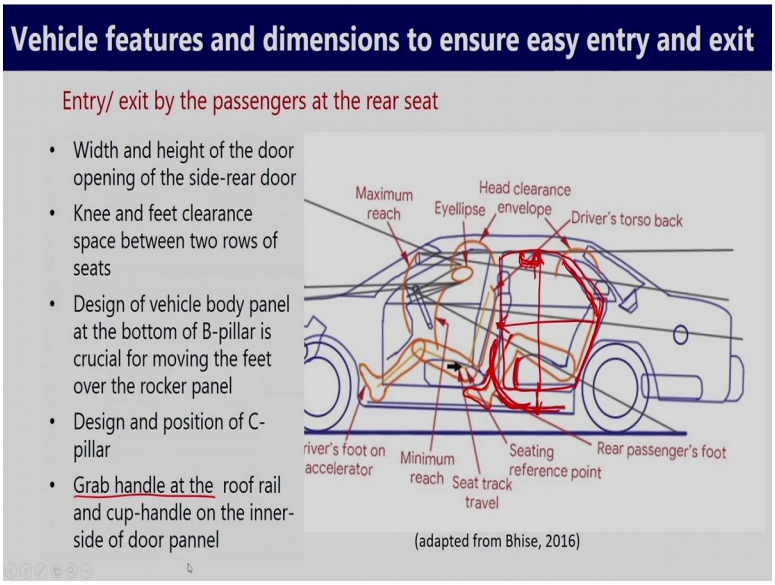

Now, apart from the driver seat, there is also co-passenger seat. So, the scenario for the co-passenger besides the driver seat is almost similar like driver seat only, but the passengers who are sitting on the rear-seats; for their entry/exit, the rear side-door dimension we need to consider; that how much is the door opening and how it is affecting?

So, now, if we look at this image, then we can see, the width, that height of the door from the rocker panel, this dimension, from the rocker panel to the roof rail, this height is actually showing that, how much head clearance is available while the driver is entering, the passenger is entering inside the vehicle. Similarly, this horizontal distance; starting from the B-pillar to the C-pillar, this dimension is indicating the lateral space or horizontal space available for the entry or exit process. So, the width of the height of the door opening as well as the width and height; these two are very important dimensions for the entry/exit of the passengers; then knee and feet clearance space.

So, from knee and feet clearance space between the two seats; this is the rear-seat front edge, and this is the rear edge of the front seat, and this is the front edge of the back seat, this distance between the rear-edge of the front seat and the front edge of the back seat; this distance is actually available for keeping the leg of the passengers. So, how much this space is available, that is ensuring the ease of entry/exit; how much ease will be in keeping the leg inside. So, in this case, the front seat, that is the driver seat or the co-

passenger seat, adjustment of the front seat on the seat track travel, seat track travel is actually determining how much space will be available between these two rows of seat. If, the front seat is moved backward, then automatically this space will be reduced.

But the design should be such that, the passenger on the rear-seat should be able to keep their leg, keep their feet below the front seat. Then, designing of the vehicle body panel at the bottom of B-pillar is crucial. Then, at the bottom portion of the B-pillar, this particular area, this portion is important. Because when the passengers are putting their leg from outside to inside, across this area or while the driver is bringing his feet out over this rocker panel, then there is the fair possibility that feet can touch this corner. So, how is the design of this corner and how much is the lateral space available; that is actually deciding the possibility of collision of the feet of the passengers sitting on the rear seat with the bottom portion of the B- pillar.

Then, the design and position of the C-pillar. So, C-pillar is also important because C-pillar is actually showing how much lateral space will be available. If C-pillar is relatively rearward, then the space available; lateral space will be more. So, this C-pillar and its design is also important in case of entry/exit by the passengers. Apart from these door related dimensions for the rear-seat passengers, there are other vehicle components, like grab rail handle at the roof rail.

So, inside this roof rail, we can see, this type of grab rail handle. So, those handles are also important, because while passengers are entering inside the vehicle or coming out from the vehicle, then they hold these type of grab rail and lift their body weight and then come out or while they are going in, hold this grab handle and then, gradually, lower down their body weight on the seat. So, this grab handle position and its design is important for the entry/exit process.

Similarly, there is also cup-handle on the inner side of the door. So, for pulling the door, closing the door, for that purpose, the location of the cup-handle, and also the opening of the rear-door, those aspects are important for the entry/exit process.

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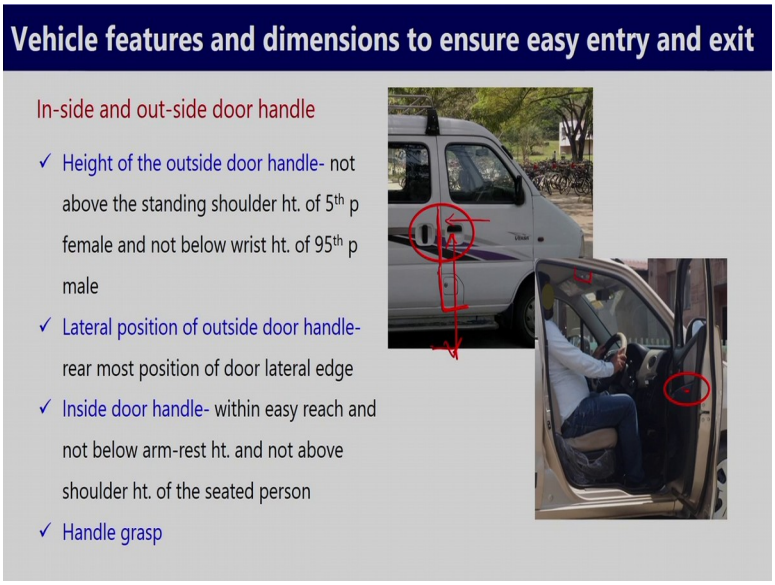

Now, inside and outside door handle. So, from this image, you can see, these are the outside door handles, for the front compartment, that is for the driver compartment, and this is the backside compartment, for the passengers. So, how should be the design of this door handle, and how should be the dimension? So, if we consider the height of the door handle from the ground. So, if we decide the height from the ground, then how much that height should be?

The height should be such that, all the driver population, means, starting from the 5th percentile body dimension to the 95th percentile body dimension can easily access the handle, and they should be able to open that one. So, one is; anthropometric dimension, at the same time, force capability to open that door. So; obviously, the required pulling force should be 5th percentile or less than that, for opening the door. So, height of the outside door handle should not be above standing shoulder height of the 5th percentile female, at the same time, it should not be below the wrist-height of the 95th percentile male. So, these dimensions should be such that, it should not be below the wrist-height of the standing 95th percentile male, means, people with 95th percentile wrist height will be easily able to access this door handle, at the same time, it should not be above the shoulder height of 5th percentile female.

So, that the people with shorter dimension, they can also easily open that door, then, lateral position of the door handle. So, these door handle should be positioned as much as

possible to the rear-side of the front door, means, gradually, it should be moved laterally as much as possible, up to this rear-edge. So, that while the driver or passenger is opening this front door, the lower portion of the front door, this portion, should not touch the sill or the lower leg of the driver. So, for this purpose, it should be positioned as much as possible rearward, towards the edge of the front door.

