Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation

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Lecture – 14
Techniques/Process of Virtual ergonomics evaluation using DHMs Part B (Part I)

Welcome to the course Digital Human Modeling and Simulation for Virtual Ergonomic Evaluation.

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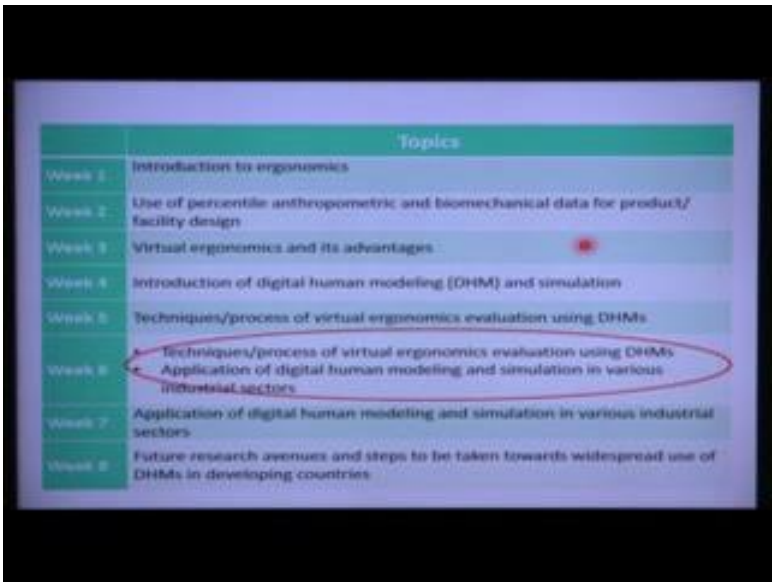

Today, we are going to discuss about our sixth week course module. So, in the first portion we will study the techniques of virtual ergonomic evaluation. Already in our earlier module we have discussed about reach analysis (Refer Time: 00:46) vision then comfort discomfort analysis, (Refer Time: 00:56) and load analysis.

So, following the analysis today we are going to discuss about ingress egress analysis in Module 6.

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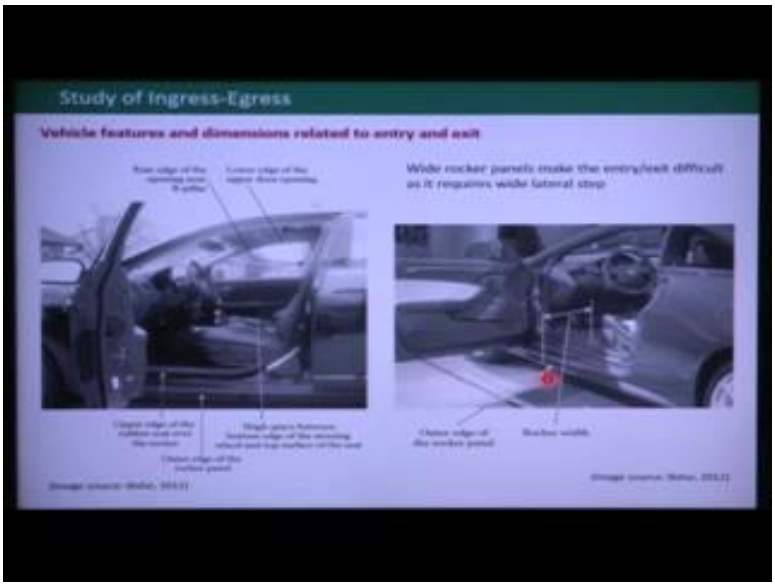

After ingress egress analysis then we will move towards industry specific. If you see in unit 6; so we are going to discuss ingress egress analysis as the application of virtual ergonomic evaluation technique. And next we will discuss about application of digital human modeling software in various industrial sectors. So, first we are coming to ingress egress study. So, ingress egress is very important, not only for vehicle work station for other workstation also. In vehicle workstation drivers as well as passengers, they enter and exit from that vehicle. While they are entering inside the vehicle or coming out from the vehicle, there are different types of problem they face. So, how we can improve that vehicle designs so that their problem for entry exit can be minimized.

Not only this type of vehicle, but also in other situation; like not only this passenger car, other say bus or truck train, or even military vehicle where there are so many other constituent that design. So, how passengers or driver enter in the respective sitting places, and how they come out from that vehicle; that is very important to study from ergonomics perspective. So, in this particular slide, these images taken from the book written by (Refer Time: 02:43) in 2012 on vehicle ergonomics. Here we mentioned various dimensions of the vehicle which are related to ingress egress. So, we mentioned about the location of v pillar, then lower edge of the upper door opening, this position. Then upper edge of the rubber seat over door rocker, this point; then outer edge of the rocker panel, this one; then pipe clearance space between the seat surface and bottom side of the steering wheel.

Apart from these, another important dimension of this purpose is the rocker wheel, in the distance from the outer edge in the inside edge of the rocker panel. So, these distances is also influenced that whether entry and exit, or ingress egress for the driver, I mean this, if this distance is more, then there will be more discomfort for entry or exit. So, while rocker panels made the entry exit difficult as it requires wide lateral step. So, person who wants to go in, from outside inside the vehicle, then he has to go for his late or the whole body, has to move from this point to this point, means it requires wide lateral step.

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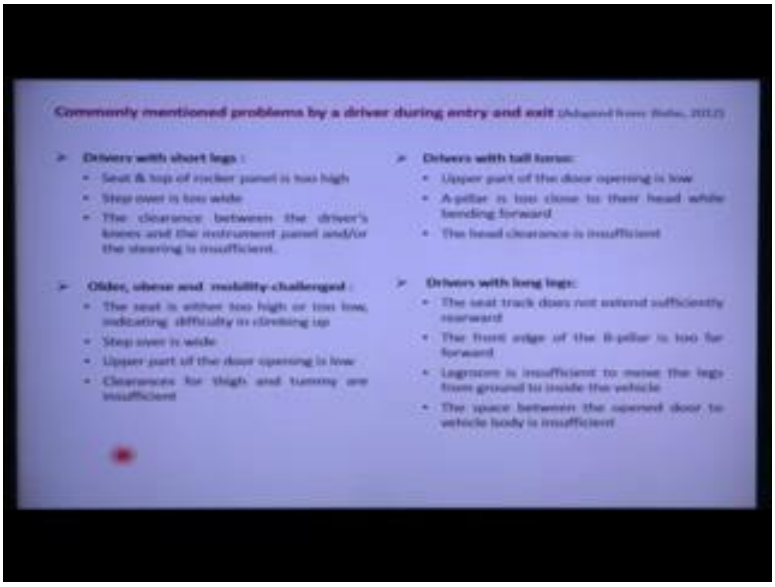

Next, while passengers are optical in this case, driver while drivers are sitting on the driving seat, then different percentile driver, means shorter average and larger driver, they, and also other particular population say older people obese and mobility challenged people, they find different types of difficulties during entry exit of the driving seat. So, driver with lower edge, driver with short legs what types of problems they face. So, from here you can see; seat and top rocker panel they feel that seat and top rocker panel is too high, it means the rocker, from the rocker panel to the seat, height is higher for them because they feel there leg is shorter. So, they have to lift the leg more.

Then step over is too high, that in the earlier slide as we have mentioned this one, rocker. If the rocker with this more than they have to move their leg more. So, step over is too high then the clearance between the driver knees, and the instrument panel or the steering is insufficient. The space between, because of the generic the driver with shorter leg

(Refer Time: 05:57) they have to move the seat forward, while they moving the seat forward the space between the instrument panel and the steering wheel column, the space from the knee of the driver is shorter leg length is actually that space is reduced, because they moved their seat forward while they are moving the seat forward, then they find that clearance between the knees and that instrument panel is placed or insufficient.

On the other hand older obese and mobility challenged driver, while they are sitting or going to sit on the driving seat, they find the different types of problem, they feel the seat height, the seat is either too high or too low indicating difficulty in climbing up. So, for them, because either they are older or obese they feel they have to lift their body and have to go inside, or from the seat they have leave their body and they have to come out. So, they feel the seat height is too high for them.

At the same time step over is wide, upper part of the door opening is low, because for them bending is the problem. So, as they cannot bend their neck more or the overall body they cannot bend, they prefer to enter as much as possible in a vertical position. So, for that reason the upper they feel that upper part of the door opening is low for them, otherwise they have to bend more. Clearance for thigh and tummy are insufficient and for particular obese driver the space from their tummy to the steering wheel is not sufficient.

