Ergonomics in Automotive Design
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Module – 09
Lecture - 11
Virtual Ergonomics evaluation technique and its application in automotive design

Welcome to the course Ergonomics in Automotive Design. Now we are going to discuss our 9th module, i.e. Virtual Ergonomics evaluation technique and its application in automotive design.

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Under this module, we will cover three topics, fundamentals of digital human modelling, secondly, the part 1 which will deal with accommodation, clearance/ interference posture, comfort discomfort and reach evaluation for the drivers in various vehicles and the thirdly, the part 2, which will be dealing with vision and ingress-egress evaluation.

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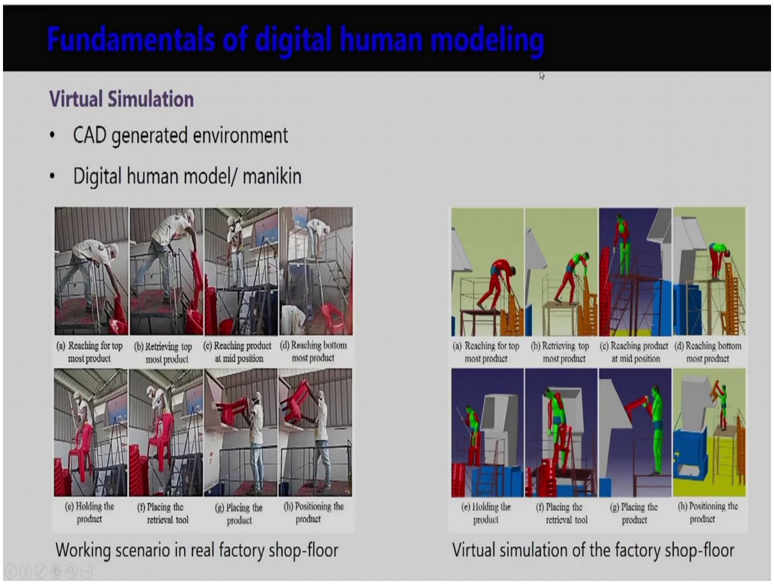

Now, first, before going to discuss digital human model, what is digital human model or what is digital human modeling process. Prior to that we should know what virtual simulation is? So, virtual simulation is the CAD generated environment or computer graphics environment, where different types of evaluation, different types of representation of human activities can be done. Now, digital human model and manikin are also CAD generated model which we use for the purpose of ergonomic evaluation of product and workstation.

We will discuss them in details in subsequent slides. Now, if you look at left side panel, it is a working scenario in real factory shop floor in an industry. So, how workers are working or how defined human are involved in different types of activities and what type of problem they are facing in terms of physical and biomechanical load and in terms of visibility in terms of their task performance. So, those aspects we can simulate in digital human modeling software.

If you look at the right-side panel, the real activity has been simulated in virtual environment with digital human models. So, you can see that person is picking up the chairs, the same thing we can simulate in CAD software. So, these type of softwares are called digital human modeling software.

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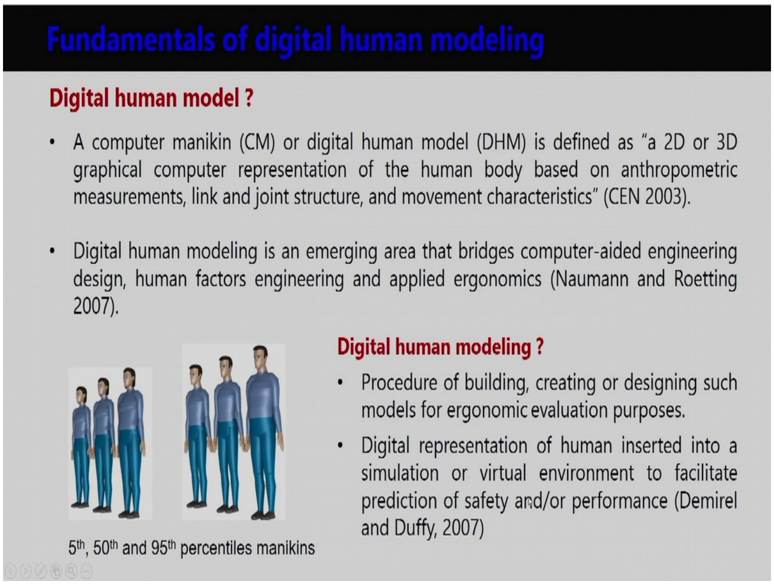

Now, what is digital human modeling software, and what is the digital human model? First, the digital human model is a computer-aided manikin or digital model which is defined as the two dimensional or three-dimensional computer graphics representation of human body; based on anthropometric and biomedical data measurements link and joint structure movement characteristics as defined by CEN 2003.

In general, we can mention the digital human model as the computer graphics representation of human body or body parts, to evaluate various ergonomic aspects of the product or workstation. For developing this type of human model, we incorporate anthropometric and biomechanical data. Now, digital human modeling is the procedure of building, creating or designing such models for ergonomic evaluation process. Digital representation of human inserted into simulation or virtual environment to facilitate prediction of safety and/ or performance as defined by Demirel and Duffy (2007).

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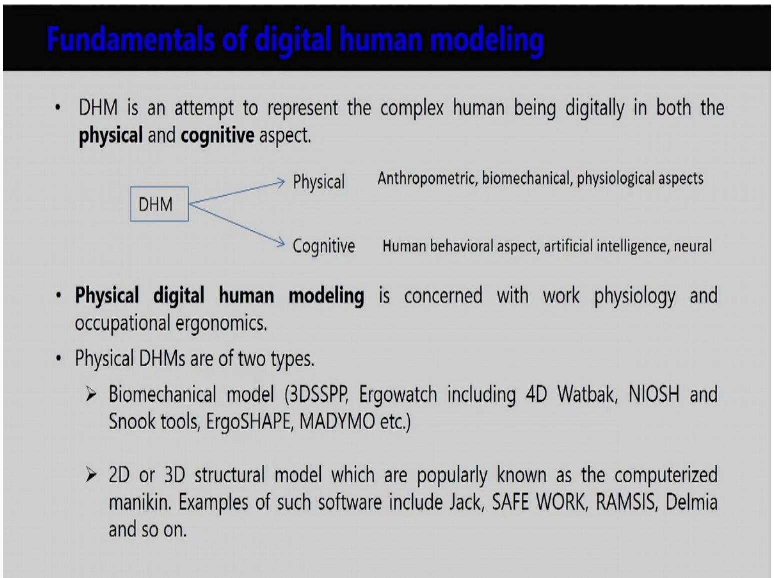

Digital human model (DHM) is an attempt to represent the complex human activity in both physical and cognitive aspect in the digital environment. DHM can be broadly categorized into two; physical digital human model and cognitive digital human model. The physical digital human model deals with anthropometric, biomechanical, physiological aspects, whereas, cognitive digital human model deals with human behavioural aspect, artificial intelligence, neural networking etc.

Out of these two types of digital human model, in the present module, we will mainly concentrate on the physical digital human model because the cognitive digital human model is still in notion state or development phase. Much development is going on it and therefore, in the current module, we will only concentrate our discussion on physical DHM. Now, physical digital human model is of two types; biomechanical model, two dimensional or three-dimensional structural model.

Under the biomechanical model, different body parts and its biomechanical aspects related to mass, motion, joint kinematics are used. So, for that purpose, we can develop hand model, leg model or spinal model whereas, under two dimensional or three-dimensional structure model, there is the human representation of human body form. For developing these models, we use softwares like Jack, Sammie, RAMSIS, Delmia and other softwares available commercially. Also, for biomechanical model, some example of the softwares are 3DSSPP, 4D Watbak, NIOSH and Snook tools, ErgoSHAPEe MADYMO.

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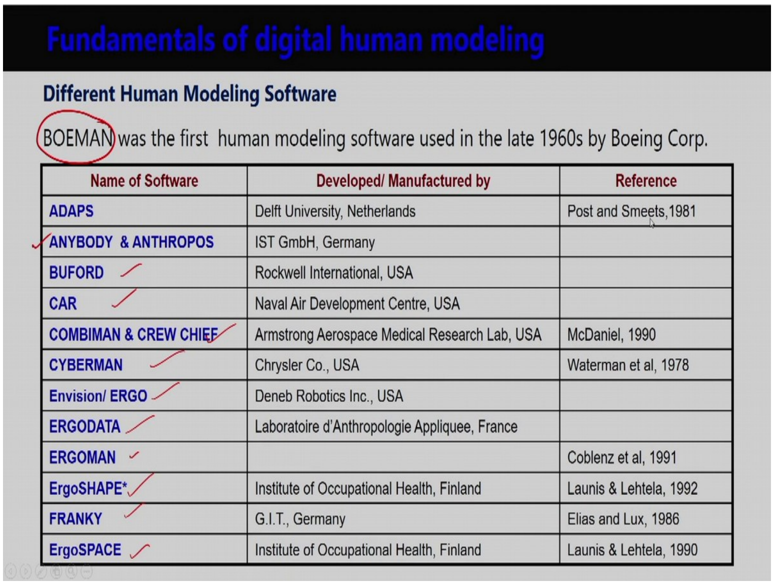

Name of Software	Developed/ Manufactured by	Reference
ADAPS	Delft University, Netherlands	Post and Smeets,1981
ANYBODY & ANTHROPOS	IST GmbH, Germany	
BUFORD	Rockwell International, USA	
CAR	Naval Air Development Centre, USA	
COMBIMAN & CREW CHIEF	Armstrong Aerospace Medical Research Lab, USA	McDaniel, 1990
CYBERMAN	Chrysler Co., USA	Waterman et al, 1978
Envision/ ERGO	Deneb Robotics Inc., USA	
ERGODATA	Laboratoire d'Anthropologie Appliquee, France	
ERGOMAN		Coblenz et al, 1991
ErgoSHAPE*	Institute of Occupational Health, Finland	Launis & Lehtela, 1992
FRANKY	G.I.T., Germany	Elias and Lux, 1986
ErgoSPACE	Institute of Occupational Health, Finland	Launis & Lehtela, 1990

The first digital human model was introduced long back in the 1960s. Its name was BOEMAN. Subsequently, so many softwares evolved and came in the market. Even many of them also abolished with time. Presently, here are the few examples of softwares that are available commercially: Adaps, Anybody, Anthropos, Buford car Combiman, Crew chief, Cyberman, Envision ERGO, Ergodata, Ergoman, ErgoSHAPE, Franky, ErgoSPACE.