Then, inside door handle. The inside door handle or cup-handle should be positioned in such a position; it should not be below arm-rest height and not above the shoulder height. So, that all the drivers of different body dimension they can easily access that one, and can easily close the door. Then, handle grasp. And there are other grab handles also, at this position, with the roof rail, those also help in entry/exit process. While we are discussing about this inside or outside door handle or grab handle; one important aspect is that the dimension of the door handle should be such that, at least four fingers of 95th percentile arm, that is a handbreadth of 95th percentile person, should be accommodated.

So, the four fingers can go inside and can pull the door handle. On the other hand, we also have to think about the drivers in a cold environment; they can also wear gloves. So, while they are wearing gloves; space should be available, that much clearance should be available, so, that with a gloved hand, they can also open the door handle easily. Now, door and hinge angle.

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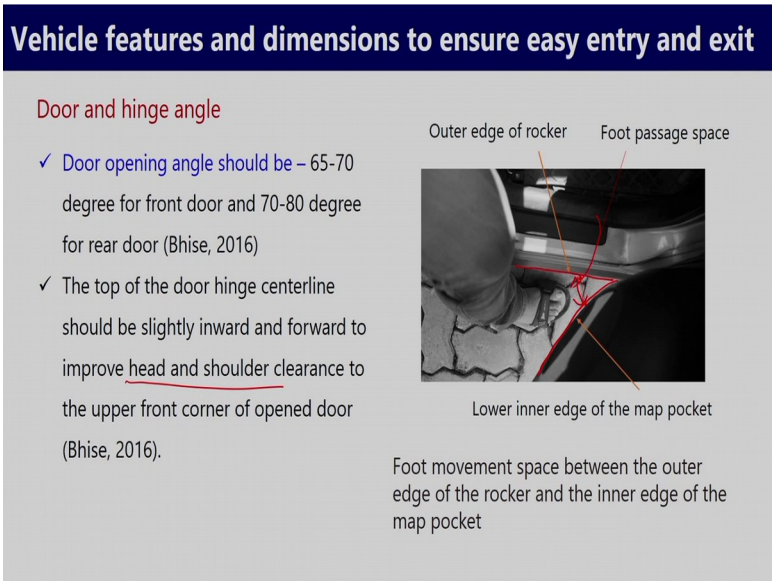

So, as we discussed earlier, the outer edge of the rocker panel and the lower inner edge of the door panel. So, this gap, this angle is very crucial for the entry/exit process because through this area actually; leg, feet come out or goes in. So, for this purpose, foot movement space between the outer edge of the rocker and the inner edge of the map pocket should be sufficient enough.

So, how is the recommended limit? So, the door opening angle should be 65 to 70 for front door and 70 to 80 degree for the rear-door; as suggested by Bhise (2016). The top of the door hinge centerline should be slightly inward and forward to improve the head and shoulder clearance to the upper front corner of the open door. So, the door hinge should be positioned in a such a way, particularly that upper portion, inward and forward most position. So, that while the door is being closed, then the upper edge of the door should not hit the head and shoulder of the driver, at the same time, this type of hinge and limit will also help in closing the door easily.

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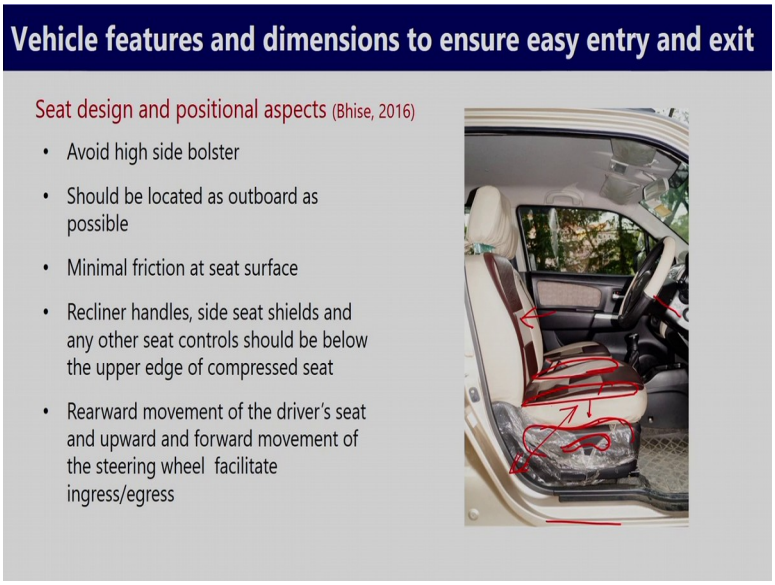

Now, seat design and positional aspect. Then, where the seat should be positioned and what are the design aspects of the seat which facilitates the comfortable and easy entry/ exit. So, first, we have to avoid the side bolster. The high side bolsters, if the side bolster is high, then what will happen? It will actually create problem in entry/exit process. Due to this high side bolster, the people with old age, aged people or people with disability or physically weak people, then they will find difficulty to lift their body weight and then

go inside the seat or while they are coming out from the seat, they have to put extra effort to lift their body weight and then coming out. Moreover, the sliding over the seat or rotating the thighs pivoting on the seat, it will also be difficult, while these type of high raised side bolsters are there.

So, moreover, the seat should be located as much as possible outboard. So, that the distance between the outer edge of the rocker panel and the seat, this distance should be minimum. Then, minimal seat friction of the seat surface. So, the material and the design of the seat surface should be such that, it should not create any friction, which actually resists the easy movement of the driver or any other passenger from the seat. Then, recliner handles; side seats. So, here the reclining handles are there, then sides, the seat shield, this type of plastic materials are there. So, the height of all these components should be below the compressed seat surface, so that, while the seat surface is getting compressed, it should not go below these components. Otherwise, these components will touch with the buttock and thigh of the passenger or driver.

So, that is why, the recliner handle, side seat shield, and any other seat control should be below the upper edge of the compressed seat surface. Then, the rearward movement of the driver seat and upward and forward movement of the steering wheel facilitate the entry/exit process. If this steering wheel, with its column, can be moved up and the seat can be moved rearward, then the available space to go inside or coming out; obviously, will be increased and it will facilitate easy entry/exit by the driver as well as by the passengers. Now, another important vehicle component related to entry/exit process is the running boards or footboards.

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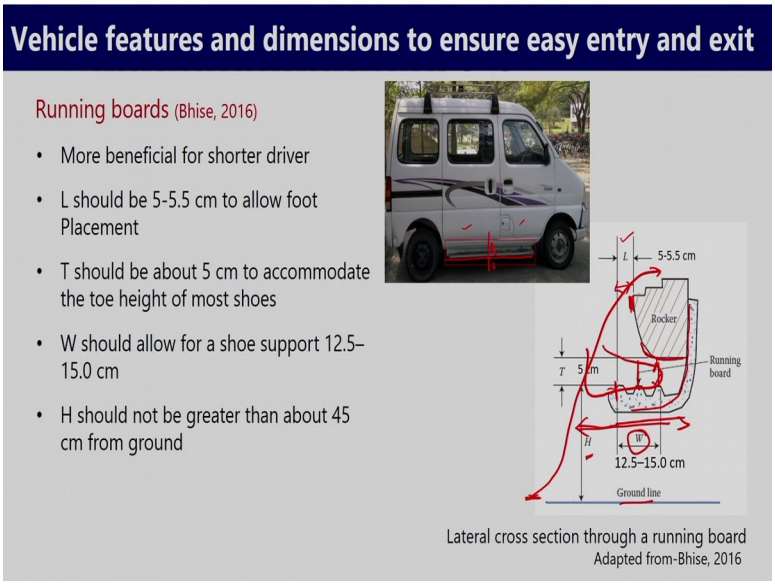

Now, if we look at this image, then we can see, below the door; front door as well as the (side-back) rear side door, there is this type of footboard or running board. So, this is very much beneficial, particularly for the drivers or passengers with shorter leg height. Then, there are various dimensions associated with this running board, and we should discuss about those dimensions, that how much minimum dimension should be there for the easy entry and exit process. So, now, if we look at this image, this is adapted from Bhise (2016). So, if we consider this 'L'; the dimensional 'L,' so, first before that, we should mention, what is this image.