Similarly, driver with tall torso, they have different types of problem, while they are sitting on the driving seat or they are entering, or while they are coming out they feel upper part of the door opening is low, because their height or stature is relatively more than the others. So, they need to bend more while they are entering in the vehicle or coming out from the vehicle, A pillar is closed to their head while bending forward. So, while they are bending forward, then they feel the location of the A pillar is nearby, their head. The head clearance is insufficient, due to their longer torso, the clearance space above their head and the vehicle root is not sufficient. So, these are the feeling of the tall driver with tall torso.

On the other hand, the drivers with long leg, they have different feelings. So, while they enter in the vehicle they are going for either ingress or egress in a vehicle, then the seat track does not extend sufficiently rearward to accommodate their long leg, they move the seat backward, but while they moving the seat backward. They feel the seat track travel

need should be more in backward direction. So, that they can accommodate their longer leg, the front edge of the B pillar is too far forward and the B pillar while they are moving the seat backward, then the B pillar coming towards their leg because they are shifting the seat backward. So, they feel that B pillar position is too far forward it should be little bit backward. Legroom is insufficient to move the leg from ground to inside the vehicle as their leg length is more. So, they feel the legroom is not sufficient for them.

The space between opened door and the vehicle body is insufficient, due to their longer leg they feel that the opening space from the vehicle body and the door that should be more. So, that they can turn their leg, longer leg, and they can enter in the vehicle. So, this is taken from book written by (Refer Time: 10:36), so from that book. So, these are the feelings of different for a particular vehicle, while the drivers are entering in that vehicle in the particular passenger car.

During the entry or exit process, different types of driver have different opinion or their feelings are different. So, these are the four categories of people we mentioned; that people with driver with shorter leg, driver with long legs, driver with tall torso, similarly obese, older, and mobility challenged driver. So, what are they feeling?

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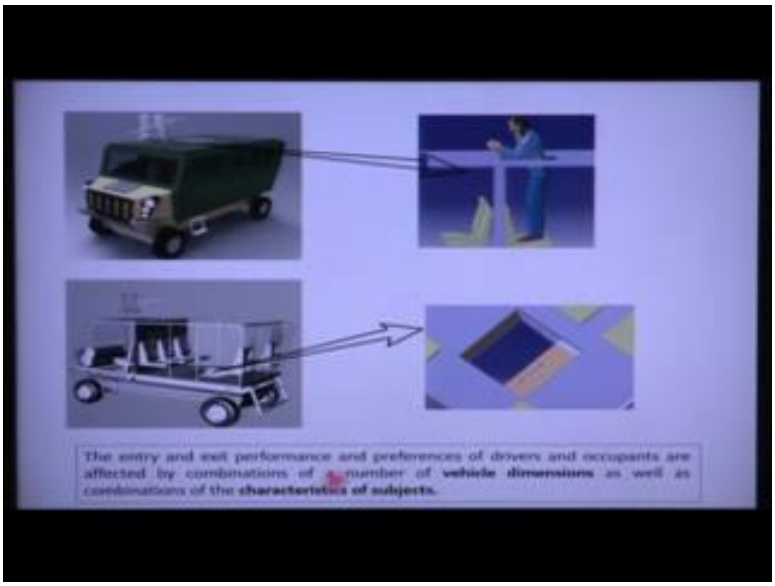

Because, this entry exit performance of drivers and occupants are affected by combination of factors their vehicle dimension, and various components dimension of the vehicle at the same time characteristics of the driver or subjects or passengers. So,

who are going to enter in the vehicle or coming out from the vehicle, their characteristics and their physical characteristics, whether they are thin or fat or their body dimension, they are stomata type that is important, at the same time vehicle dimension, so, roof height (Refer Time: 11:56) door opening size all these factors are actually very important.

So, in this particular side if we take the example of this army vehicle, so in this army vehicle there are different entry exit points. So, apart from this normal door, for enter entry or exit there are other rooms like at the top there is hatch, this hatch is used for firing, but this is also they can use for their emergency exit or exit while they require. Similarly, on the vehicle floor there is sure edge, in through the sure edge they can also go down. So, dimension of those exit points also you have to design as per the body dimension of the intended user population so; obviously, the dimension should be such that people with larger body dimension can easily pass through.

So, in a vehicle not only this type of normal door, the side wise or at the back the backdoor, where there is ladders or steers, apart from these two types of door side door or front door or back door there may be other entry exit point, like as you mentioned steer edge or overhead edge. So, while in specific type of vehicles this type of provisions different provisions are there for ingress egress and all those points we need to evaluate and we need to design as per the requirement of the intended user population. So, we have to ensure that people with larger body dimension can easily go in and out easily.

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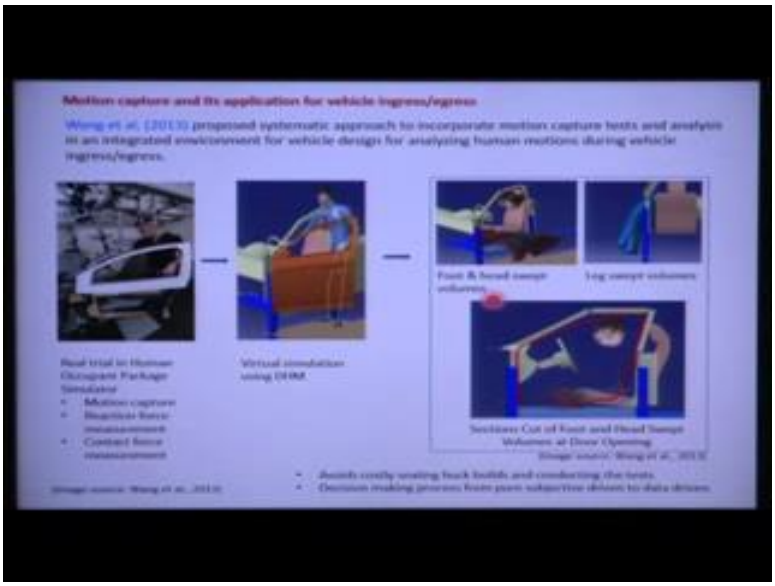

Now, in subsequent slides, we will discuss about various research papers, where researchers have used digital human modeling software to study ingress egress or to demonstrate how digital human modeling software can be used for effective analysis of ingress egress. And vehicle design can be modified to ensure comfortable and is entry exit. So, in this particular slide we are going to discuss from the paper research paper by Wang et al 2013. So, in that paper they demonstrated; how motion capture and it is application for vehicle ingress egress. So, they demonstrated that motion capture system can effectively be used for vehicle ingress egress analysis. They proposed systematic approach to incorporate motion capture tests and analysis in an integrated environment for vehicle design for analysing human motions during vehicle ingress egress process.

So, for that purpose they developed this type of test mock up, where real driver can go into that driving simulator or mock up. And that time data can be collected using motion capture system. So, what is this motion capture system motion capture system is actually camera based system generally higher camera infrared camera which (Refer Time: 15:44) markers are positioned on the drivers body and those camera actually trace those markers location. And based on that markers location actual software in that from that captured data by that camera, it is transferred to the software motion analysis software and in this motion analysis software based on that marker position 3D model, of linked segment is developed and various types of body joint angle can be evaluated.

So, this motion analysis system actually captures the human motion, while that real driver is entering into that simulator. So, in the study they use the motion capture system, at the same time reaction force measurement system and contact force measurement system. So, all these they use to get different types of kinetic data, kinematic data, as well as contact force data. So, those data particularly that motion capture data they transfer to digital memory software that is in the CATIA, where they use CATIA software. In CATIA software that following the real human trial real driver trial the data collected to motion analysis system, camera based motion analysis system that data transferred to digital human modeling software CATIA. And in this software then they evaluated how ingress egress process can be evaluated in virtual environment of cad software.

So, this is visual simulation of digital human modeling. Then with that cad software this is the foot and head safety volume. So, while the digital human modeling is entering in that vehicle or coming out, so this is actually the profile for that foot and head (Refer Time: 17:49). So, this portion is for head (Refer Time: 17:50) in how that is moving from outside in the vehicle or coming out from the vehicle. Similarly, for the foot how foot is going from outside the vehicle to inside, or while the driver is seated on the seat, while he is coming out that how feet is also coming out. So, this is actually the shaped volume for feet.

Similarly this is the shaped volume for head they also analyse the shaped volume for the leg. So, it is repented here, then this is the section cart of foot and head shaped volume at door opening. So, this is for the shaped volume for foot and this is the shaped volume for head. So, following this shaped volume actually this cart section can be defined. So, how much space actually required. So, that driver can go easily and come out from the vehicle without collision at any part of the door opening. So, the data which was captured from motion analysis system that has been transferred to cads of CATIA, this digital human modeling software, and from digital human modeling software, we can evaluate at what should be the optimal size of the door opening. So, the based on the foot shaped, leg shaped, and head shaped the volume.