These digital human model softwares are developed or manufactured by the different organization as it is listed in the table (list of developer or manufacturer). At the same time many of these softwares have been used for ergonomic evaluation of product and workstation which have been reported by various researchers that references are also available in the last column.

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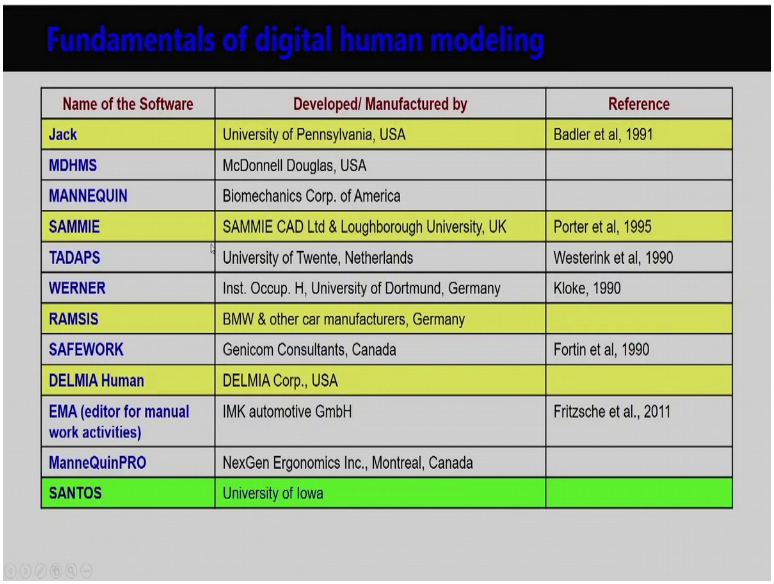
Fundamentals of digital human modeling

Name of the Software	Developed/ Manufactured by	Reference
Jack	University of Pennsylvania, USA	Badler et al, 1991
MDHMS	McDonnell Douglas, USA	
MANNEQUIN	Biomechanics Corp. of America	
SAMMIE	SAMMIE CAD Ltd & Loughborough University, UK	Porter et al, 1995
TADAPS	University of Twente, Netherlands	Westerink et al, 1990
WERNER	Inst. Occup. H, University of Dortmund, Germany	Kloke, 1990
RAMSIS	BMW & other car manufacturers, Germany	
SAFEWORK	Genicom Consultants, Canada	Fortin et al, 1990
DELMIA Human	DELMIA Corp., USA	
EMA (editor for manual work activities)	IMK automotive GmbH	Fritzsche et al., 2011
ManneQuinPRO	NexGen Ergonomics Inc., Montreal, Canada	
SANTOS	University of Iowa	

Similarly, few other sets of software you can see in this particular slide. These are other softwares and there developer popularly used in the industries and some references related to these softwares are available in column 3.

Out of these softwares, those highlighted with yellow colour like Jack, SAMMIE RAMSIS DELMIA are popularly used all over the world. Recently, SANTOS software is developed by University of Iowa under their virtual soldier research program. This software is very good and also being marketed as one of the best software with many advanced features.

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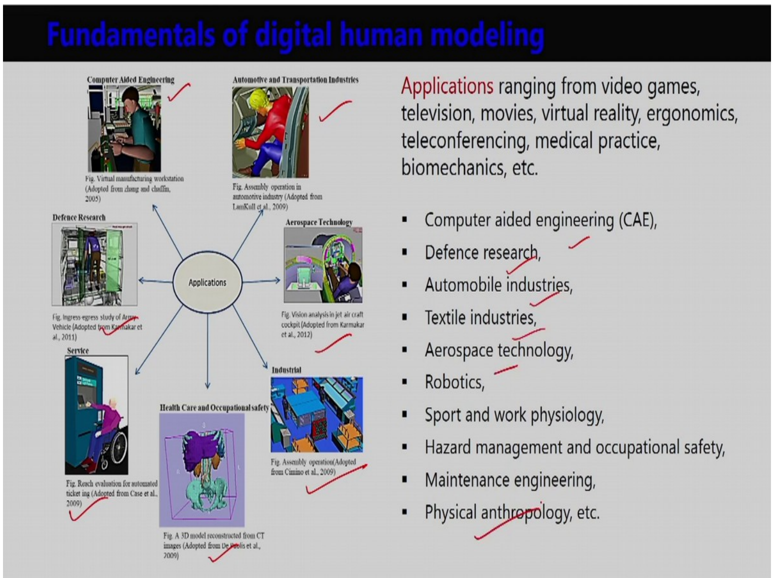

Moving to the application of digital human modeling software, their applications are in almost every fields wherever human being is involved. It is related to computer-aided engineering, its application is in automotive or any other industries in aerospace engineering, industrial sectors, then healthcare, occupational safety, then service industries, then defense research.

So, in this way, for any aspects of life where human beings are involved, we can simulate the human activity using digital human modeling software. Thus application ranging from video games, television, movies, virtual reality, ergonomics, teleconferencing, medicine practice, biomechanics and so on. So, we have a few list of application areas as we mentioned earlier also, computer graphics engineering, defense research, automotive sector, industrial textile sector, automotive technology and so on.

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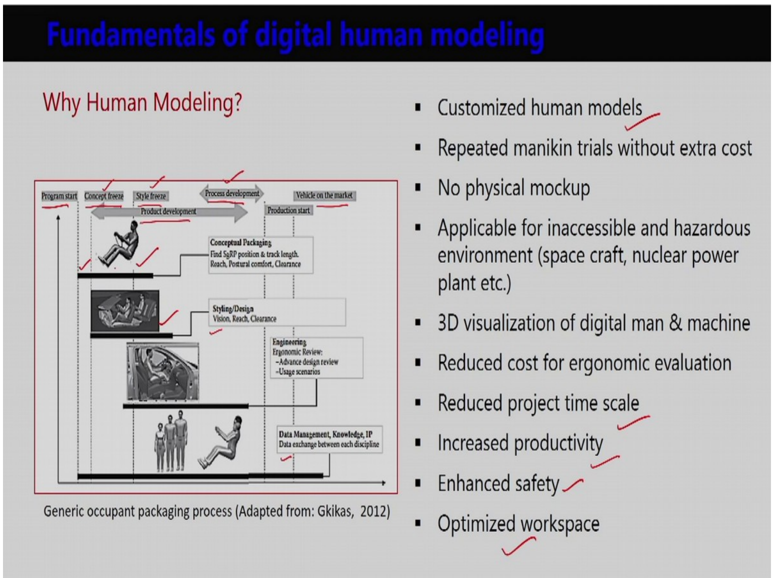

Why digital human modelling? Why this topic is important and why digital human modeling is also important for ergonomic evaluation? First, looking at this image taken from Gkikas (2012), the concept of the first program starting here, then concept freeze, style freeze, process development and lastly the vehicle in the market. These three, the concept freeze, style freeze, and the process development are coming under product development phase.

Under the product development, firstly, we will discuss on occupant packaging. How the driver will be positioned inside the vehicle in relation to other controls? For that purpose, sitting reference point, seat travel length, reach postural comfort clearance aspects are considered at the first phase during concept phasing.

Thereafter, while thinking of the style freezing or finalizing the style, we need to consider the vision, reach, and clearance. Then, various engineering consideration in the next phase, i.e. ergonomic review related to advanced design review, use a scenario by different types of users, the starting from driver, passenger or other maintenance operators. Also, finally, data management, the last phase the data management where we are discussing the knowledge, IP data, exchange between various disciplines.

So, in this way, in the automotive sector, the digital human modeling is actually being introduced, i.e., the starting from the conceptual phase (we can mention this as the pre-conceptual phase). From the very beginning of the design development process, we need to consider proactively that how human can be incorporated in the design process? And, why this digital human modeling is important?

First, we can generate a customized human model using digital human modeling software. What does it mean by customized digital human model? We can develop digital human modeling software as per our requirement; it may be as per the age variation, children model, adult model or aged model; at the same time we can go for six variations, male model female model. Similarly, we can create variation in terms of somatotypes ectomorph, endomorph, mesomorph. We can also create human models based on percentile data; 5th percentile human model, 50th percentile human model 95th percentile human model or the human model for a particular individual as per his body dimensions.

There are different options for creating the human models according to the user requirement and targeted population. We can use those human models for virtual ergonomic evaluation of the facility or the workstation. Also, we can go for repeated trial and modification in the virtual environment with the digital manikin or human model. There only the initial setup cost, however, when the initial setup of the computer hardware and graphics are established, then there is no extra cost.

So, we can go for n number of design modification and repeated trials with the manikin. Whenever any problem or any design flaws is found, we can go for design modification with no extra cost. Also, there is no requirement of physical mock-up and the whole evaluation is possible in the virtual environment in the CAD software. The digital human model is also applicable in a hazardous environment for evaluation of hazardous environment, then inaccessible environment, for example, if we just talked about inaccessible environment, like spacecraft.

While developing a spacecraft, it is not possible to evaluate it before making the actual prototype of the spacecraft. On the other hand, it is also not possible to evaluate the spacecraft workstation in the space or we cannot send that real human being. In other scenarios, where there is hazardous working environment like nuclear power plant, chemical workstation, real human trail is very difficult, and unsafe. Therefore, it is better to go for virtual ergonomic evaluation using digital human model. Then 3D visualization of digital man machine interface, we can see and rotate the models from various angles and visualize if there is any clearance interference related issues.