So, this is actually the cross-section, if we take the cross-section of this running board, then it will look like this. So, this is the rocker panel and below that rocker panel is the footboard or that running board. So, the lateral distance between the rear edge; of the outward edge of the rocker panel and the front edge of the footboard or running board, these distances should be at least 5 to 5.5 centimeter. It allows foot placement, during climbing inside the vehicle or getting down. Then, the dimension 'T'; that is the space available between the bottom of the rocker panel and the running board, this height; how much this height should be? It should be 5 centimeters, so, that the people with higher feet height or with shoes can easily enter, can keep their foot like this.

Then, the next dimension is 'W'; this dimension 'W' allows for shoe support, and its dimension should be 12.5 to 15 centimeters. Next dimension is the 'H'; this is the height

of the running board from the ground level. So, the recommended value is 45 centimeters from the ground. So, if we can follow, these types of recommended dimensions while we are designing the running board or footboard, then that will ensure easy and comfortable entry or exit by the people with shorter leg height but on the other hand, if this dimension, means, 'W' is relatively bigger, it is coming out, then what will happen? That may create problem for the taller driver or taller passengers, while they are keeping their leg, while they are moving their leg from the ground to inside the vehicle or it is on the rocker panel; then, this portion may touch with their feet because they are not going to use this footboard or running board. So, while their leg is moving from the ground, the feet are moving; leg or feet is moving from the ground to the upper surface of the rocker panel. Then, this extended portion of the running board may get touched with their feet.

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Now, drivers with short legs (predominantly woman). Now, we are discussing problems faced by drivers with different anthropometric and somatotype as well as other drivers with disabilities. So, we will discuss different types of drivers and their problems in the entry/exit process. So, first, we are discussing; drivers with short legs. So, generally, it happens for the female drivers and with 5^{th} percentile leg dimensions. So, how they find; they generally complain that the seat and top of the rocker panel is too high.

So, this is the seat height and the top of the rocker panel from the ground. Seat height; from the ground as well as the rocker panel height from the ground is too high; for them.

Step over is too wide, the step-over, means, this is the distance, sidewise from the rocker panel to the vehicle; for this lateral distance, that is also too wide for them. They have to pull their leg from outside to inside, and that distance traveled is more, they feel. The clearance between the driver's knee and the instrument panel and/or the steering wheel is insufficient because they move the seat in forward direction.

When they move the seat in forward direction for accessing the foot pedals as well as the steering wheel, automatically, the distance or the space; knee clearance space; between knee and this instrument cluster or the column of the steering wheel reduces and as a result, they complain, that space is relatively less for them. So, here we can see, this is the space available; this space is very less for them.

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Now, like drivers with shorter leg length, similarly, there is also a problem for the drivers with larger lower limb dimensions, particularly, for 95th percentile lower leg dimensions. The seat track does not extend sufficiently rearward; they feel that seat should move more backward, so, that their upper leg will be accommodated comfortably. The front edge of the B-pillar is too far forward, as they are moving their seat backward. So, automatically the B-pillar is coming forward for them.

As they are moving their seat in the rearward direction. So, the B- pillar is coming in; they are feeling that the B-pillar is more forward for them; it should be little bit rearward. Then, legroom is insufficient to move the legs from ground to inside the vehicle, then the

space available here, that space is also relatively less, so, that they can move their feet from outside to inside the vehicle. The space between the open door and the vehicle body is insufficient; similarly, this angle, this space is also less.

So, that they can tilt; the space is not sufficient for them for moving their leg from outside to inside or while they are coming out during the egress process or exit process, then this space is not sufficient for accommodating their foot length. So, for this type of drivers, whose lower leg dimension is more or the drivers whose upper body portion, means, with taller torso, means, 95th percentile torso dimension, they also find different types of problems; upper part of the door opening is too less for them.

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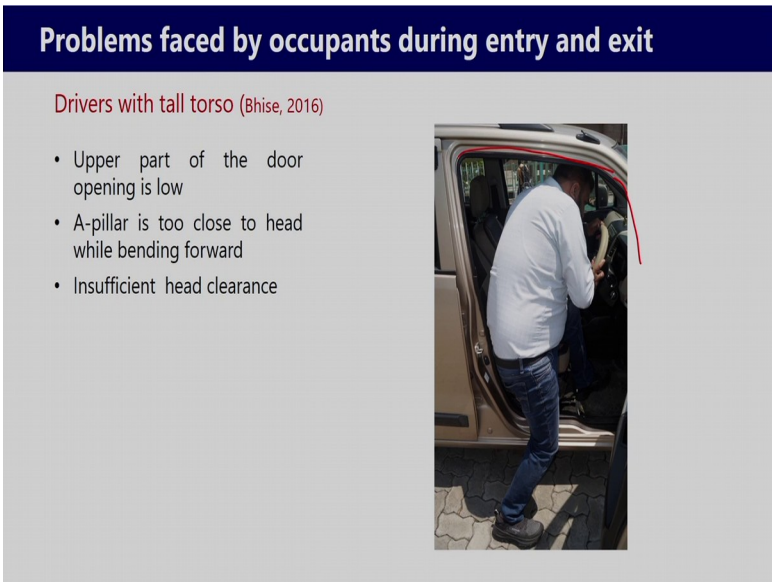

So, they find that the upper edge of this roof rail is low, the height of the roof rail is relatively low for them; they need to bend-forward. First, they hold the steering wheel; then they need to go inside. So, this dimension is not appropriate for them.

On the other hand; they also feel, the A-pillar is too close for their head while they are bending their head to go inside, as the roof height is relatively less, they bend their torso forward, and the head reaches almost towards the A-pillar. So, they feel that A-pillar is too close to their head, it should be moved little bit forward, and due to their bigger torso dimension, they have insufficient head clearance.

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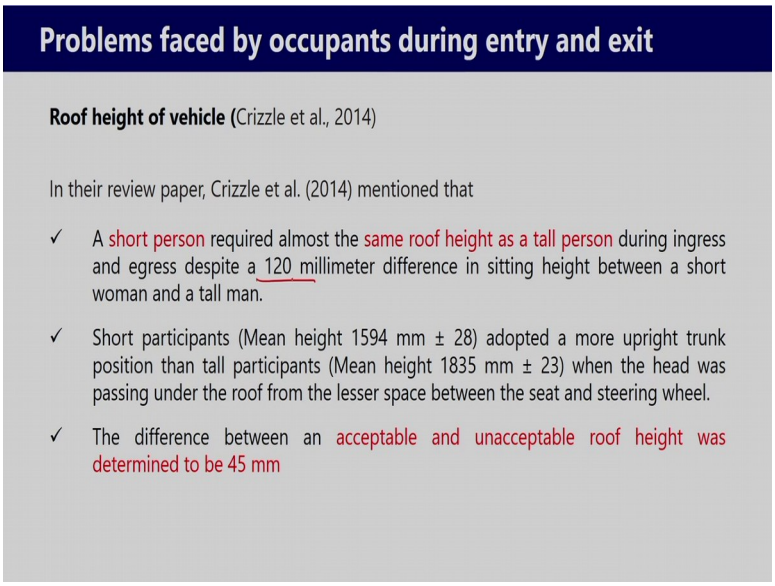

Now, we are discussing about some information from a research paper, particularly review paper by Crizzle et al. in 2014. In the review paper, they mentioned the impact of roof height of the vehicle in the entry/exit process. So, they mentioned; short person required almost the same roof height as the tall person during ingress or egress despite a 120-millimeter difference in sitting height between a short woman and the tall man.