So, in this way without real human trail, we can use digital human modeling software and based on the digital human modeling software analysis we can design the door opening, or we can define what should be the optimal door opening. So, they concluded

this evaluation technique actually avoid costly steering back wheels and construction of, and conducting real human tyres.

Then it also helps in decision making process from pure subjective driven to data driven. So, otherwise what is required we have to go for real human tire, we have to ask their comfort discomfort during entry exit, but in this case with this type of software digital human modeling software, based on the motion analysis data we can easily create this data the this type of shaped volume for different body parts and based on that shaped volume we can define the sizes of the door opening.

So, ultimately followed these, their study indicating that digital human modeling software is actually very useful for ingress egress study of vehicle and how the design of the vehicle component particular it is a door opening can be modified as per the ergonomic analysis.

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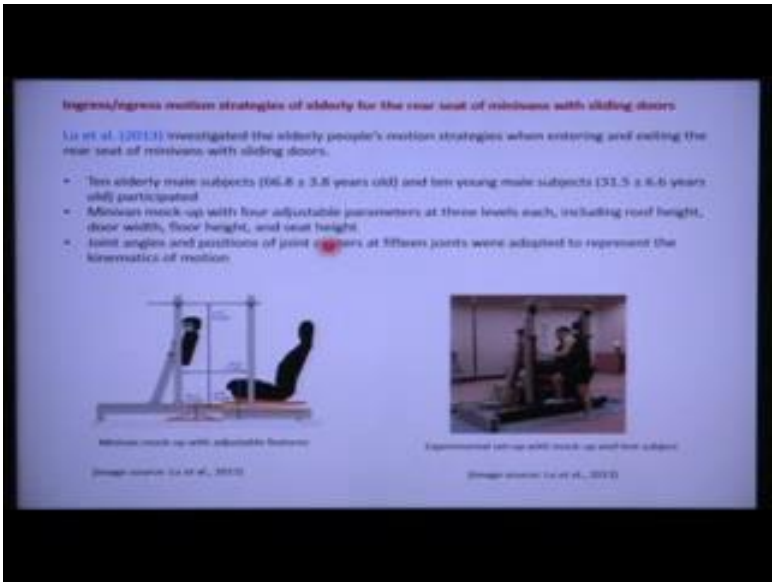

Next, in another paper Leo et al 2013, they also demonstrated that ingress egress motion strategies for elderly, for the rear seat of minivans with sliding doors. So, in minivans their research is in this particular case is related to minivans and that is the rear seat. So, while elderly people sitting at; I mean either going in or coming out in entry exit for the rear seat of the minivan. So, how elderly people's behaviour is different from the adult people, non-adult people or adult people? So, they conducted one study in that study ten elderly male subjects and ten adult male or young male subjects participated.

And from that they investigated that elderly people strategy while entering and exiting from the rear seat of minivans with sliding doors how it is different from the young people. So, minivan mock of with four adjustable parameters at three levels each including; roof height, door height, floor height and seat height. So, these four variables they considered and they made all these things adjustable at three different levels. So, this is the mock up and experiment and this is the real human subject who is checking that experimental set up, while driver is going in and coming out then the data is actually recorded.

While real humans are real drivers or elderly people is going for sitting on the minivan seat, or he is coming out then his joint angles and position of joint centres at fifteen joints are adopted to represent the kinematic of motion. So, their body joint angles changes during this entry exit process are recorded using motion analysis system.

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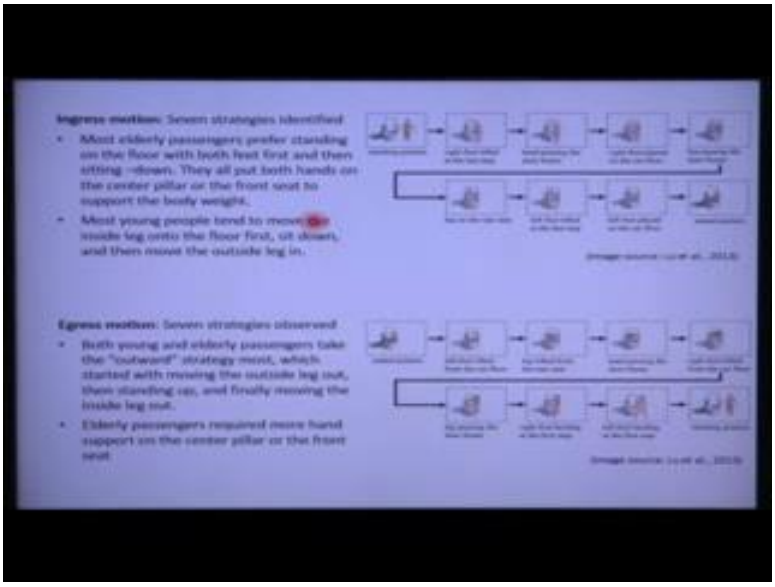

Based on that data, it was identified that during ingress motion seven different strategies are actually adopted by the people. Most elderly passenger prefer standing on the floor, with both feet first and then sitting down. So, elderly peoples, so what they identified, the elderly peoples in that strategy is actually different from young adults or adult peoples in the strategy. So, there they have shown different steps from mobile the person is standing outside of the vehicle and gradually step by step moving in and ultimately sitting on the vehicle seat. So, this is the total sequence for ingress.

Generally also this they out of this sequence they identified that specifically there are total seven different strategies, which are adopted by the drivers, but elderly peoples generally prefer, they first stand on the floor beside that vehicle door and then with both feet they move towards the vehicle and then sitting down on the vehicle. After that they pull both the hands put both the hands on the centre pillar, or the front seat support to support the body weight.

So, most elderly people how just what is their strategy, they first stand they sit on the seat and then hold the centre pillar, either v pillar and otherwise, the front seat and they gradually took the legs in. Most young people tend to move and contrary what young people do most young people tend to move the inside leg on to the floor first, then sit down then move the outside leg in. So, young people strategy is different. So, they first they do not follow the like aged old aged people elderly person they do not sit on the seat first what they do; first they put their one leg inside, then they sit down after that they enter they pull the another leg inside. So, there is significant difference between the strategy followed by elderly people and younger people.

Similarly, there is also difference in egress motion also. So, egress motion if you look at the egress motion there are various states. So, initially the driver is seated on the seat and gradually coming out, step by step coming out and ultimately standing outside the vehicle. So, from that minivan rear seat elder drivers are coming out that egress motion is actually defined for young and elderly. Both young and elderly passengers take the outwards strategy most which started with moving the outside leg then standing up and finally, moving the inside leg out.

So, first they move their one leg out, then they stand up and finally, moving the inside leg out, but elderly passengers required more hand support on the centre pillar, or the front seat. So, in case of egress motion, although there strategy to some extent similar, but, in terms of support, elderly people actually require more body support on the centre pillar, or on the front seat and based on that support they gradually comes out. So, from their study Leo et al actually demonstrated, that motion strategy for going in, or coming out from the vehicle is actually different for not only for different individuals also it is different types strategy, and the strategy adopted by older people or elderly people is different from the young adult.

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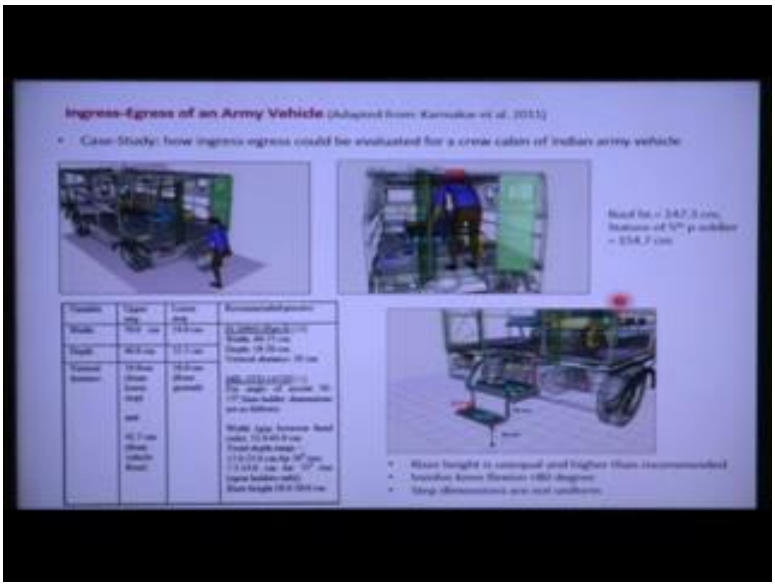

In another research paper (Refer Time: 28:40) 2011, they demonstrated how digital human modeling software can be used for, ingress egress analysis in army vehicle. Particularly in this paper they demonstrated how the entry exit process to the real door of the army vehicle can be evaluated. So, from the existing army vehicle they developed the cad model and that cad model was evaluated with different percentile of army population starting from 5th percentile to ninety 5th percentile.