Then there are so, many other benefits like deducing projects time scale increased productivity, enhance safety optimized workspace. So, there are many benefits to achieve from the application of digital human modeling.

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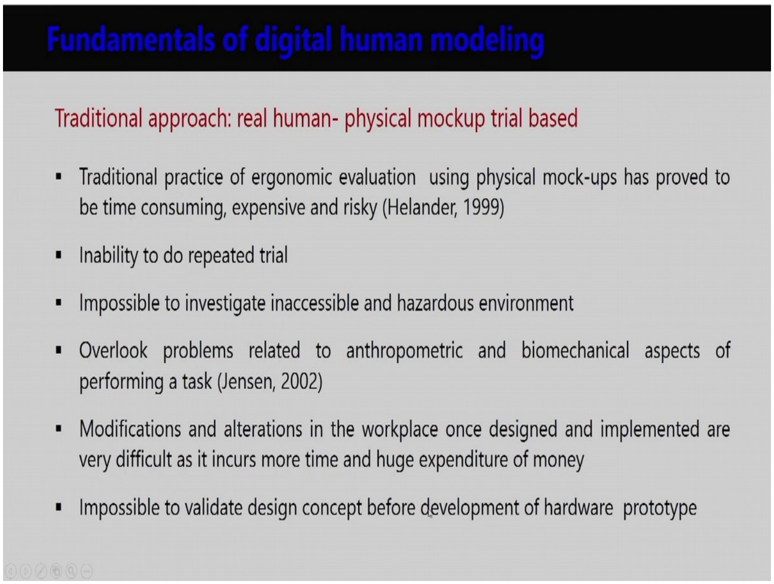

Now, we are going to discuss the traditional approach that is the real human physical mock-up based trial versus the digital human modeling based approach. So, first, we are going to discuss the traditional approach, what essential points there are, and how it is different from the digital human modeling based approach.

The traditional practice of ergonomics evaluation using physical mock-up has proved to be time-consuming, expensive and risky as reported by Helander (1999), then inability to repeated trial. In traditional approach, where real human, real physical mock-up trial is going on that time repeated trial and modification is difficult because you cannot ask the participant to come many times, it is difficult to identify the targeted user population as per percentile anthropometric data, then, impossible to investigate in inaccessible and hazardous environment that is unsafe, then real human trial also overlook the problems related to anthropometric and biomechanical aspect of the during performing a task in many times.

So, in this type of study, there is also overlook of problems related to the anthropometric and biomechanical aspect of performing a particular task. The modification and alterations in the workplace once designed and implemented are very difficult, as it incurs more time and expenditure of money. So, once the design is finalized, then it is very difficult for redesign and modification because for that purpose, the raw material is required, manpower is required and at the same time, time is required.

This is the reason why real physical trial in mock-up or prototype, i.e. costly and time-consuming. This type of evolution also impossible to validate design concept before development the actual hardware prototype this is only possible after developing. So, this is in reactive in nature, but digital human model allows in proactive ergonomic evaluation. Now, we will discuss about digital human modeling based approach.

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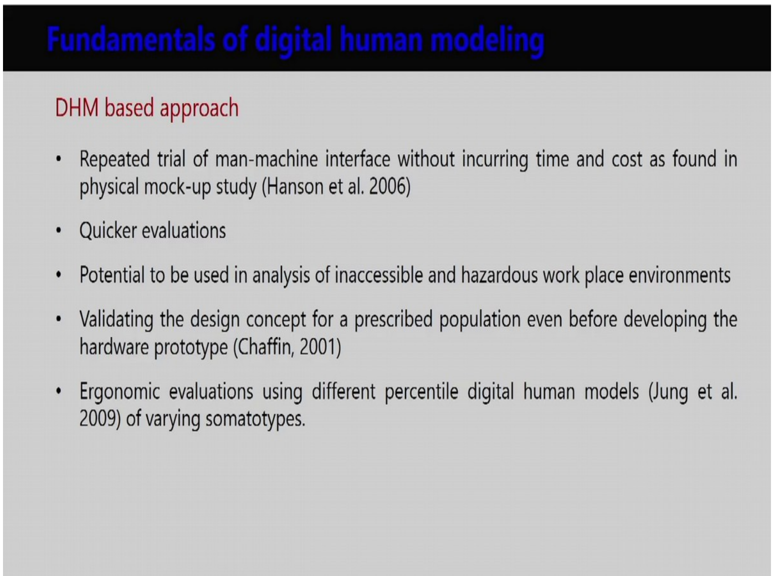

In digital human modeling-based approach, we can go for a repeated trial of man-machine interface without incurring time and cost has found in physical mock-up study as stated by Hanson et al. (2006). Quicker evaluation of the workplace or the facility or the product is possible. DHM could be used in analysis of inaccessible and hazardous environment as we have already discussed. Also, validating the design concept for a prescribed population even before developing the actual hardware prototype is possible.

The proactive nature of ergonomic evaluation could be achieved using digital human modeling software, even before developing the actual physical mock-up or prototype.

Ergonomic evaluation using different percentile digital human model of varying somatotypes is also allowed by digital human modeling.

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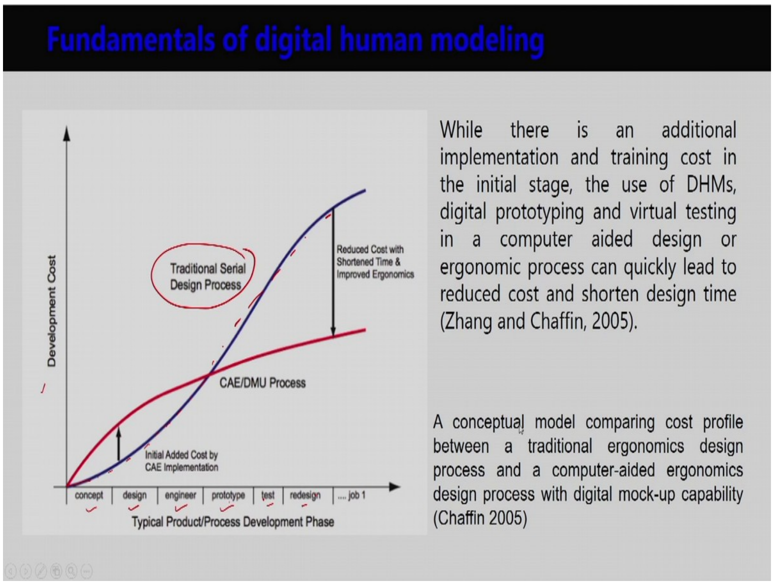

In continuation of the importance of digital human modelling, if we look at this particular graph where on x-axis it is represented concept, design, engineering, prototyping, test, redesign. These are the various a typical product and process development phase. On the other hand, on y-axis it is shown development cost that how much cost is involved for that particular developmental phase? Now if we look at the blue graph, i.e. the initial blue graph which is related to traditional or serial design process using real human trial, real physical mock-up or real prototype in that case what is happening in the first phase concept design, the cost involved is low, but later on the cost is gradually increasing.

On the other hand whenever we are going for the computer-aided engineering, digital mock-up unit or we are going for digital human modeling trial then what is happening? At the beginning stage is like concept, design, engineering in the spaces the initial cost is high, but later on cost is subsequently low in later phases mean prototype testing redesign, then the developmental cost which is involved in these phases those are very less.

So, comparing this blue curve and the red curve we can understand during the initial phases, the cost for digital human modeling based approach is higher than the traditional approach where more cost is involved in case of digital human modeling because we have to develop the infrastructure for high-end computers, then we have purchased the CAD software we have to install training is required, but once the setup is ready and concept development design is starting, then we can go for a digital prototype mock-up development, then we can go for testing, we can go for redesign for that purpose no extra cost is involved.

But in the traditional process, the initial cost is less in comparison to the digital human modeling or computer-aided engineering based approach, but later in the prototyping and redesign phases, the cost is very high in comparison. Because for redesign and modification, material cost, and manpower is involved. Thus, although there is initial higher cost added by the computer-aided engineering implementation, the final reduction of cost.

For DHM approach, the initial cost is relatively high, but the final cost reduction is very much. This is the reason of using of digital human modeling or computer-aided engineering is very much beneficial in comparison to the traditional approach of serial design process involving real human and physical mock-up or physical prototype. While there is an additional implementation and training cost in the initial phase, the use of digital human models, digital prototyping and virtual testing in a computer aided design or ergonomic process can quickly lead to reduced cost and shortened design time as reported by Zhang and Chaffin (2005).

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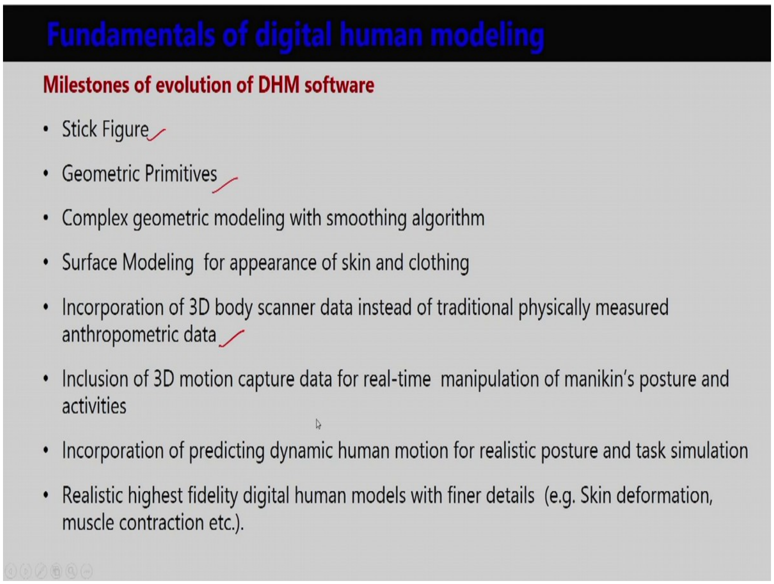

Now, if we look at the evolution of digital human modeling software, it has gradually evolved over the years. So, initially digital human models are stick figure, geometric primitive (robot-like appearance). There were primitive geometric shapes like sphere, cuboid, a cylinder. Afterwards, complex geometric modeling with smoothing algorithm came and digital human modelling and its feature were improved (human model with a surface geometry).