So, the data which they considered; according to that data, although there is the difference between shorter woman and tall man and the difference is about 120 millimeters, means, 12 centimeters, but there is no significant difference in the roof height for both of them, means, as per their response.

So, that is why they reported; a short person requires almost the same roof height as the tall person. The short participant, according to their data; that 'mean height' 1594 millimeter plus-minus 28 adopted a more upright trunk position than tall participant.

The tall participant height is 1835 millimeter plus-minus 23 centimeter; when the head was passing under the roof from the lesser space between the seat and the steering wheel. The difference between the acceptable and unacceptable roof height was determined to be 45 millimeters, as per their study. In the same review paper; they also mentioned the impact of door sill design and seat orientation on the entry/exit process.

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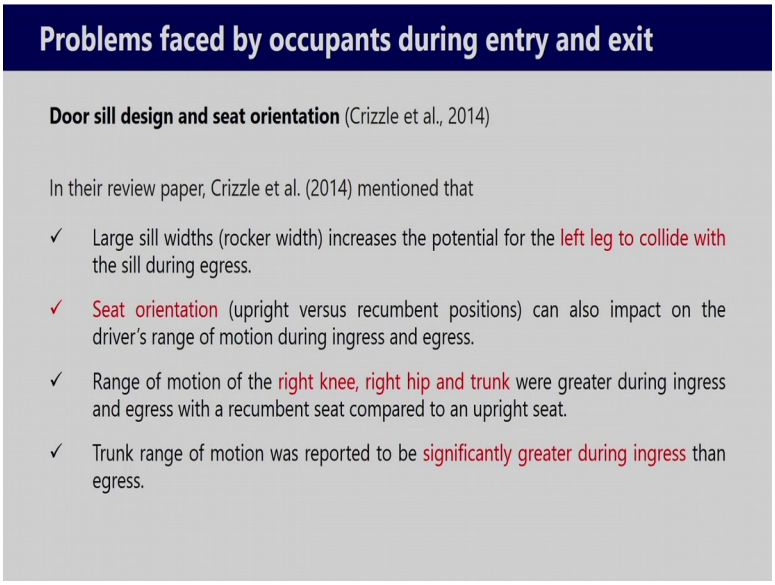

So, large sill width; that is the rocker width; increases the potential for the left leg to collide with the sill, during the egress. So, there is possibility, that left leg may collide with the sill, that is the rocker width. Seat orientation (upright versus recumbent position) can also impact on the diverse range of motion during ingress/egress. Range of motion of the right knee, right hip and trunk are greater during ingress/egress with recumbent seat; as compared to the upright seat.

So, if the seat is in the recumbent position, then the range of motion of the right side of the body, that is the right knee, right hip, trunk, for all these body parts, the range of motion is relatively high. The trunk range of motion was reported to be significantly greater during ingress than egress.

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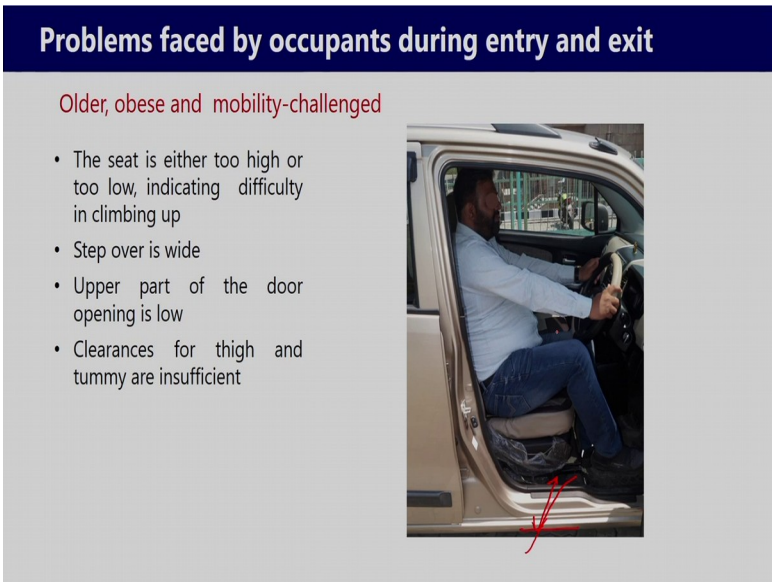

Older, obese, and mobility challenged drivers; they also find the different types of difficulties in the entry/exit process. So, they feel; the seat is either too high or too low indicating difficulty in climbing up or settling down. So, as they have the physical problem. So, they find it difficult to lift their body weight from the seat and at the same time sitting on the seat. So, for that purpose, they feel, that seat is either too low or too high for them; then step over is wide. The step over that is the outer edge of the rocker panel to the inside driver seat; this distance, they feel this distance is also wide. Because they need to lift their leg by contracting their leg muscles and they have to move their leg from the outside and move over this rocker width and then go inside the vehicle.

So, for this purpose, they need to put extra efforts, they need to put effort to pull the weight of the leg, and as it is difficult for them to lift the lower leg. So, they feel the stepover is too wide. Upper part of the door opening is less because they need to bend forward, they have to lean, and then they need to enter the vehicle, then clearances for the thigh and tummy are insufficient.

If, the driver is obese or fat; then what will happen? The available space; although they are adjusting the seat, but the available space between the steering wheel and the thigh and driver's stomach, space is relatively less for them.

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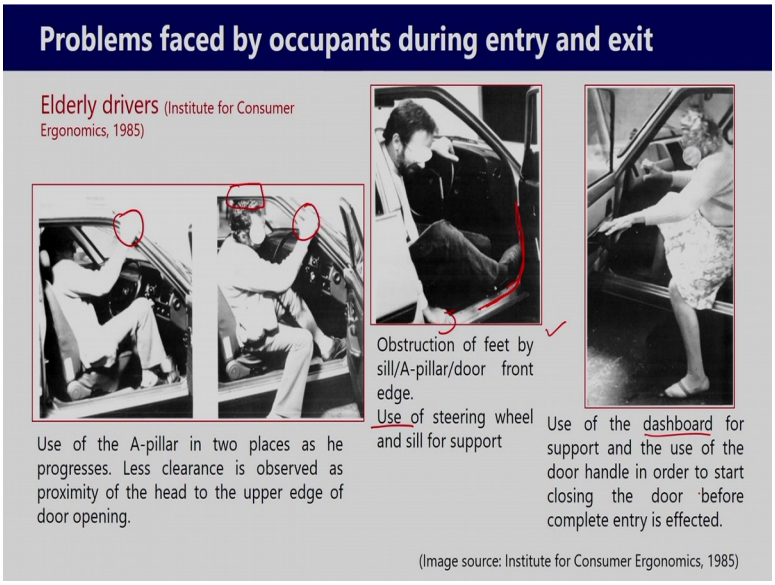

Now, the Institute for Consumer Ergonomics (1985), they reported various problems related to entry/exit by the elderly drivers. So, here you can see from the images, the use of A-pillar in two places. So, they need to use A-pillar; this is the A-pillar; they need to hold this portion as well as this portion. While the person is going inside, less clearance is observed as proximity of the head to the upper edge of the door opening and this space is also relatively less. Now, if we look at this image, then obstruction of the feet by sill, that is the rocker panel and A-pillar or door front edge.