So, it was observed from their study that even the steps or ladder, which is existed in the existing vehicle that is actually not properly designed, not properly designed in terms of the national international standard that was not followed, because the if you look this particular image the razor height, from first step from first step to second step from second step to vehicle floor this razor height are not uniform. So, these are varied. So, as this razor height is not uniformed.

So, during, while the army person are going or in a hurry or taking or carrying load or going inside or coming out, due to that rapid movement their they may fell down, there is chance of accident, due to this uneven distribution of the razor height. So, calling this analysis it was recommended that this height should be razor height should be uniform at the same time it was also observed from their study that these dimensions of the steps are also different. So, this may also lead to error and accident.

Apart from these in this particular vehicle the space from ground to the roof, the vertical space or the opening of the door is not sufficient, for entry comfortable entry even for 5th percentile soldier or 5th percentile army population, because the design was constant by some other criteria. So, following this virtual ergonomic evaluation of the existing cad model it was clearly identified with that; what are the problems in this design existing and how those can be overcome by design solution.

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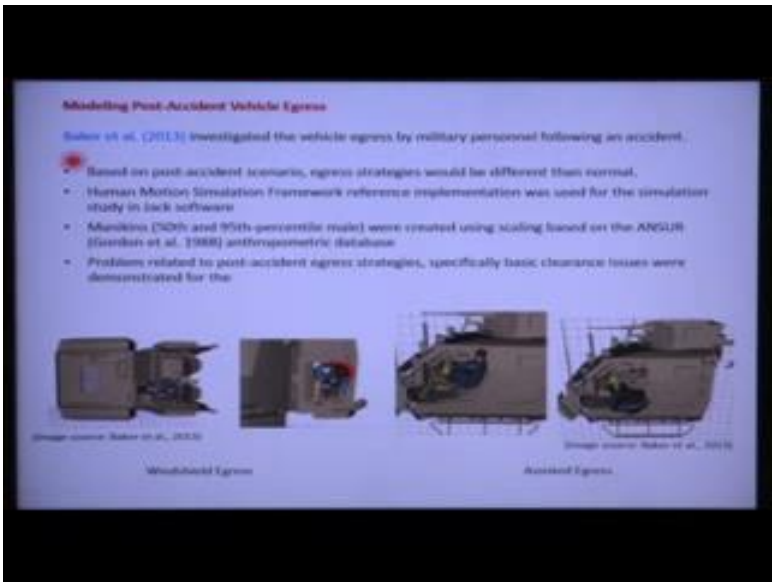

In another study, baker et al 2013, they investigated vehicle egress by military personnel following accident. See normal situation in many research papers it has reported that how ingress egress can be evaluated for different types of vehicle, but in this particular paper baker et al demonstrated that ingress egress status actually different, while that vehicle particularly military vehicle is under is facing any accident. So, following accident the ingress egress strategy actually different, they cannot come out through normal entry exit process. Based on post accident scenario ingress egress would be different than the normal.

Human motion simulation framework reference implementation was used for the simulation in this case using jack software, manikin's fiftieth percentile and ninety 5th percentile male I have created using scaling based on A N S U R anthropometric database. So, in this particular case they use jack software and for developing digital human modeling software they referred this anthropometric database.

Problem related to post accident egress strategy, specifically basic clearance issues. I have demonstrated for the vehicle. So, in normal case they can enter through the side door, but in accident scenario they may have to that is driver or that army personnel who is driving that vehicle they may have to come out through the windshield. So, while they are coming out from the windshield, whether the space provided in the windshield, is it sufficient for coming out the person with the arms and evaluation attached to with his body, or the backpack attached with his body. So, this is very crucial or this fact should be considered during army vehicle design because following accident, that person may, that army personnel may have to come out through the windshield opening.

Similarly, then it was observed that actually the opening was not sufficient and there is collision with the body and that vehicle parts on the other hand if. So, there are two types one is wind shielding this may be by the person, may be the army personnel of his own otherwise, it may be assisted egress means some other army personnel helping that person to come out.

So, in that case whatever is the opening, door openings size is it whether is it sufficient for assisted egress now, he is not coming out in following normal egress process his body has to move and that body has to come out like this horizontal posture. So, these various issues have been demonstrated and accordingly they suggested, that what type of modification in this army vehicle to be implemented.

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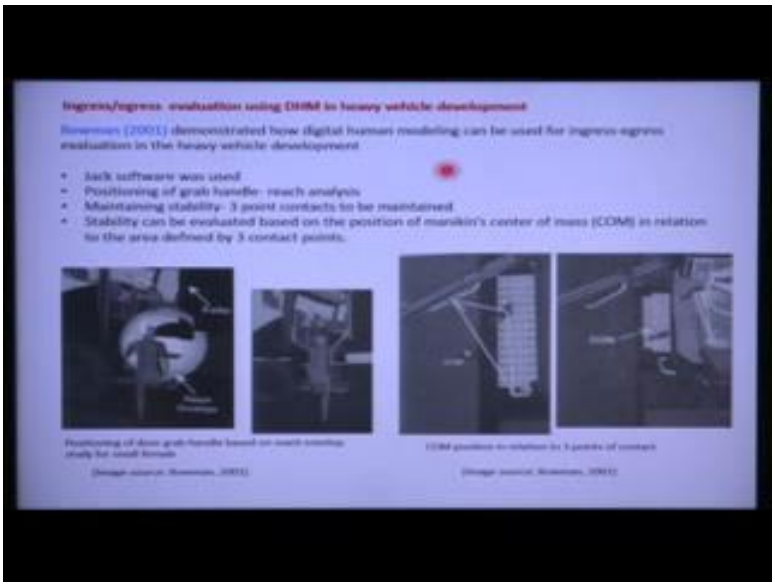

There are various research papers related to ingress egress for different types of vehicle. So, we have we will discuss few more research paper here. So, in this slide we are discussing the paper by bowman et al. In bowman et al, they evaluated ingress egress using digital human model in heavy vehicle development process. In the heavy vehicle development process they used digital human modeling software jack and bowman demonstrated positioning of grab handle or reach analysis. So, where in that vehicle through that while that person or driver is going in that driving cabin.

So, where that grab handle should be positioned for that purpose they evaluated the two types of reach; one is this type of they created reach in (Refer Time: 36:40) based on that reach in (Refer Time: 36:41) area is actually while that person in this case they considered as the reach and (Refer Time: 36:49) reach for the people with shorter body dimension, who will be smaller. So, they considered 5th percentile female model. So, for 5th percentile female model the developed the reach and (Refer Time: 37:03) and based on that reach and (Refer Time: 37:03) they identified where should be the position of the door grab handle. So, that person with the smaller body dimension can hold the door grab handle and can go inside.

Similarly, in this case based on reach and (Refer Time: 37:23) at the same time while that while the using the digital human modeling they demonstrated that how the dimension of the door grab handle should be decided. In that paper they also bowman 2001, he also showed that how stability can be maintained during egress process. So, maintaining stability three point contacts to be maintained. So, with this three contacts either one hand or both leg or one leg and one hand.

These three points of contacts to be maintained for maintaining the stability so they demonstrated while the driver is putting his leg on the steps for climbing to the vehicle driving cabin, then while driver is putting two hands on the one is here and another is here on the grab handle, and one feet on this particular step then this is the triangular space that is actually defining the three point contact, and this is the area this area and this is the area defined by this three contact point.

This triangular area and the centre of mass of the body, whether the centre of mass is nearby or within this standard, or it is away from this standard based on that they evaluated the stability. Stability can be evaluated based on the position of manikin's

centre of mass in relation to the area defined by three contact points; so with digital human modeling software, where they used jack so they really demonstrated that how during ingress egress process, by using these contact points and also the projected centre of mass how stability can be defined, and accordingly designed can be improved.