Gradually, there was incorporation of 3D body scanning data in place of the traditional physical measured anthropometric data. Then, inclusion of motion capture data for real-time manipulation of manikins posture and activities. So, with the advancement of technology, digital human modeling software, and its developments also moved forward. Incorporation of predictive dynamic human motion for realistic posture task simulation gradually came. Finally, realistic highest fidelity digital human models with finer details also came in the market like skin deformation, muscle contraction, physiological aspects like respiratory rate, energy expenditure those things gradually came in the digital human modeling software.

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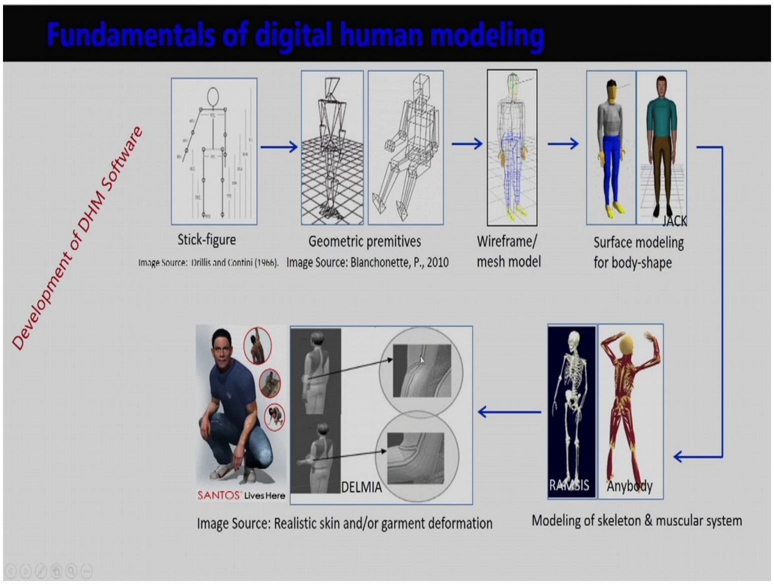

If we look at this particular slide, we can see that how gradually digital human modeling software evolved. It started from the stick figure like appearance gradually to move to geometric primitives like overt like appearance, then wireframe like model, shaded model with surface modeling with smoothing algorithm we can see this type of dressed model.

Another advancement is about muscle, ligaments, and skeleton structure. Now, most has debunked digital human model with a feature like cloth wrinkles, body part deformation, skin deformation, movements of body parts. These types of real human-like simulation is possible with the SANTOS or DELMIA software.

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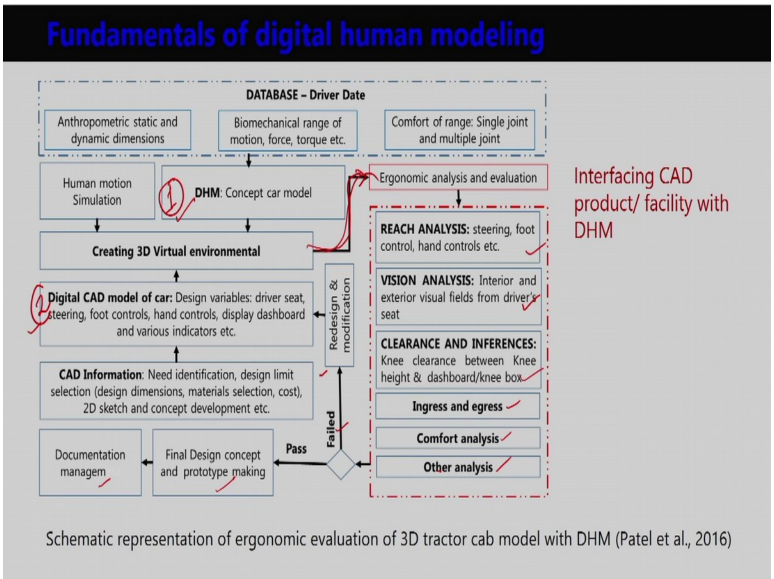

After discussing the evolution of the digital human model, you should know how these digital human modeling softwares are being used for various types of product and workstation particularly for automotive design or automotive workstations. So, first if we look into how digital human model is being generated?

For that purpose, if we want to develop digital human model for concept car model, we require a database of the drivers. So, we need anthropometric static and dynamic dimensions, and we need biomechanical data related to range of motion force torque. Also, we need comfort range of motion data, single joint or multiple joint comfort databases.

Now, based on this information we can incorporate that information in the digital human model and accordingly we can create our digital human models as per our requirement, that maybe percentile digital human model that may be subject phase to digital human model. Now after making the digital human models ready we are also developing the digital mock-up or digital model of the car.

CAD-related information, need identification, design limit selection, design dimension, material selection, cost to these sketches concept development. So, various information is required before developing the CAD model of the product here particularly the vehicle. Now, those information are used for various design variables, driver seat design steering wheel, foot controls, hand controls, display board, and various indicators.

Based on all these individual parts model, finally, it is assembled and we get the car model of the vehicle model. Now, this is a two these two first one is the digital human model a second is the car model or the vehicle model. These two are brought to the computer graphics environment that is the digital platform where these two things are interfaced for further ergonomic evaluation. Then it is going for ergonomic evaluation that digital human model interfaced with the product or vehicle model.

After interfacing, we can go further different types of ergonomic evaluation like reach analysis, vision analysis, clearance interference analysis, ingress-egress analysis, comfort analysis and various other types of analysis. Following all these analyses in the virtual environment of CAD software, if we find that that the design is proper it is compatible with the human requirement or the user requirement, then we can go for final design concept and prototype making and finally, documentation and management.

But if we find that there are some issues the design modification is required, then again we will go back to the redesign and modification of the car model and in this way even redesign and modification of the car model and then even interfacing with digital human model and again that loop will continue until the ergonomic evaluation is complete and all the ergonomic evaluation criteria or aspect is full satisfied, then only we will move for prototype development and documentation.

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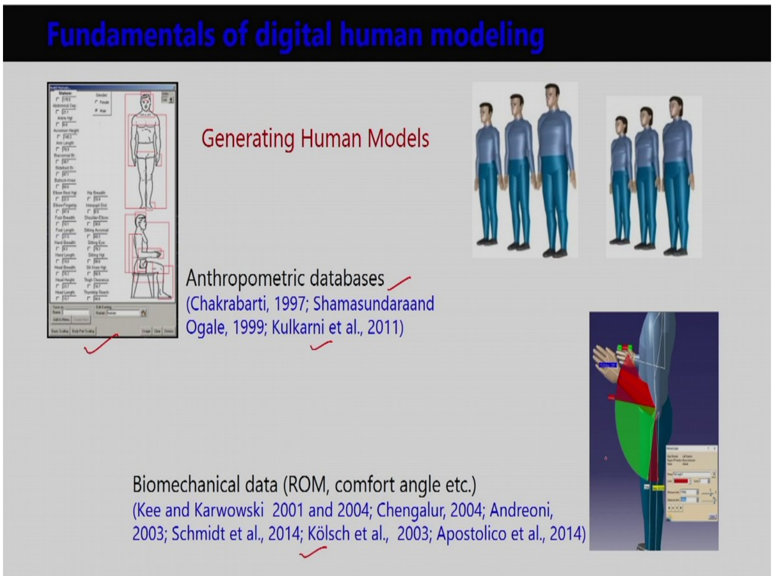

Now, as we discussed earlier that, the first phase is the creation of digital human model or developing of the digital human model for ergonomic evaluation. The second is the development of the product or the workstation. So, first if we are going to develop in digital human modeling how should we proceed? So, most of the digital human modeling softwares, there is this type of spreadsheet-like interface where various body parts are mentioned and how much is the value you have to put there.

So, you can put hand length, leg length, head length, head width the various variables listed there and against each variable you have to put the value from the anthropometric databases. So, all about well there are various anthropometric databases size India size, Japan size, China. So, here few references are given where from we can get the anthropometric databases for a particular population. Based on that database we can generate as per our requirement the digital human models. For example, we can develop the 5th percentile human model 50th percentile or 90th as the representative of smaller body dimension, average body dimension, and larger body dimension.

These aspects actually covering the anthropometric variation of the human models; besides this anthropometric variation, another important aspect is the biomechanical data incorporation. So, how we can incorporate biomechanical data in the digital human model, subsequently, for ergonomic evaluation. For biomechanical data incorporation we need to know the range of motion complete range of motion for each of the body joints, its degree of freedom and comfort range of motion.

Various databases are available related to the range of motion data as well as comfort databases. Based on the context whether this is automotive industry or any other industry or what type of evolution we are going to proceed, accordingly we have to select the comfort database and range of motion database, and we will go for ergonomic evaluation. So, here are some references provided. So, these references you can explore for incorporating a range of motion data as well as comfort range of motion data.