So, this portion, rocker panel, and the door front portion, this space is relatively less for them, and it creates obstruction for their feet movement. Use of steering wheel and sill for support. So, they prefer to use steering wheel; they prefer to hold steering wheel and the sill or that rocker panel portion to go inside or coming out from the vehicle. Similarly, for the elderly person, they need to use the dashboard for the support, and they use the door handle in order to start closing the door before complete entry is effected.

So, they prefer to move that. In case of elderly people, they sit on the seat, then they try to drag the door little bit inside because once they are seated on the seat, it is not possible for them to, means, lifting their body weight again and bending sideways to reach the door handle. So, for that purpose, they prefer to move the door little bit closer to them, while they are going inside.

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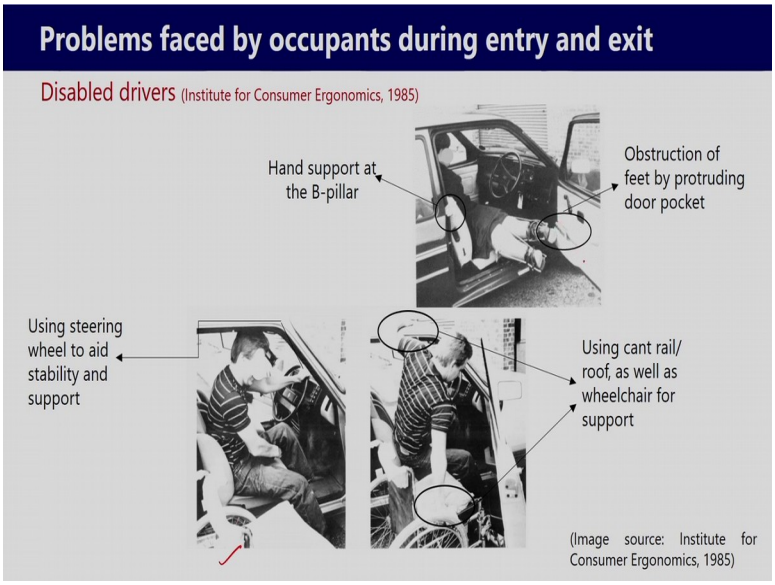

In this report by the Institute for Consumer Ergonomics (1985), it was also reported; various problem faced by the disabled drivers. So, as it is shown, in this image, the person is using a steering wheel to aid stability and support. Here, it is shown that he is using cant rail or roof as well as the wheelchair for the support while going inside or coming out.

Then, hand support; similarly, for the physically challenged person, while they are going inside the vehicle, then they are holding that, they are taking the support from the B-pillar by holding that middle of the B-pillar but they are also finding obstruction of their feet by the protruding part of the pocket attached with the door panel.

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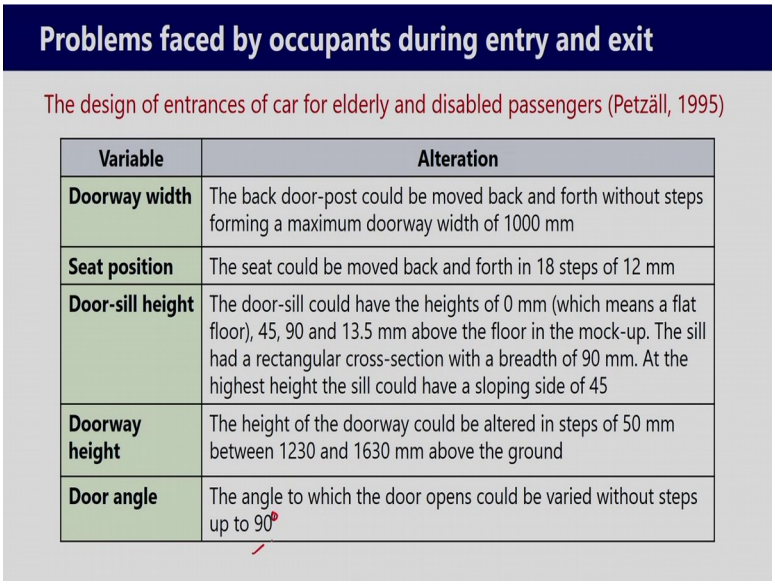

Now, the design of entrances of car for elderly and disabled passengers, according to Petzall (1995). For that, various guidelines have been provided by Petzall (1995). So, variables; here in the left side column variables are mentioned and what type of alterations are required; that is mentioned in this right-side column. So, doorway width; the back-door post could be moved back and forth without steps forming a maximum doorway width of 1000 millimeter, means 100 centimeters.

Then, seat position; the seat could be moved back and forth in 18 steps of 12 millimeters. So, seat could be moved forward and backward in 18 steps of 12 millimeters; then door sill height. The door sill could have the heights of 0 millimeters (which means a flat floor), means; it is same as the vehicle floor; otherwise 45, 90 and 13.5 millimeters above the floor in the mock-up. The sill had a rectangular cross-section with a breadth of 90 millimeters. At the highest height the sill could have a sloping side of 45.

Then, door-way height; the height of the doorway could be altered in steps of 50 millimeters between 1230 and 1630 millimeter above the ground, and for a door-angle, the angle to which the door opens could be varied without steps up to 90 degrees. So, maximum 90-degree door opening could be provided.

In our earlier discussion; we mentioned. So, if we look at this slide. So, for the front door, it should be 65 to 70 degree and for the rear door it should 70 to 80 degrees, but right now; we are discussing that at the most it can be provided as 90 degrees.

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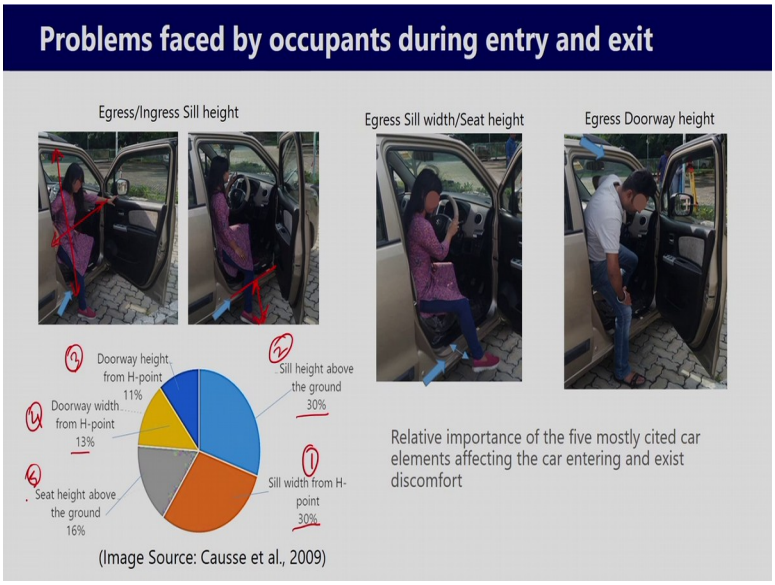

Now, the problem faced by the occupants during entry/exit. So, Causse et al. (2009) reported the various elements; five important; mostly cited car elements affecting the car entering and exit discomfort. So, these five elements are; sill width from H-point. So, 30 percent of the people reported; that they find problem associated with the sill width, that is the rocker panel width. Then, a sill height above the ground. So, 30 percent of the people have reported; that the height of the sill, means, rocker panel height or the sill height from the ground, in 30 percent of the study people, reported that they find difficulty for this height.