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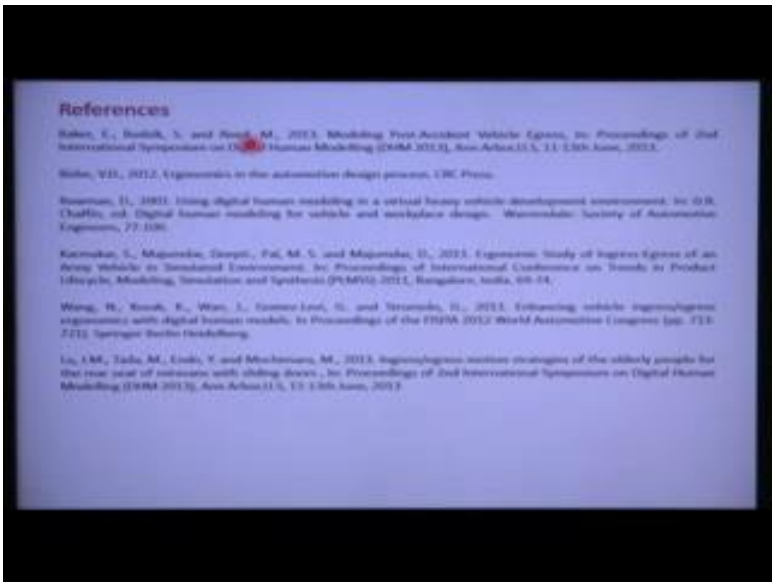

So, these are the various references, which have been used in our earlier slides in this slide, but there are. So, many other research paper where various researchers have demonstrated how digital human modeling software can be used effectively for evaluation of ingress egress process for driving cabin, or in the crew cabin, and also for specific type of vehicle like army vehicles. So, I suggest all the students to explore more in this regard download more research paper and go through then we get clear idea, that how digital human modeling software are actually used for ingress egress study.

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Now, in earlier section what we discussed; we discussed ingress egress study and in our earlier models. We discussed different types of ergonomic evaluation which is possible with digital human modeling software. Now, in the next subsequent slides we will discuss about how digital modeling software is been used by various researchers in various industrial sectors.

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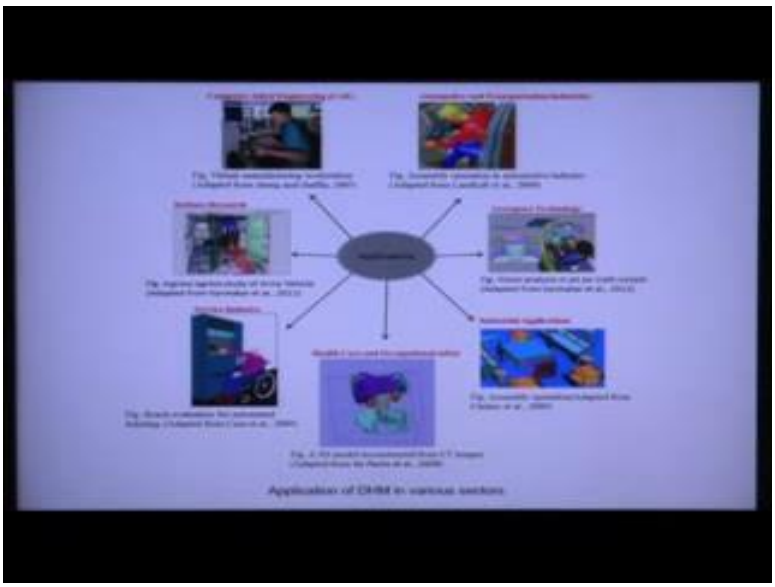

So, in this slide this is a representation that digital human modeling software is like; nowadays, used in almost every occupational set up, it may be defence research, it may

be computer aided engineering, or automobile assembly, or aerospace technology, or industrial application, industrial software evaluation, or health care application, various types of service industry. So, everywhere there is application of digital human modeling software and researcher's designers and engineers are effectively using this software for virtual ergonomic evaluation and getting benefit out of this software following this virtual ergonomic evaluation and design modification of those work spaces.

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Now, we are going to discuss about how digital human modeling software are being used in automotive industry by various researchers and engineers. So, in automotive design process digital human modeling software is actually used for both vehicle occupant packaging, mean how that driver cabin or passenger cabin can be designed as per the requirement, and ensuring comfort of the driver or passengers. Not only for vehicle occupant packaging, is it also being used in digital manufacturing in the automotive manufacturing software.

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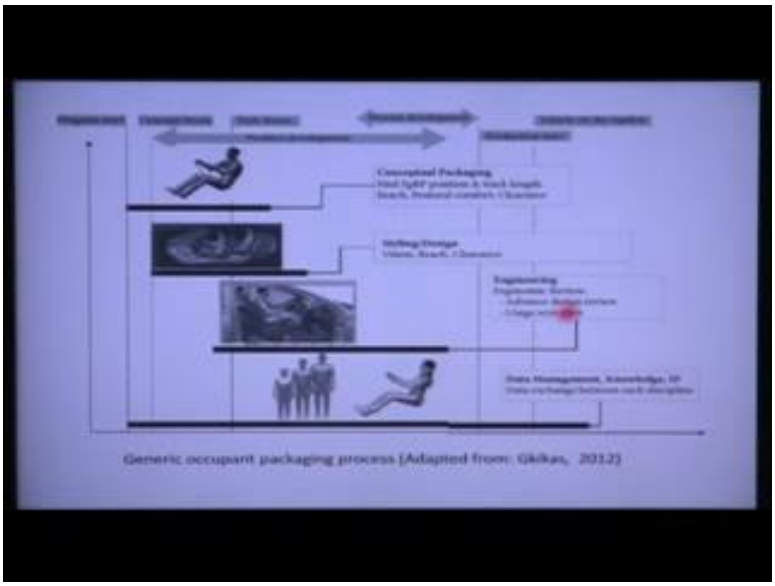

So, this is schematic diagram taken from taken from book written by Gkikas, 2012; where he demonstrated that generic occupant packaging process in the vehicle development. So, vehicle development process is starting here. So, first there is concept phase, then style phase, then process development, then production start, and then making in the market. So, in the product development there are various steps; conceptual packaging, where find S R P position, then track travel length each postural comfort clearance, all these are involved then in the next phase styling or design (Refer Time: 43:03) all these things is that to be considered then in engineering or ergonomic review. So, advanced design review, user scenario all these things should be considered. So, in each of these steps there is use of digital human modeling software.

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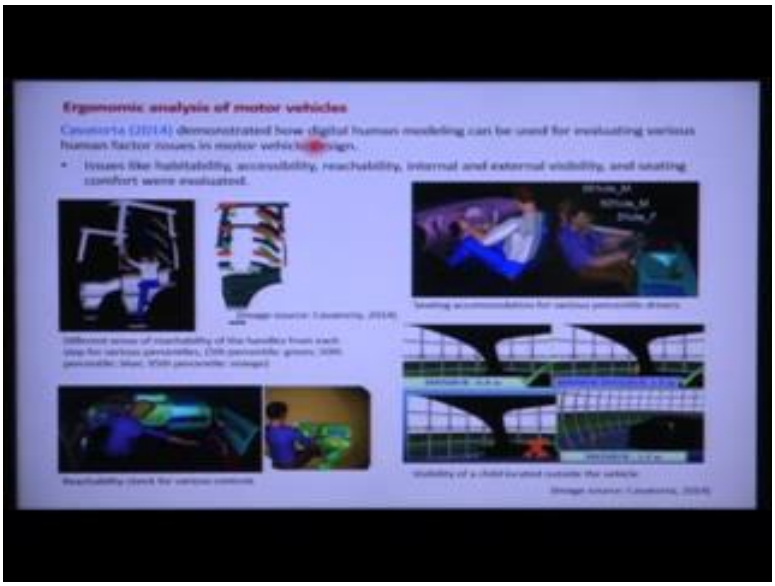

So, digital human modeling software is very important in occupant packaging that is for driver as well as for other passengers. Cavatorta, 2014, demonstrated, how digital human modeling can be used for evaluating various human factor issues in motor vehicle design. So, they studied various issues like; habitability, accessibility, reachability, internal and external visibility, and seating comfort. So, using jack software, they demonstrated that, while driver is going in, or during the ingress, how different radius of reachability of the handles for each step for various percentile of driver; 5th percentile, 58 percentile, 98 percentile.

So, while step by step while the driver is going in then higher is their (Refer Time: 45:51) position. So, which define colours colour coding they have used they have demonstrated, that how is the reach for 58 percentile and 98 percentile driver. So, based on these analysis it would be easy for positioning the grab handle. For, sitting arrangement, or sitting comfort, they 5th percentile, 58 percentile and 98 percentile for digital human model they positioned on the seat and evaluated various types of vehicle driving seat related parameters.