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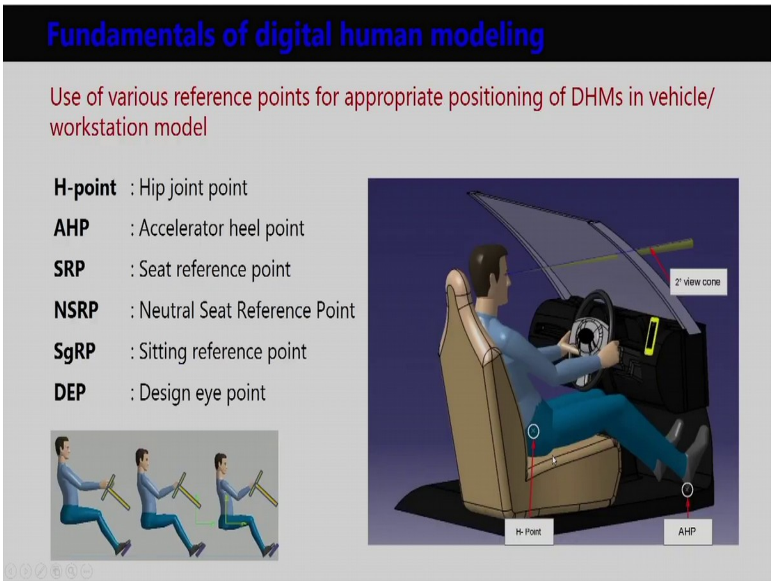

After using these anthropometric and biomechanical database, when you are developing the digital human models of varying percentile as per your requirement, now the question is coming how you will position those digital human models inside the vehicle or any other workstation. So, for that purpose for proper giving appropriate posture and positioning the digital human model inside the vehicle or cab model or any other workstation model we need some reference points.

Earlier in the modules, we have discussed about various reference points which are used in the automotive industry or for vehicle design or occupant packaging. So, major reference points which have been used for automotive industry are H point, hip joint point, accelerator heel point, seat reference point, neutral seat reference point, sitting reference point and one more is the design eyepoint.

Here from the slide, you can see the H point for the driver. We position the digital human model on the vehicle seat or the car seat based on the H point (95th percentile human model). While we give the 95th percentile digital human model in the driving posture and putting their heel on the accelerator heel point, we can adjust the seat as per our requirement. Similarly, while positioning 5th percentile or 95th percentile driver, we can move the seat to accommodate them in that vehicle.

From the image, you can see the H point, and accelerator heel point. These are the two important reference points for positioning the driver model on the vehicle seat.

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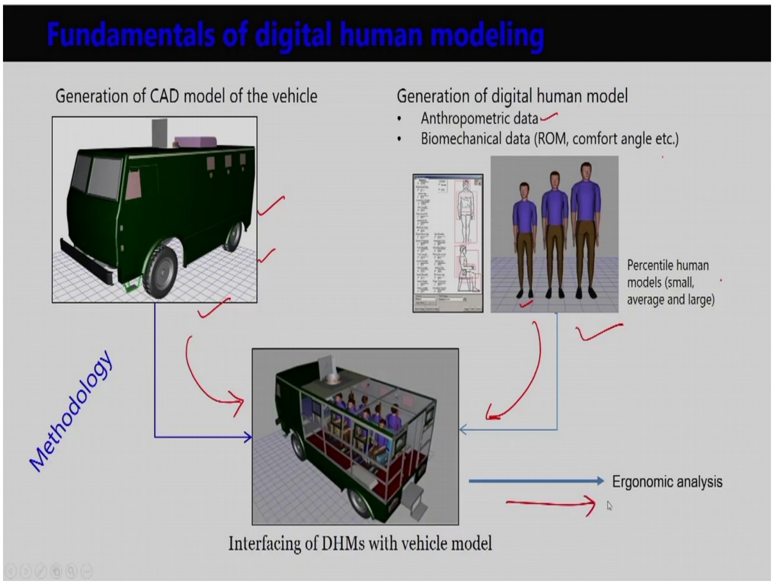

In this slide, we are going to discuss how digital human models and digital mock-up model or digital prototype of the vehicle or the workstation is generated and interfaced. We can generate or develop this type of CAD model of the vehicle or any other workstation in various CAD software may not be digital human modeling software. We can use other softwares like SolidWorks, CATIA, Unigraphics different types of softwares we can software we can use and using the software we can develop the CAD model of the vehicle and we can import those vehicle model or the workstation model in the digital modeling software. On the other hand, many of the digital human modeling software have limited mean to some extent the capability to develop this type of workstation model, but that is very limited. Now digital human being software is also aligned to develop digital human models as per the requirement.

For that purpose, as we have discussed already that we use anthropometric data, biomechanical data and based on those anthropometric and biomechanical data, we develop this type of digital human model which are generally we use 5th percentile, 50th percentile and 95th percentile model which are the representative of smaller body dimension, average body dimension, and larger body dimension. After developing this type of vehicle model and the digital human model, we interface the two.

Appropriate posture is made to follow the reference points and position the human models inside the vehicle model or work station model and then we proceed for different types of ergonomic evaluation.

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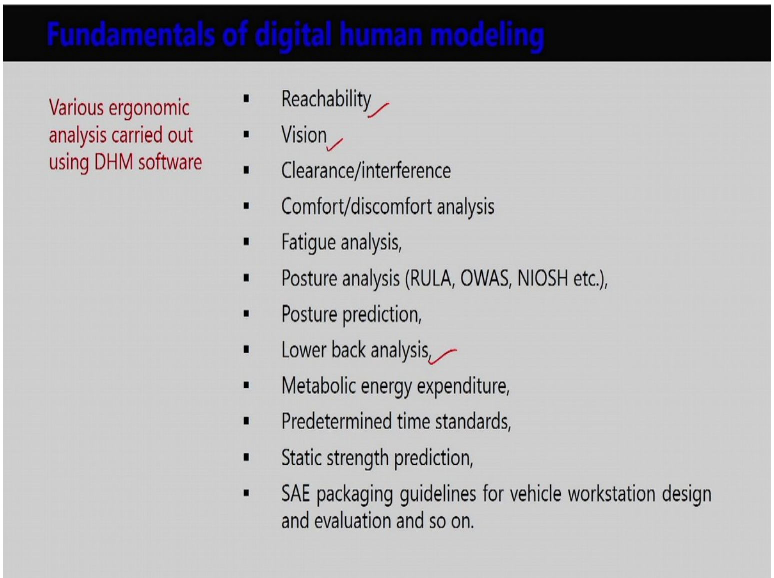

Now, what types of ergonomic evaluation are possible? We can go for reach analysis, vision analysis, clearance dimensions. When the driver or passenger going inside the vehicle, whether there is any clearance or interference we can visualize? We can also study the comfort/ discomfort, and fatigue analysis. There are various types of posture evolution tools like RULA, OWAS, and NIOSH. They can be used for analysis of the posture and posture prediction. If we define the position of the foot pedals position of the steering wheel position of the seat accordingly how will be the driver's posture that also can be predicted.

Lower back analysis or spinal load analysis for L4/ L5 spinal compression force or shearing force can also be done. Metabolic energy expenditure, predefined time standard, static strength prediction can also be calculated. Particularly for automotive industry, the society of automotive engineering packaging guidelines for vehicle workstation design and evaluation is also there.

Now, we are going to discuss few research papers where they have reported about the application of digital human modeling for various types of vehicles workstation design that may be for a passenger car, truck or any other automotive products.

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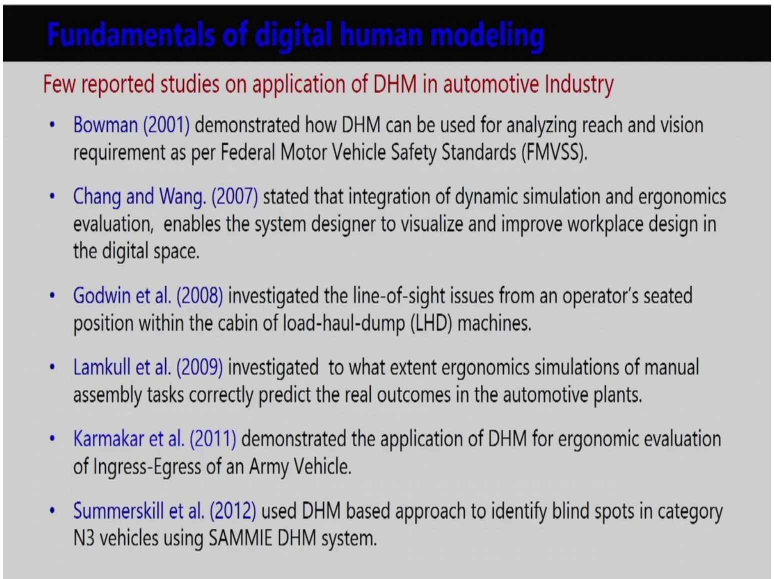

Bowman (2001) demonstrated that digital human model can be used for analyzing the reach and vision requirement as per the federal motor vehicle safety standards. In another paper by Chang and Wang (2007), they stated that the integration of dynamic simulation and ergonomic evaluation enables the system designer to visualize and improve workplace design in the digital space. Godwin et al 2008 they investigated the line of sight issues from the operator seated position within the cabin of LHD machines.

Lamkull et al. (2009) investigated to what extent ergonomic simulation of manual assembly task correctly predict the real outcomes in the automotive plants. When we are using digital human model, how much it is it can predict the real scenario. Karmakar et al. (2011) demonstrated the application of digital human model for ergonomic evaluation of ingress-egress process in an army vehicle. Summerskill et al. (2012) use digital human model-based approach to identify blind spot in category n three vehicles using SAMMIE digital human model system.

There are so, many other researchers all over the world who are using digital human model software in automotive manufacturing aspect, automotive assembly, automotive maintenance.