Then, doorway height from the H-point; that is reported by the 11 percent people. Then, doorway; this is the doorway height; 11 percent people reported, that they find difficulties or this one; door-way height. Similarly, 13 percent of the people reported that door-way width from the H point, this door-way width, they have difficulties, or they find that it is insufficient, in case of 13 percent people. Then, seat height above the ground and they find difficulties, or these are the reason for their discomfort; reported by 16 percent people. So, these are the five design elements associated with the discomfort for during entry/exit; as reported by the Causse et al. (2009).

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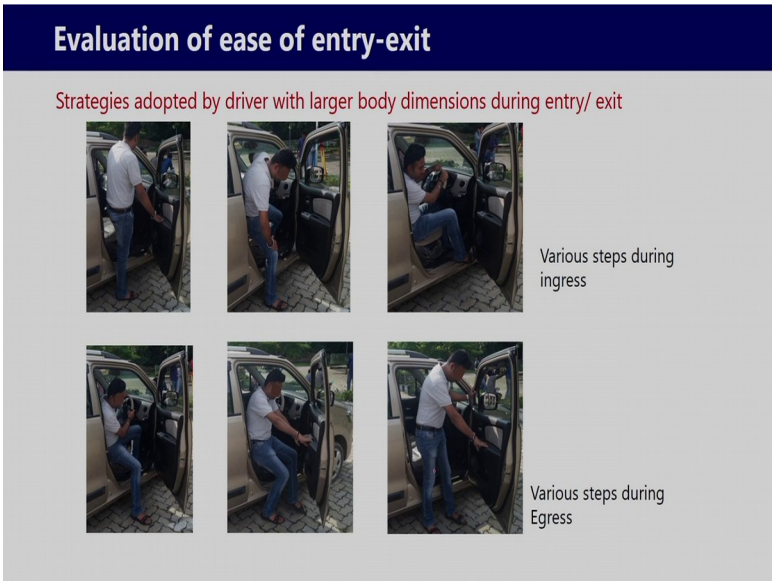

Now, different strategies are followed by the taller and shorter driver during entry/exit process. Taller or people with larger body dimension, means, relatively larger body dimension, say, 95th percentile body dimensions.

So, those types of drivers or passengers, they follow different types of strategy, while they are entering. So, here we can see; while the driver is going inside, so, how they are holding the door handle; either they are taking the support from the door panel, then sitting on the seat and then, gradually, pulling their leg inside. On the other hand, while they are coming out, that is the egress process; then they are holding the steering wheel, then bringing one leg first out; then two legs, and then standing upholding some part of the door panel and at last; they are standing and coming out.

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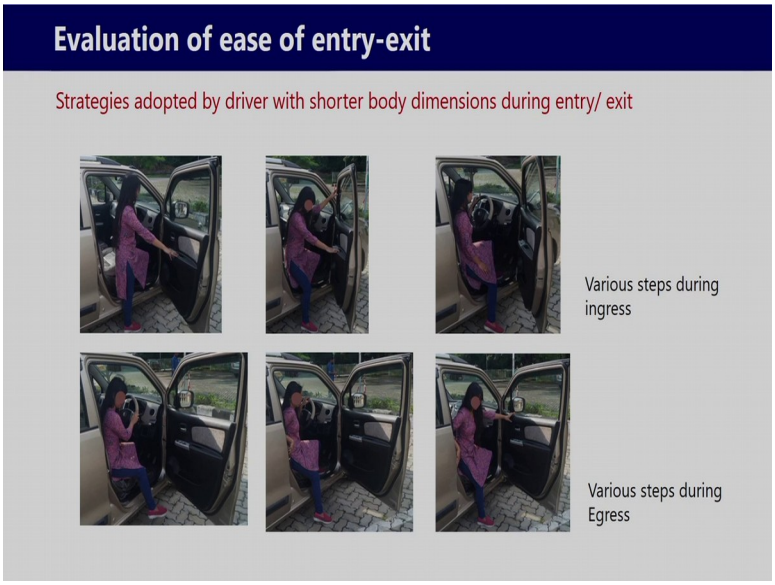

Similarly, for the shorter driver or driver with relatively smaller body dimension, particularly female with 5th percentile body dimensions, for them, they also need to hold the different portion of the vehicle, while they are going in. So, here you can see. So, person to person, it will vary, but as their body dimension is relatively small. So, they obviously, find the height from the ground to the seat or the rocker panel is relatively more and then accordingly, they try to manage and enter inside the vehicle.

Similarly, during coming out, they also adopt various positions, here you can see this particular case, that driver with smaller body dimension or relatively the 5th percentile body dimension, they are holding the steering wheel, then the side of the B-pillar and then, coming out from the vehicle.

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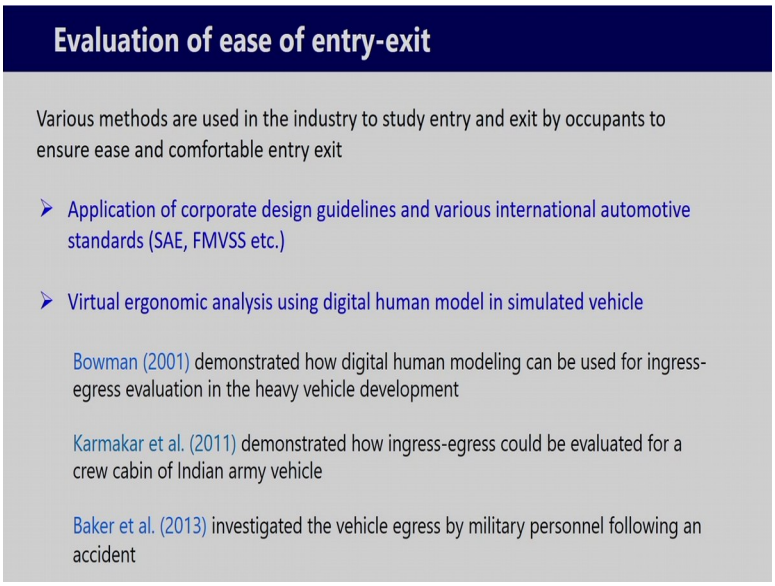

Now, evaluation of ease in entry and exit. So, various methods are used in the industry to study entry and exit by occupants to ensure ease and comfortable entry/exit. So, for this purpose, there is application of corporate design guidelines, developed by the companies or based on the various standards and feedbacks collected from the users and customers. Moreover, in the industry also; various International Automotive Standards, like Society of Automotive Standards, Federal Motor Vehicle Safety Standards; these types of standards are adopted for ensuring ease and comfortable entry/exit.