Then also they studied reachability in reach analysis, two types of reach evaluated; one is normal reach, creating reaching (Refer Time: 46:43), that while reach (Refer Time: 46:45) is created that which areas of the control panel, or different components on the dashboard can be accessed by the driver that has been evaluated, at the same time reach

by extended arm. So, how much body zone movement is there for accessing a particular control, or particular component in the vehicle that is also evaluated. Apart from that, they also in that study it has also evaluated the vision the visibility of a child located outside the vehicle that, whether while one child is located outside the vehicle, define distance at which location that child is visible because to the driver and which location it is not possible. So, with different aspects in motor vehicle development has been studied by Cavatorva in 2014, in the research paper.

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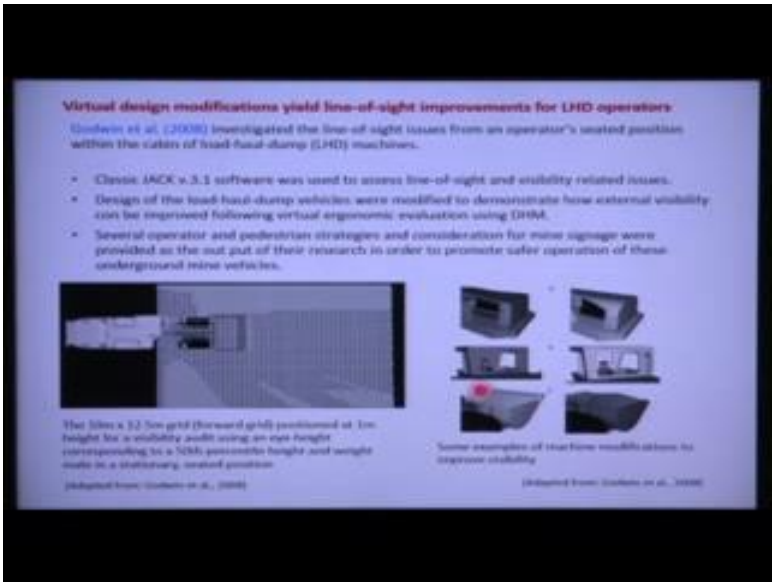

Another research reported by Godwin in 2008, Godwin et al in 2003, investigated the line of sight issues from operators in seated position within the cabin of a load haul dump machines L H D machine. So, in load haul dump machine, virtual modification, and virtual design modification yield line of sight improvements, for L S D operators. So, ultimately in their study they used jack software digital modeling software jack to assess the line of sight, and visibility related issues design of the load haul dump vehicle were modified demonstrated how external visibility can be improved following virtual ergonomic evaluation using D H M.

So, in this particular event they should that while that L S D is positioned beside a tunnel. So, which area is actually visible and which area not visible. So, for that purpose they created 10 meter in to 12.05 meter width, forward width position at 1 meter height

for a visibility audit, using eye height corresponding to a fiftieth percentile height, and weight male in stationary seated position.

So, they created one vertical plane in front on 1 meter away from that driver seating position and the driver will they consider that fiftieth percentile driver with driver width fiftieth percentile height and weight, so, while the driver is looking outside which area is actually visible to him. So, this on this particular plane they demonstrated with this outer parts these areas is actually visible and these area that actually not visible. So, visibility can visibility, external visibility from that L H D can be evaluated using this jack software. They really demonstrated that not only that visibility they also checked that how this line of sight as well as external visibility can be improved by re design various components of that L S D machine.

So, these are the various components of the L S D machine. They modified this is the modification, and following modification they again analysed, that how the external visibility has been improved. So, they clearly demonstrated that digital human software can effectively use for design modification and based on that design modification that range of visibility external visibility can be improved.

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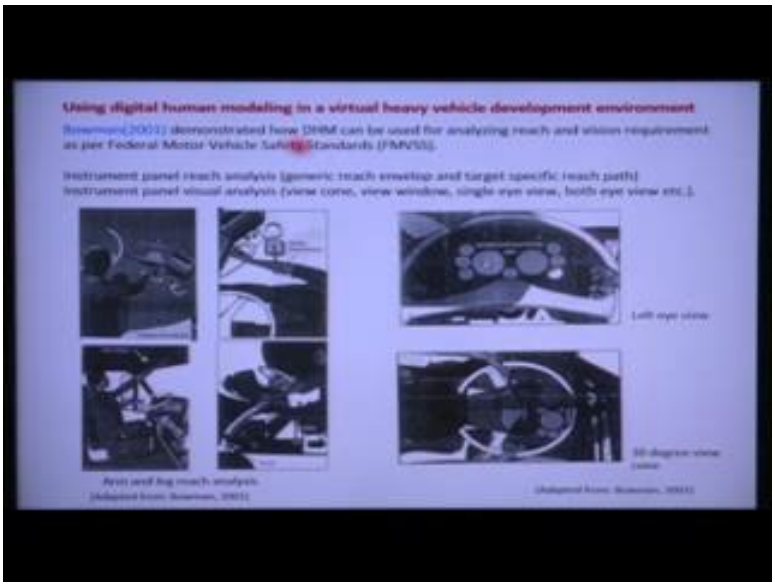

Next, in another paper research paper, this is published in 2001, by bowman. So, in that research paper, this paper has actually related to using digital human modeling in virtual heavy vehicle development environment. So, in heavy vehicle development

environment, how digital human modeling can be used. So, Bowman demonstrated digital human modeling can be effectively used for analysing reach, and vision requirement, as per federal motor vehicle safety standard is a following federal motor vehicle safety standard, how various ergonomic issues can be evaluated in the heavy vehicle development. So, they created reach and vellow and also identified that collision during different types of operation. So, they created arm and leg reach and they analysed arm reach for various components, as well as leg reach for leg control operation like; wheel, clutch, accelerator, where for this purpose.

At the same the reach envelop, for studying the overall reach on the instrument panel. So, both reach envelop by creating the reach envelop at the same time target specific reach they evaluated. Apart from reach, in this paper they also demonstrated how vision analysis tool of digital human modeling software can be effectively used for evaluating the position of dashboard, display on the dashboard.

So, this is the view of left eye view. So, vision instrument panel on the dashboard vision analysis. So, for that purpose view cone can be created, eye view window can be created, and then there is single eye view, both eye views. So, these are the various tools available in the digital human modeling software using those tools vision can be evaluated. So, here this is the visibility of the left eye view, and in this image it is shown that with 30 degree view cone.

So, this is the 30 degree view cone in this 30 degree view cone in which area of the view cone is actually visible to that driver. So, in 2001, they with this jack software they bowman et al clearly demonstrated that digital human modeling software can be effectively used for, positioning various components in the vehicle, and also checking those position, and arrangement of various controls inside the vehicle workstation.

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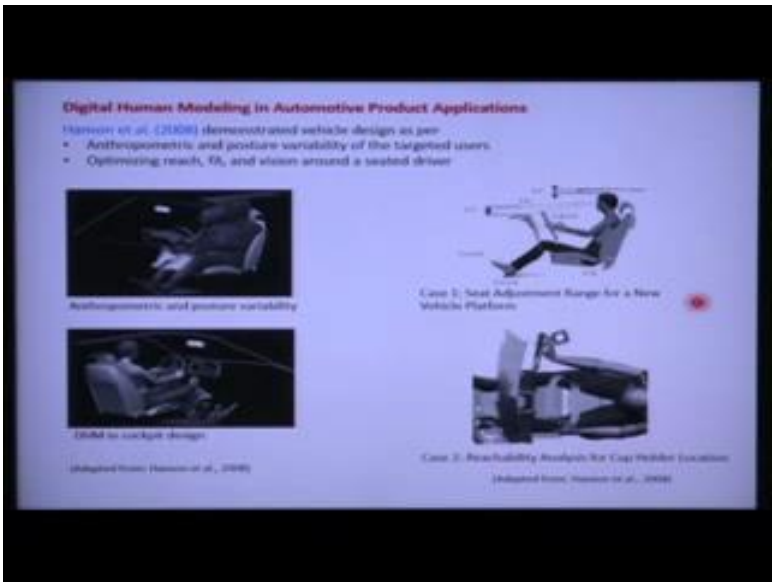

Hanson et al 2008, in the research paper, digital human modeling in automotive product analysis they demonstrated, how digital human modeling software can be used for automotive product analysis. So, anthropometric postural variability of the targeted user they considered. So, anthropometric as well as the posture of various percentile driver they considered, but they did not create like; 5th 58 98 percentile driver they actually based on statistical analysis, they multi various statistical analysis, they created this digital human models and those human models.

They use the digital human model in the cockpit design of that vehicle, for various aspects between these analyses. These analyses they have used. After in the paper they also demonstrated two case study; one case study for seat adjustment range, for new vehicle platform, and in another case study, reachability analysis for cup (Refer Time: 55:52) allocation. So, in this paper also it was clearly demonstrated that the digital human modeling is very effective tool for, automotive design process, particularly vehicle design and occupant packaging.