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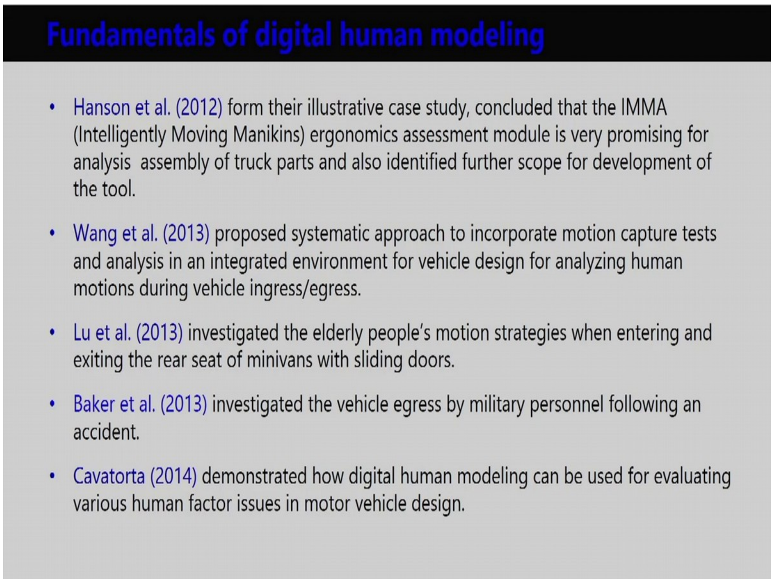

You may explore more research papers and conference proceedings for this purpose. Hanson et al. (2012) from their illustrative case study concluded that IMMA, i.e., intelligently moving manikins, ergonomic assessment module is very promising for analysis of assembly of truck parts and also identified further scope of development of that particular software tool. Wang et al. (2013) proposed systematic approach to incorporate motion capture test and analysis in the integrated environment for vehicle design for analyzing human motions during vehicle ingress-egress process.

Lu et al. (2013) investigated the elderly people's motion strategies when entering and exiting the rear seat of minivans with sliding doors. In 2013, Baker et al. investigated and reported the vehicle increase by military personnel following an accident. When there is accident of the military vehicle it is toppled down that time how the soldiers can army personnel can come out from the vehicle they demonstrated. In 2013, Cavatorta demonstrated how digital human modeling can be used for evaluating various human factor issues in motor vehicle design.

So, in this way, there is numerous research reported by the researchers and designers for successful application of digital human modeling for various stages of vehicle design and development process.

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That is the part 1: Accommodation, clearance interference, posture, comfort, discomfort and reach evaluation in automotive product particularly for the passenger car or other vehicles.

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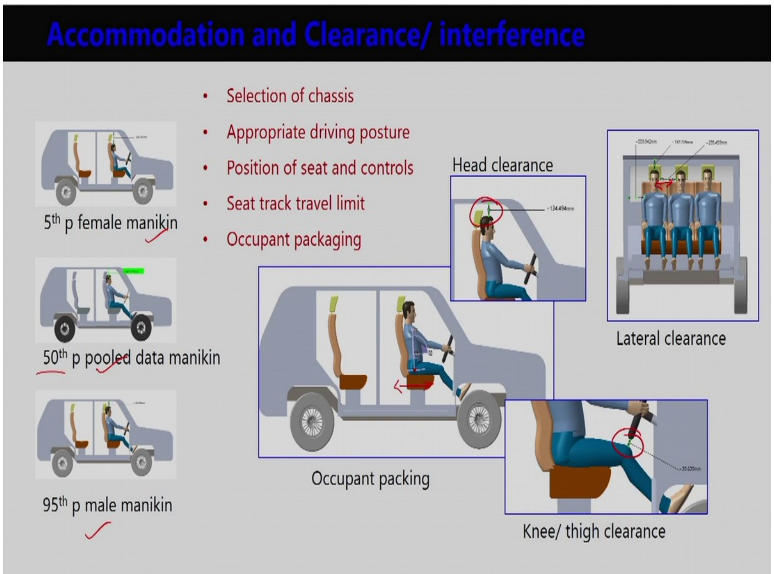

So, how we use digital human modeling software for the evaluation of various types of vehicles? First, we start with the selection of chassis. So, we think about the chassis model in the CAD software, and what will be the size and dimension? Then after the chassis is finalized, we give the appropriate driving posture of the drivers or other passengers and positioning them in that vehicle. For the positioning as we mentioned earlier reference point is very important. So, we have to think about the control position.

After selection of the chassis, we have to look at the position of the various foot controls. Accelerator, brake, clutch and when we are giving the appropriate driving posture to the driver and putting that digital human model on the driver seat, the foot of the driver or heel of the driver will on the accelerator heel point. Also, based on the driving posture, we adjust the seat forward and backward to accommodate the particular percentile driver; larger driver or average driver or smaller driver accordingly seat will move forward and backward to accommodate drivers of different percentile dimension.

After positioning the driver model based on the reference points like accelerator heel point, SGRP or any other seat reference point for 5th percentile and 50th percentile driver. We arrange all other controls and displays like steering wheel, dashboards control, dashboard displays around the driver and the passenger as per the requirement. It will ultimately help in the occupant packaging from the very beginning of the vehicle development process.

After positioning the digital human model of driver or passenger, we can go for different types of ergonomic evaluation for clearance and interference study, e.g., how much head clearance is available or 5th percentile, 50th percentile or 95th percentile manikin? how much clearance is available within that clearance within the recommended limit? Similarly, we can check how much knee clearance or thigh clearance is available? We can also study the lateral clearance while driver and co-passenger or the passengers in the rear seat they are sitting. How much lateral space is available between two passengers or between the driver and the co-passenger? Whether space is sufficient or not? We can evaluate and accordingly we can go for design modification. Now, here we can see if we position different percentile human model like 5th percentile female manikin as the representative of smaller driver, then pull the data manikin mean neither male nor female that is the combined database of male-female database and from that we are developing a 50th percentile digital manikin we are positioning that one and the 95th percentile manikin.

So, how is the variation in their accommodation or occupant packaging due to variation of their body dimension? Accordingly, adjustment of the seat forward/ backward, arm reach envelope for steering wheel and other controls on the dashboard could be done.

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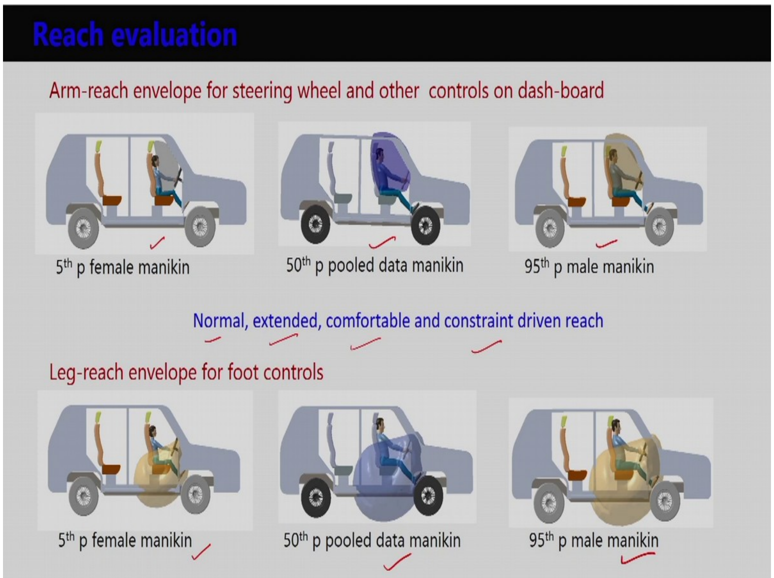

With this type of digital human modeling software, we can create arm reach envelope. This envelope for arms reach or leg reach can be of different types it may be normal arm reach or leg reach, extended one, comfortable one and constraint-driven one. So, generally we can start the arm reach assuming that the seatbelt is attached. When seatbelt is attached then hand movement is only possible from the shoulder joint.

While the arm is moving and reaching towards the dashboard for various controls, the starting point of joint movement is the shoulder joint. Accordingly, we can create the reach envelope, area or volume that the driver manikin can access. The size is defined for 5th percentile, 50th percentile, and 95th percentile manikin. Based on this reach zone or reach envelope we can finalize the position of the various controls and displays around the driver.

For this type of reach, we should consider 5th percentile female driver because their body dimensional or arm reach is relatively less. So, all the controls position on the dashboard or around her she should be able to access. So, 5th percentile reach envelope is very important for this purpose. Then if there is no seatbelt or if there is seatbelt, but the person for the driver is extending his body forward then actually the body movement is happening from the waist joint. When the body is moving from the waist joint then the extended arm reach is more, and they can access more area.

So, for that type of evaluation, we could understand how much area or reach is possible in within the comfort hand movement or leg movement. Similarly, we can also go for evaluation of constraint-driven reach and is moving only from the elbow joint or hand is moving only from the wrist joint. So, this type of evaluation is also possible in different types of digital modeling software, and the lower panel we have shown that 5th percentile female manikin how is the leg reach envelope for 50th percentile pull data manikin and 95th percentile male manikin.

The leg reach is important to understand because based on that we can position the foot controls and all those foot controls should be accessed by the various percentile in digital manikin. So, that in real scenario drivers population with varying dimensions from 5th percentile to 95th percentile leg dimension they can access the foot controls while the seat is adjusted forward and backward within the seat at travel limit.

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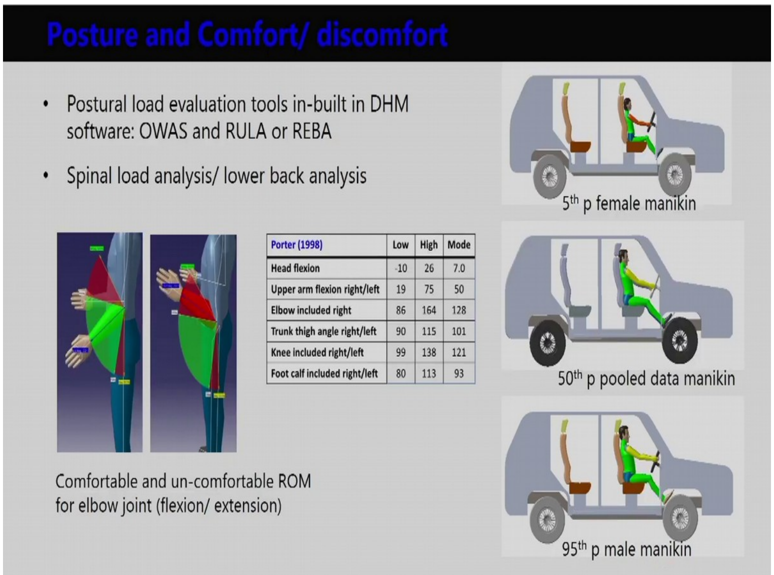

How we can use digital human modeling software for evaluation of posture and comfort discomfort? As we discussed earlier for comfort discomfort evaluation it is important to understand the range of body motion, a range of body joint/ ROM and at the same time the comfort range of motion within the total range of body joint movement.