Then, there is also a virtual ergonomic analysis using digital human model in a simulated vehicle environment. So, various researchers have already reported; that, how digital human modeling software can be used for virtual ergonomics evaluation of the entry/exit process and accordingly, how we can guide the design modification process.

So, here, three references are given (Refer Time: 42:52). Bowman (2001) demonstrated how digital human modeling can be used for ingress/egress evaluation in heavy vehicle development. In this research paper; he showed that; how for heavy vehicle, like truck, while the driver is climbing up or getting down, then three points of contacts need to be maintained; either; two hand-one foot or two feet and one hand; these three contact points should always be maintained; to maintain the balance of the driver while climbing over the stairs for going inside the vehicle.

Another paper reported by Karmakar et al. (2011) demonstrated how ingress/egress could be evaluated for a crew cabin of Indian Army vehicle. So, what type of door grab handle should be provided, how much should be the step-width, then step-height for the ladders.

So, this type of information has been provided in that paper. Then Baker et al. investigated the vehicle ingress by military personnel, following an accident. While the vehicle is not in upright condition, toppled down, then, how the drivers or the army personnel can come out from the vehicle has been reported by Baker et al. (2013).

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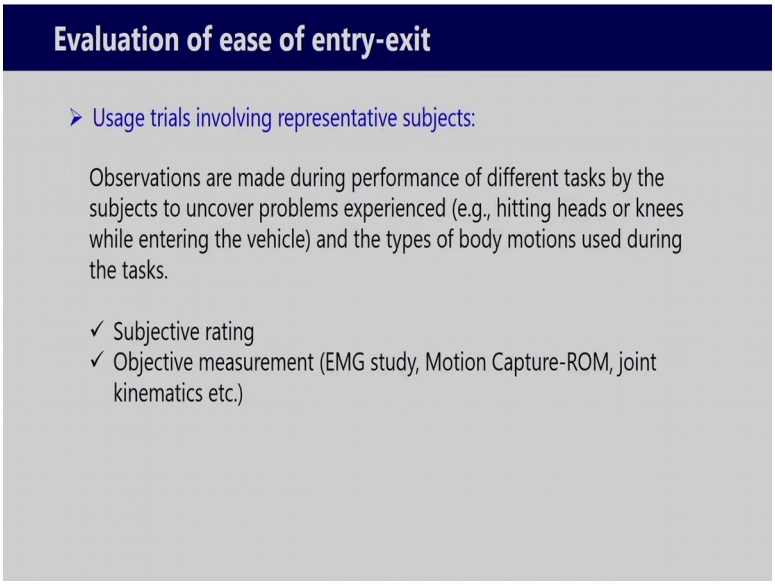

Then, usage trial involving representative subjects. So, representative subjects can be called for a trial of the vehicle or the mock-up. So, in that case, observations are made during performance of different tasks by the subjects to uncover problems experienced. For example, hitting heads or knees while entering the vehicle and the types of body motion used during the task; so, for that purpose, subjective evaluation can be done as well as objective measurement is also possible.

So, subjective evaluation, generally, done based on the questionnaire, interview; at the same time, on that questionnaires, some different types of rating scales are used. In objective measurement process, electromyographic study, motion capture using camera, then, joint kinematics, these are the process for objective measurement to study the entry/

exit process, what type of problems exists, means, how easy is the entry/exit process or how difficult is this process and accordingly we can go for the design modification.

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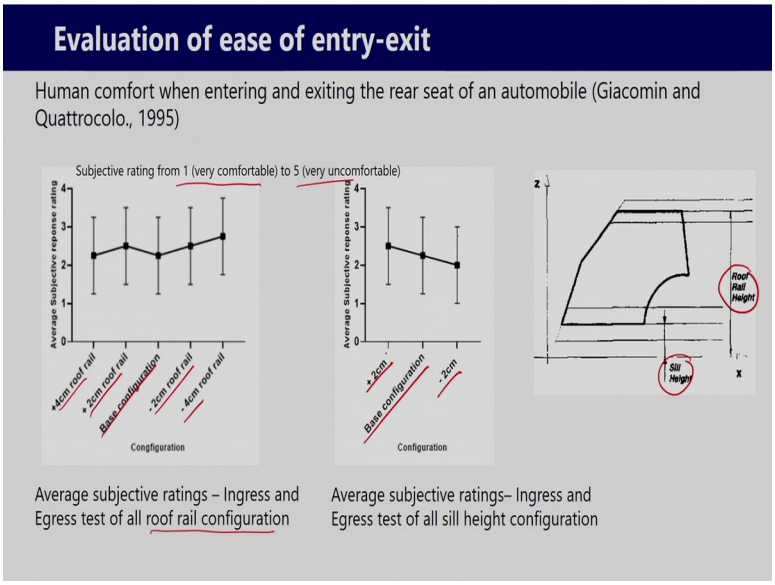

Now, here we are discussing about one research paper, where Giacomin and Quattrocolo (1995) described about; how we can take the rating regarding the sill height, roof rail height and other variables, like seat dimension, then rear seat height.

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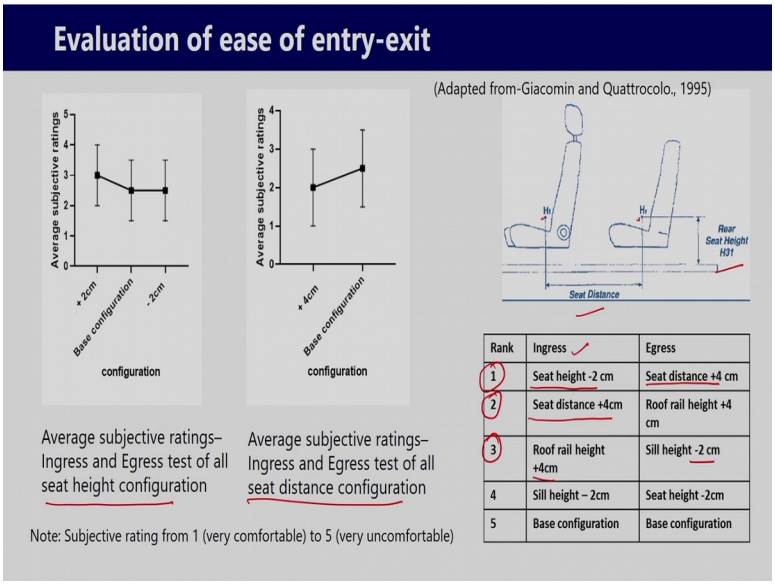

Rank	Ingress	Egress
1	Seat height -2 cm	Seat distance +4 cm
2	Seat distance +4cm	Roof rail height +4 cm
3	Roof rail height +4cm	Sill height -2 cm
4	Sill height – 2cm	Seat height -2cm
5	Base configuration	Base configuration

So, they asked the subjects to rate the rating scale, where 1 is very comfortable, and 5 is very uncomfortable, for different vehicle components. So, for a sill height, so, average

subjective ratings during ingress/egress process; for the roof rail configuration. So, this is the initial roof rail configuration; if the roof rail height is reduced by minus 2 and increased by plus 2, plus 4, and minus 4 centimeters; then how is the subjective rating, that is shown; the average subjective rating by the people. Similarly, in this graph, it is shown that. So, earlier we discussed the roof rail height, now, sill height, if the sill height is also modified.