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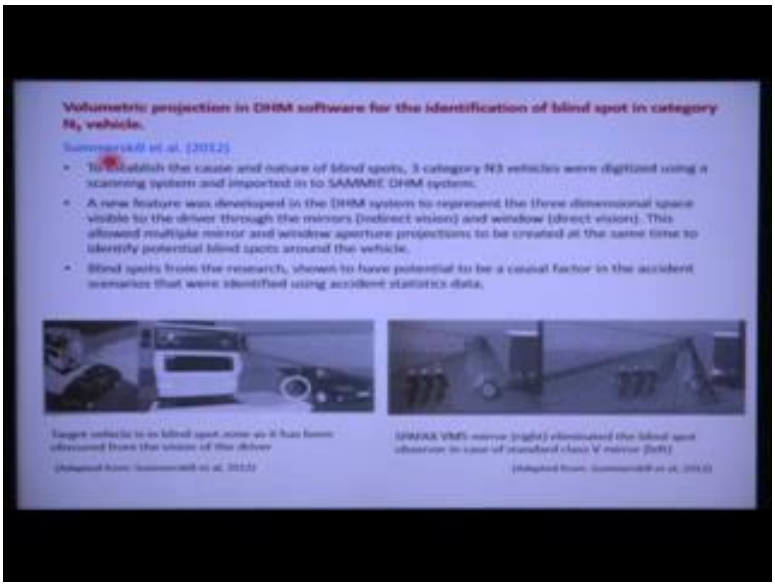

Summer skill et al 2012, in their research paper they demonstrated that, how this digital human modeling can be used for volumetric projection of digital human modeling software, for identification of blind spot in category n three vehicle. So, they demonstrated that volumetric projection in digital human modeling software. So, for blind spot analysis to establish the cause, and nature of blind spot, three category n three vehicle were digitised using scanning system and imported in S A M M I E cad system. So, three types of n 3 vehicle, they scanned, and those cad model were imported to S A M M I E D H M system and then different types of analysis was performed. In the analysis they used a new feature was developed in this digital human modeling system, to represent the three dimensional space visible to the driver through the mirror. So, while driver is looking through the mirror direct that is the indirect visibility.

At the same time while driver is looking through the windshield, or cut out portion of the door, that is a direct visibility. So, while they are looking through the window, or windshield, or through the indirect vision, though mirror then which area is actually visible to the driver? So, for that purpose they created volumetric projection from the mirror, volume will be projected and the projected area is actually indicating that, those areas is actually visible to the driver.

So, while driver is on the driving seat and looking at the various mirrors, placed in this particular case there are total five mirrors, through that five mirrors which area is

actually visible and which area not visible. The area which is actually not visible that is called blind spot. So, in this case in n three vehicles while that vision analysis was done by creating that volumetric projection, it was observed that in this particular image, it is visible that this vehicle which is passing beside these truck that is actually not, that is actually coming to the blind spot zone, means this is not visible to the driver.

These volumetric zones are for one mirror, this is volumetric zone for another mirror, but none of the volumetric zone of the mirror is actually covering these vehicles. So, as this vehicle is in the blind spot. So, this vehicle will not be visible to the driver. Similarly, if you look at this particular image, these three cycle riders are going and none, there is actually in the blind spot zone. None of the volumetric field of those mirrors is actually covering them. So, they are in the blind spot zone, but after that, after following this analysis they changed the mirror type and they placed a different mirror called SPFASGM five mirror.

While they position the particular mirror then they eliminated that blind spot zone. So, after that when they change the normal mirror type, normal v five mirror class normal classes five mirrors while it is replaced by S P F X G M five mirror then that blind spot zone actually eliminated.

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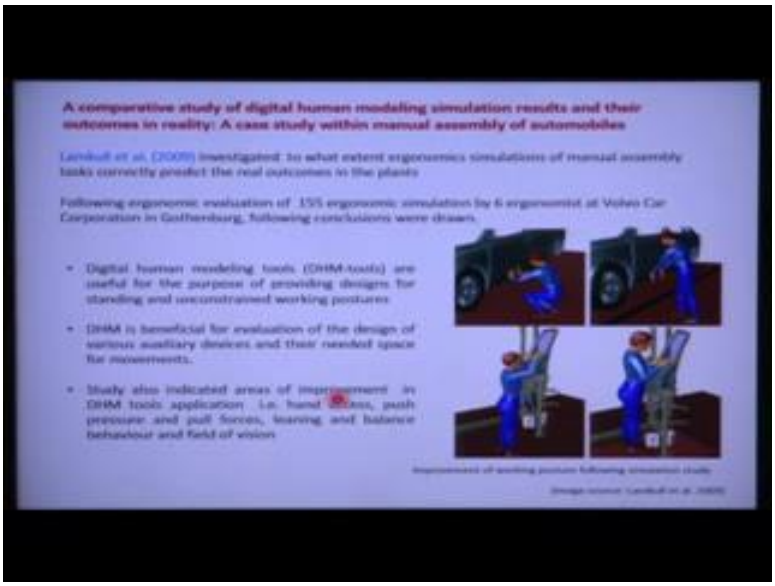

So, from these analyses they clearly demonstrated that using this type of mirror actually that blind spot zone can be eliminated. This observation was very important because due

to this type of exist, means existence of this type of blind spot zone around the vehicle is actually may lead to different types of accident. So, blind spot, from the research shown to have potential to be casual factor in accident scenario, that are identified using accident statistic data. So, from this study, summer skill at el, they clearly demonstrated the digital human modeling software is very effective, using this type of volumetric projection mirror projection zone, and identifying blind spot area, and how the blind spot area can be eliminated by the design intervention, by using different types of mirrors. So, so far what we discussed in the earlier slides all these are related to vehicle occupant packaging, visibility reach, inside and outside the vehicle.

Now, we are going to discuss about application of digital human modeling software in automobile digital manufacturing software. So, while digital manufacturing software is used by different researchers, for assembly process in manufacturing workstation, then how digital modeling software actually help designers or engineers. So, Lampual et al 2009, in their research paper a comparative study of digital human modeling simulation, results in the research paper, entitle a comparative study of digital human modeling simulation results and their outcomes in reality. So, what results they are getting from the human modeling simulation and it was compared with the result with reality. So, a case study within manual assembly process of automobiles. So, they investigated to what extent ergonomic simulation of manual assembly tasks correctly predicts the real outcomes in the plants.

Following ergonomic evaluation of 155 ergonomic simulations by 6 ergonomist at Volvo Car Corporation in Gothenburg, following conclusions were drawn. So, digital human modeling tools d h m tools are useful, for the purpose of providing designs for standing and unconstrained working posture. Digital human modeling is beneficial for evaluation of design of various auxiliary devices and their and their needed space for movement. So, while those auxiliary tools or equipments are being used how much space is actually required that can also be defined using digital human modeling study. Study also indicated areas of improvement in the digital human modeling tools application that is; hand access, push pressure, pull forces, leaning and balance behaviour, and field of vision. So, in this area they identified further improvement is possible in the digital human modeling software.

So, overall from the paper it was clearly identified that digital human modeling software is can be effectively used for this type of manual assembly process and providing better workstation condition. So, that human modeling can do their activities avoiding awkward posture. So, if you sit (Refer Time: 64:47) and that person need to sit, with the awkward posture and then do the assembly role, but now the vehicle model have been shifted up, then that person can do his work by maintaining this type of relatively better posture. Similarly, for shorter assembly worker, earlier they had to work by raising their hand.

Now, after design modification, now that person can do their activity below the shoulder level. So, problems can be identified in virtual environment, using digital human modeling software and as per that evaluation design modifications can be proposed and proposed modification can even be evaluated with digital human modeling software. Now, if these solutions are implemented in real scenario then; obviously, that manufacturing industry will be benefited.