For that purpose, we need to collect the comfort database and range of motion database. Based on the range of motion database for a particular body joint for a particular degree of freedom, we can set the total range of motion say. For example, if we take the example of elbow joint, then how much elbow joint can move in the software some value is already given. Assume for the elbow joint the flexion/ extension value is given from 0 degrees to 170 degrees, but if you feel that you want to change that range of motion from 0 degrees to 160 degrees you can change the joint limit.

The options are available in the software. Here, if you look at this left image, it is shown that the middle is a starting point and this is the endpoint. So, out of this whole range of movement the first portion that is red in this is not comfortable the middle portion that is a green zone that is a comfortable range of motion and the final portion even the red portion that is not comfortable.

Thereafter defining this type of comfort zone within the total range of motion, we can go for evaluation whether for a particular activity or performing a particular task, the driver particular body segment is within the comfort zone or not. Accordingly, their colour will be changed now when the hand movement within this range the colour of the hand segment will become green. On the other hand, when the hand is moving in the red zone of the body joint movement then the colour of the hand segment is becoming red.

If we will incorporate this type of comfort range of motion in the body joints and accordingly give the colour coding, whenever you are using that human model for ergonomic evaluation of the vehicle for comfort analysis of the driver, automatically it will show which body parts is within the comfort or discomfort zone. So, for comfort zone for 95th percentile, it is showing green colour wherever it is showing green colour mean those body parts are in comfort range of motion whereas, yellow mean little bit is the comfort and wherever it is red that is completely discomfort in terms of body joint angle.

Apart from this type of comfort joint angle based comfort evaluation, we can also go for posture evaluation with the standard inbuilt ergonomic tools like OWAS over co working posture analysis system or RULA Rapid Upper Limb Assessment REBA Rapid Entire Body Assessment this type of posture evaluation tools are inbuilt in many of the digital human modeling software. And, we can use those tools for posture evaluation or postural load evaluation.

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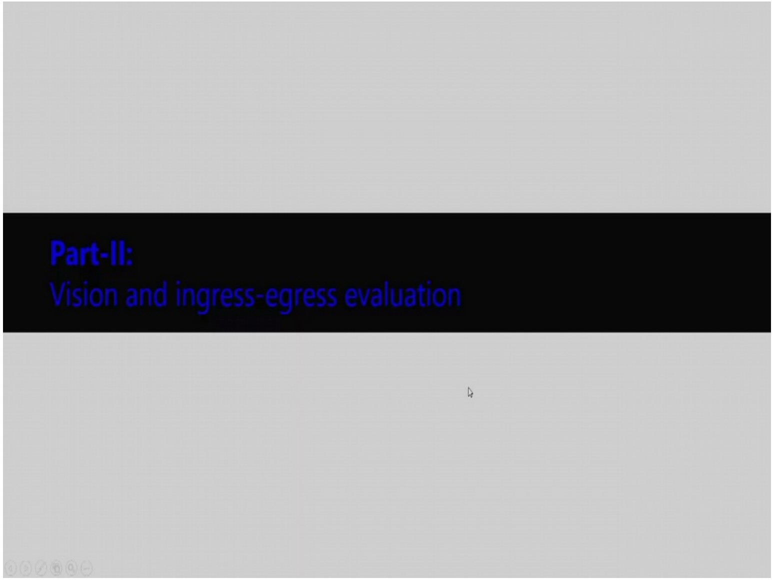

Now, moving to part 2, we will discuss the vision and ingress-egress evaluation in vehicle workstations. There are different types of vision analysis tools available in different digital human modeling software.

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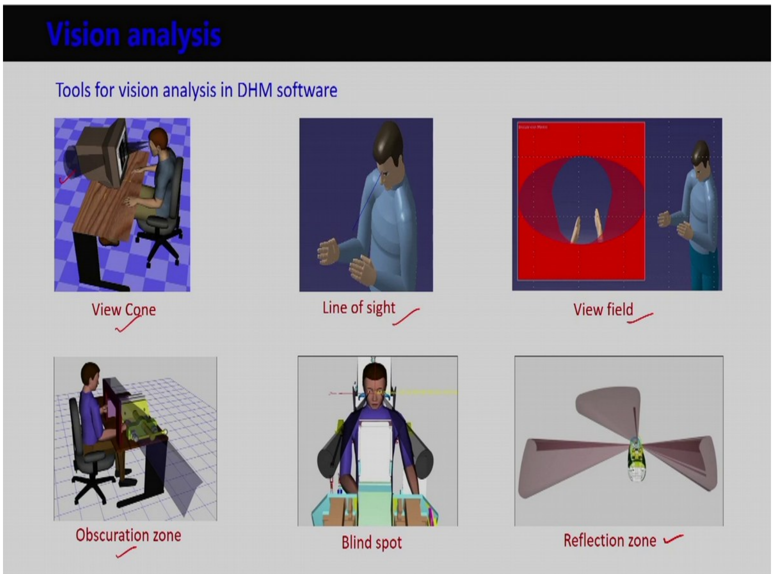

For example, there is this type of view cone where we can create view cone of varying angles. It is shown that we can create view cone of 15 degree, 30 degree as per our requirement. We can define the view cone and the size of the view cone also mean in terms of distance. Accordingly, we can check whether the particular object or particular display or control.

Similarly, we can create the line of sight that where the diver is looking at how much is the neck angle, how much is the eye movement angle we can measure using the line of sight. Similarly, there is field of view while the manikin is looking at a particular direction or particular position that how much area of the external environment is visible through his eyes that comes in a separate window which is mentioned as the view field or eye view window.

Due to the presence of any object or any component, how much area is not visible to the driver or to the manikin can also be evaluated using the tool obscuration zone analysis. Also, there is tool for vision analysis which is related to blind spot which area at the blind spot zone for the diver or the pilot or any other workstation operator. Accordingly, we will try not to put any of the control or display within the blind spot zone. In many of the software there is also a reflection zone you know say for example, particular this is very much helpful for mirror view.

While divers are using different types of mirror side, view mirror or inside mirror, how much area is visible to the driver that can be evaluated using reflection zone. Here are some example of how we can use digital human modeling software and vision analysis tool for vehicle inside or outside visibility evaluation.

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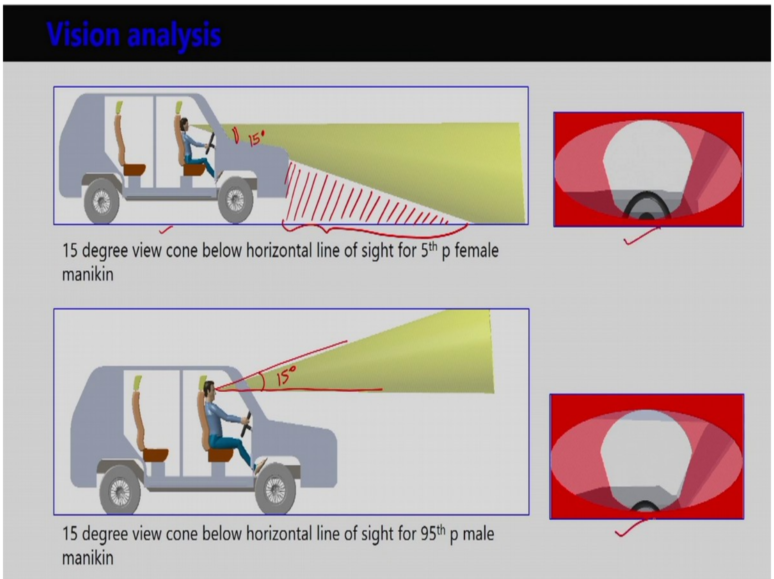

As you can see, we have created a 15 degree view cone. So, here in the above example, we have positioned 5th percentile female manikin and we are showing that for 5th percentile female manikin at least 15 degree downward visibility below the horizontal eye level should be there above the bonnet so, that she can see the road properly. So, in this particular example, the zone in front of the vehicle, which is not visible for the driver. So, this is the red zone for this 5th percentile driver above this zone it is visible for the driver, but this distance from the front portion of the vehicle is not visible to the driver.

If some small objects or animals pass by this area, it will not be visible for the driver. On the other hand, it is important to evaluate the upward visibility for the 95th percentile and larger driver. So, for any vehicle while we are deciding about the lower edge of the roof or the top edge of the windshield, we have to decide that for the 95th percentile driver at least 15 degree upward visibility should be there. So, that the driver can see the external images like hoarding, sign edges, traffic signals while he or she is driving.

For the purpose with position 95th percentile male model which are the larger in body dimension and for them at least 15 degree upward visibility through the windshield in front of the vehicle should be available. And while the divers are looking forward then how much area is actually visible that is coming in this type of eye view window.