If it is increased by 2 centimeters or decreased by the 2 centimeters from the existing one, that is the base configuration, then, how is the rating by different subjects and based on the subjective rating, the average and the standard deviation has been plotted here. Similarly, the subjective rating is also collected for the seat height configuration as well as the seat distance configuration between the distance between H-point of front seat and H-point of the back seat.

And based on this study they come to the conclusion that for ingress process the most important factor that is the seat height variable; exactly that is the seat height of minus 2 centimeters, it is good and that is ranked one by the respondent. Similarly, seat distance of plus 4 centimeters was ranked 2; roof rail height increased by 4 centimeters was ranked 3 for the ingress process. Whereas for the egress process, seat distance of plus 4 centimeters was good and that was ranked 1 by the respondent. Similarly, the subjects also mentioned that; roof rail height of plus 4 centimeters is good for the egress process; they ranked it as 2 and a sill height of minus 2 centimeters, means, sill height; when the rocker height was lowered by 2; minus 2. (Refer Time: 47:54) Lowered by 2 centimeters; that was ranked as the 3 by the respondents.

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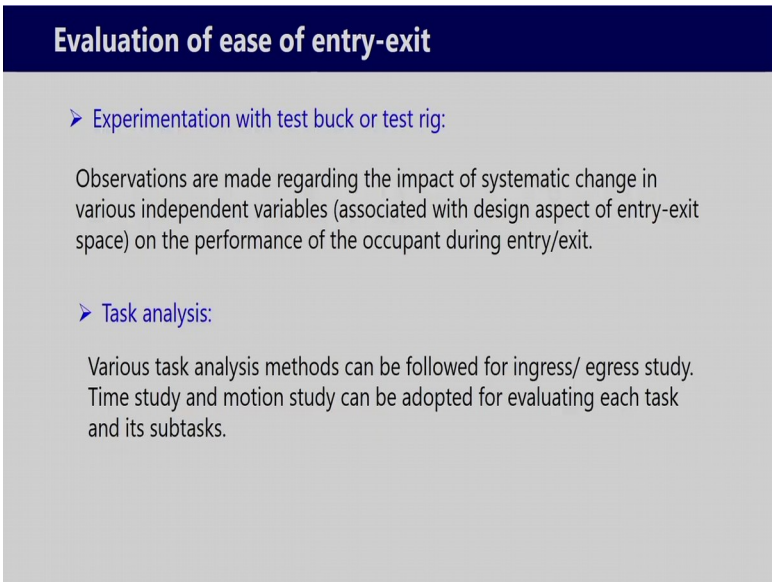

Now, other evaluation processes. So, experimentation with test buck or test rig. Observations are made regarding the impact of systematic change in various dependent variables (associated with the design aspect of entry/exit space) on the performance of the occupant during entry/exit. So, as we discussed, various door openings related dimensions, vehicle components; like grab handles, door handles, these are associated with the entry/exit process, and they are designed such that, their dimensions affects the entry/exit process for the drivers and passengers.

So, an experiment can be conducted in the test buck or test rig by changing the design and dimension of these various vehicle components and accordingly we can get the test result from the test subjects; following this type of experiment. And accordingly, we can understand that which is the best combination and how the design should be modified or while we are going for designing a new vehicle, then to ensure comfortable easy entry/ exit process, what type of vehicle door should be designed, so that, the drivers and passengers should not report any drawbacks related to design in terms of entry/exit.

Then, there is also the process of task analysis. So, we can ask the drivers and passengers or the test subject to perform a series of activities related to ingress/egress and during, while they are performing those tasks or sub-tasks. Then, we can go for time study and motion study and accordingly we can understand, that, what type of improvement is

required in the design to achieve optimal design for ensuring safe and comfortable or easy and comfortable entry/exit process.

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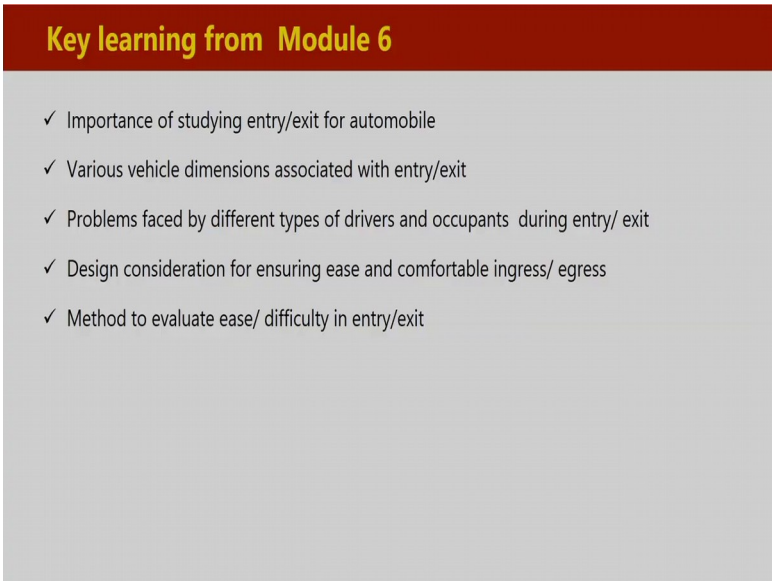

Now, after discussing these various aspects of the entry/exit process. So, what are the key learnings from this module 6. So firstly, we learned about importance of studying entry/ exit for automobile, then various vehicle dimensions which are associated with the entry/exit process, then problems faced by different types of drivers (with varying age, somatotype, anthropometric and biomechanical characteristics) that we discussed in detail. Then, what are the design consideration for ensuring ease and comfortable ingress/egress process that has been discussed in various slides. We also discussed in the last portion, the method to evaluate ease and difficulty in the entry/exit process.

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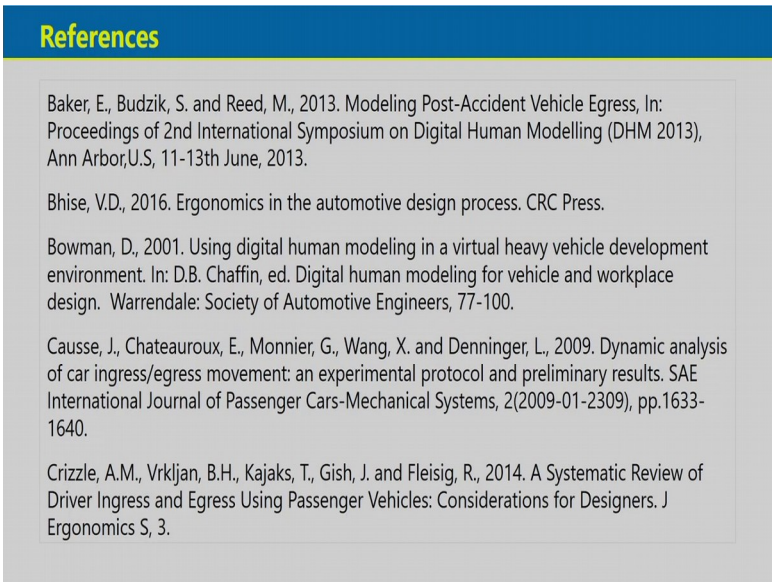

Now, these are the various references which have been consulted in preparing this slide. So, I ask all of you, that you can go through these references for understanding more on this topic and getting your idea more clear.

Thank you.