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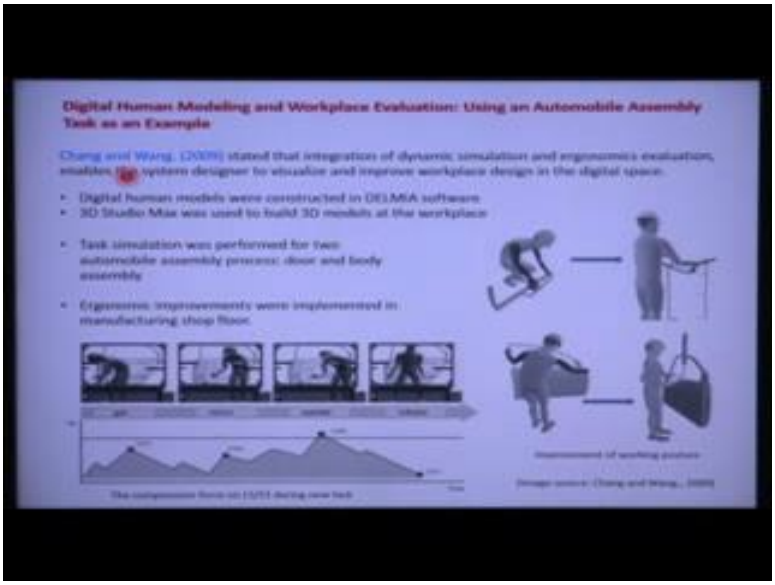

In the research paper Chang and Huang 2009 that research paper is digital human modeling and workspace evaluation using an automobile assembly task as an example. So, how actually they demonstrated how the digital human modeling software can be used in the automotive assembly process. So, for that purpose they used jack sorry delmia digital human models and 3 d studio max was used for creating the 3 d models of

the workplace. So, 3 d models of the workplace was created in 3 d studio max and then it was imported to delmia software for virtual ergonomic evaluation.

So, they stated that, integration of dynamic simulation and ergonomic evaluation enables the system designer to visualize and improve workspace design in the digital space. So, task simulation was performed for two automotive assembly processes; one is door assembly, and another is body assembly. So, two assembly process; they demonstrated in that paper and in those assembly process how digital human modeling can be used. So, ergonomic improvements are implemented in manufacturing soft floor

Following that analysis in real life they implemented those improvements. So, earlier in that manufacturing software workers use to work like this type of awkward bending posture, but then they modified their workstation in such way. So, that person can do their activity in this type of standing posture. Similarly, in earlier case they had to carry the door like this type of bending posture. Now, the door actually is carried with the hanger. Now, the person can stand comfortably in standing posture and do their assembly work.

So, just one intervention, by using a hanger, it actually changes the posture of the human. So, before that design modification how was the condition they evaluated using digital human modeling software they analyse the spinal load and after modification also they evaluated that, how the spinal load cab be reviewed by design modification of this work station.

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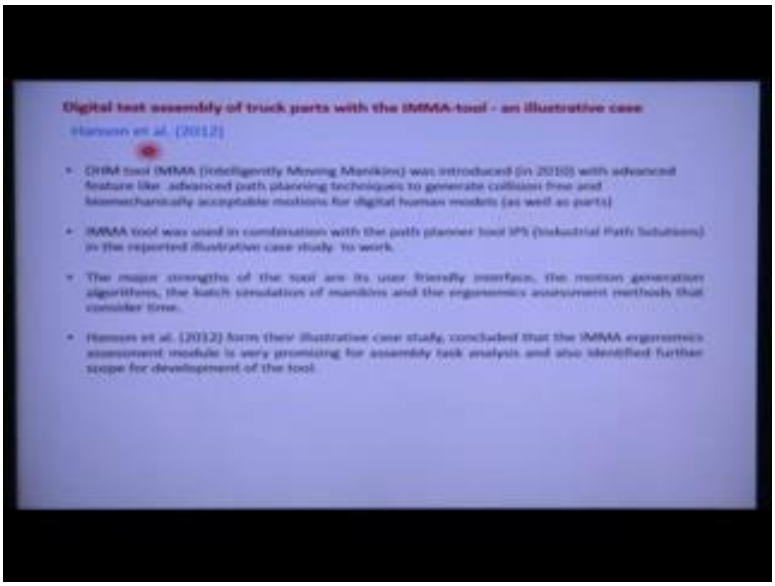

Hanson et al 2012, in their paper digital test assembly of truck parts with I M M A tool and elastative case. So, in that paper D H M tools call I M M A mean; intelligence moving manikins was introduced in two thousand ten they mentioned that it is particular human modeling software was introduced in 2010, with advanced feature like; advanced power, planning techniques, to generate position free, and biomechanically acceptable motion, of digital human models as well as parts. This I M M A tool was used in combination with path planner that is I P S industrial path solution in the reported elastic case study. So, the case study who is the reported they not only used I M M A tool, but they also used I P S tool.

The major strength of this I m a tool are the user friendly interface, the motion generation algorithm, the best simulation of manikin, and ergonomic assessment method, that consider time. Hanson et al from their illustrative case study, concluded that this I M M A ergonomic evaluation that digital human modeling tool, actually helps in ergonomic assessment of these I M M A means ergonomic assessment module is very promising for accessing task analysis and also identifying further scope for development of the tool.

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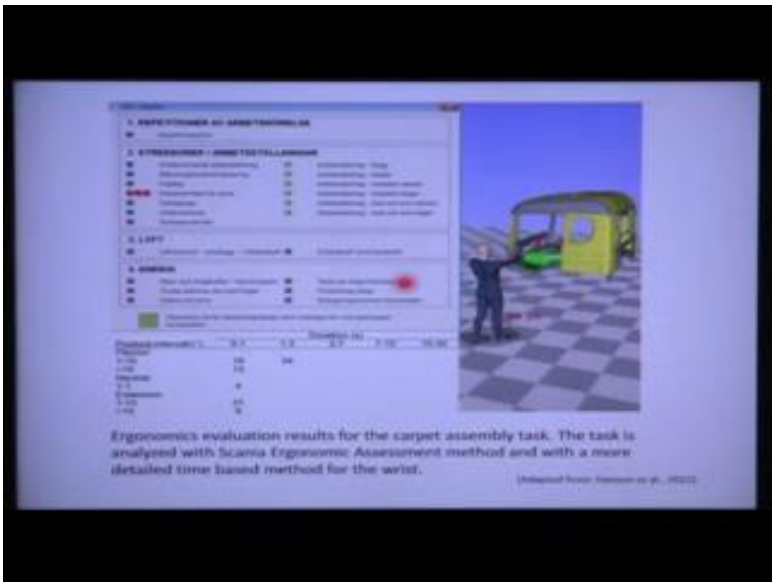

So, in the task assembly, they use this I M M A tool, and demonstrated how that can be used, at the same time where the scope for improvement for this particular tool are. So, this is that using that I M M A tool, where actually demonstrating here that ergonomic evaluation of carpet assembly task. In this vehicle they are actually putting that carpet on the floor and in that assembly activity, or task simulation they evaluated the posture and different types of lifting, then various types of ergonomic stresses repeatability, all these variables they studied. Ergonomic evaluation results from the carpet assembly tasks. The task is analysed with scania ergonomic assessment method and with more detail time based method for the wrist.

So, from this carpet assembly task they demonstrated that, this new digital human modeling tool, which they introduced in 2010, this I M M A can be is very promising for assembly task analysis. So, we discussed few of the research paper, where in automotive industry various researchers, or engineers are used various types of digital human modeling software in combination with motion capture system, or force reaction system. So, different types of other system, they have used digital human modeling software, for various types of occupant packaging as well as for digital manufacturing in automotive assembly task.

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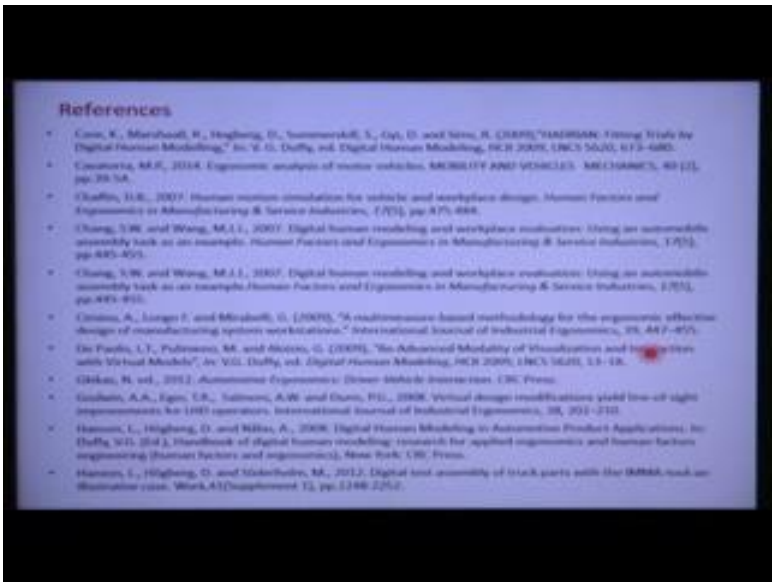

So, these are only few papers which have been discussed here, but there are many more papers. So, I suggest all the students who are going through this course they should go through. They should explore more research paper, should go through this paper to understand details about how these digital human modeling software are been used by various researchers in automotive industries because, the automotive industries the one the largest industry which is adopting digital human modeling of the motion. So these are the references.