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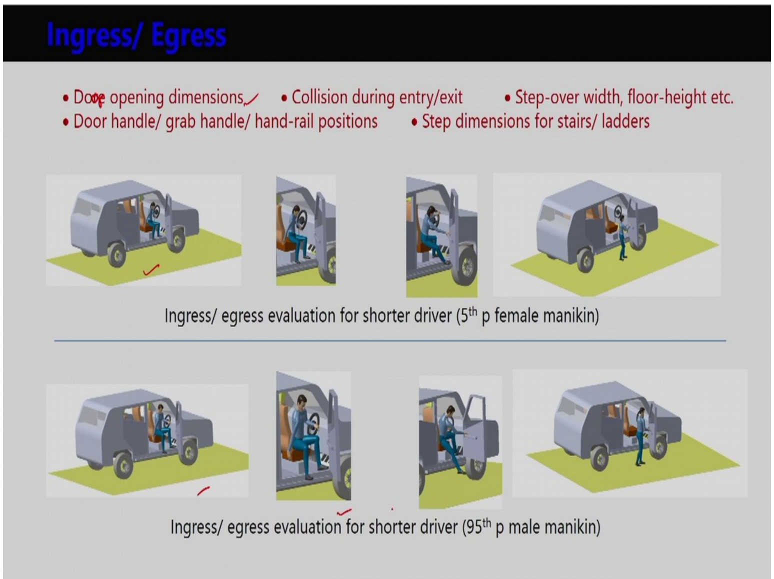

Apart from this, vision analysis digital human modeling software is also helping in ingress-egress analysis. So, various aspect of ingress-egress analysis meanwhile the driver or passenger is going inside the car or any other automotive vehicle and coming out then what type of problem they are facing and how much is or how much comfortable that entry-exit we can evaluate using digital human models.

Various aspects of entry-exit which we can evaluate with digital human modelling, for example, door opening dimensions, collision during entry-exit, step over width, floor height, door handle, grab handle, handrail position, and step dimension for stairs or ladders. So, these are the various aspects which are associated with the entry-exit process for the drivers and passengers. So, we can check these aspects through digital human modeling simulation. So, from the first panel, we can see that ingress-egress evaluation for shorter driver are showing with 5th percentile manikin.

How the driver is coming out or going inside the vehicle step by step and each and every step? Whether they have any difficulties in terms of holding grab handle or the dimension of the door? How much is the step width? How much of the the height of the vehicle floor? Whether they are facing any difficulties or not? If we find some issues related to these aspects, we have to redesign that automotive product to make it compatible or comfortable for all percentile of driver population. Similarly, while the same vehicle is being used by a 95th percentile manikin which is the representative of drivers with larger body dimension, then we can see how they are performing the ingress-egress activity and accordingly if there are any design loopholes, then we can go for design modification.

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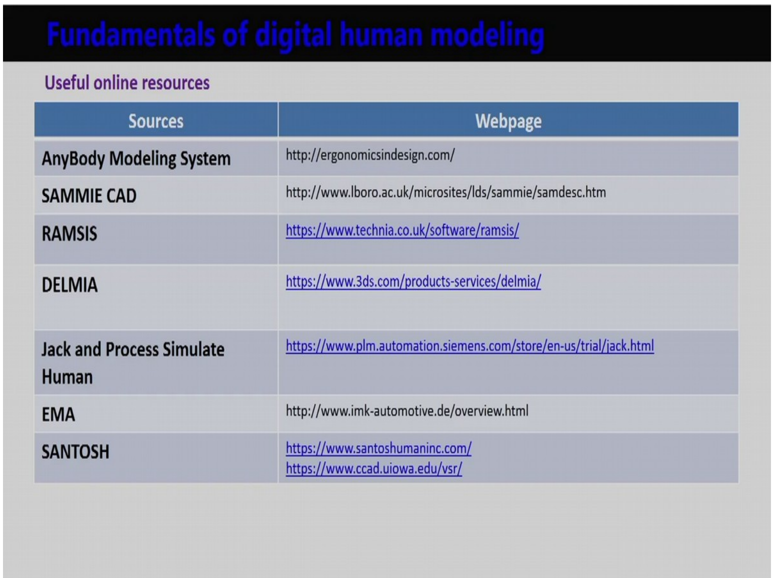

Sources	Webpage
AnyBody Modeling System	http://ergonomicsindesign.com/
SAMMIE CAD	http://www.lboro.ac.uk/microsites/lds/sammie/samdesc.htm
RAMSIS	https://www.technia.co.uk/software/ramsis/
DELMIA	https://www.3ds.com/products-services/delmia/
Jack and Process Simulate Human	https://www.plm.automation.siemens.com/store/en-us/trial/jack.html
EMA	http://www.imk-automotive.de/overview.html
SANTOSH	https://www.santoshumaninc.com/ https://www.ccad.uiowa.edu/vsr/

So, in this slide, we are presenting some of the important online resources, where you can get information about various digital human modeling software like SANTOSH EMA, Jack DELMIA RAMSIS. So, you can explore these web links for knowing more about the software.

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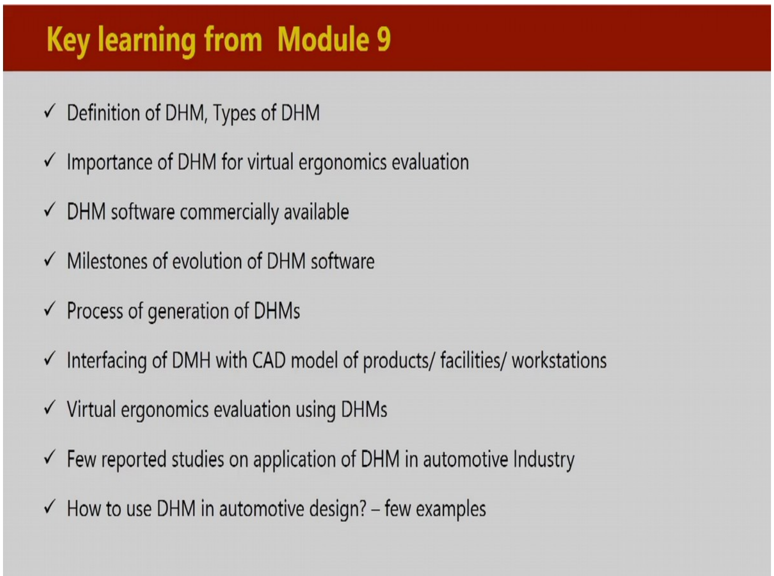

Now, after discussing all this thing, we are concluding by the key learnings from this module 9. So, in this module we have discussed the definition of digital human model, various types of digital human model, physical digital human model. Here, we have mentioned about two dimensional, three-dimensional representation manikin as well as biomechanical manikin.

Moreover, we have discussed about the importance of digital human model in virtual ergonomic evaluation, digital human model softwares which are commercially available, starting from Bowman in 1960s up to today, many advanced softwares like SANTOSH Jack SAMMIE RAMSIS, milestones of evolution of digital human modeling software, evolution of digital human modeling software over the year starting from the stick figure to the realistic human model in current scenario.

Also, we have discussed about digital human model interfacing with the CAD model of the product or the workstation or vehicle model and various types of ergonomic evaluation, virtual ergonomic evaluation using digital human model various aspects reachability clearance, interference, comfort or discomfort, entry-exit, vision.

We have also discussed use of digital human model in automotive design, particularly for vehicle occupant packaging and evaluation. We also discussed them with some examples.

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Now, these are the list of references which has been used for various slides.

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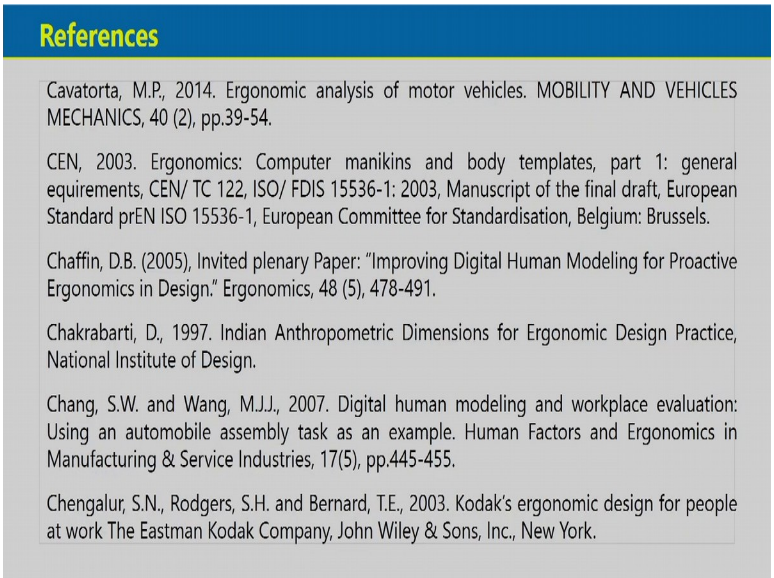

So, you can go through these references for a detailed understanding of this topic.

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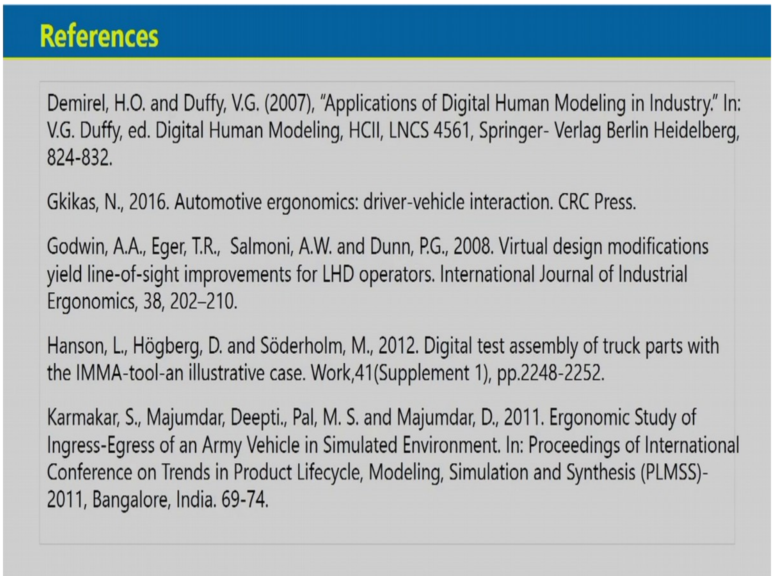

And how digital human model is being used by various researchers, why this software is important for the virtual ergonomic evaluation of automotive products.

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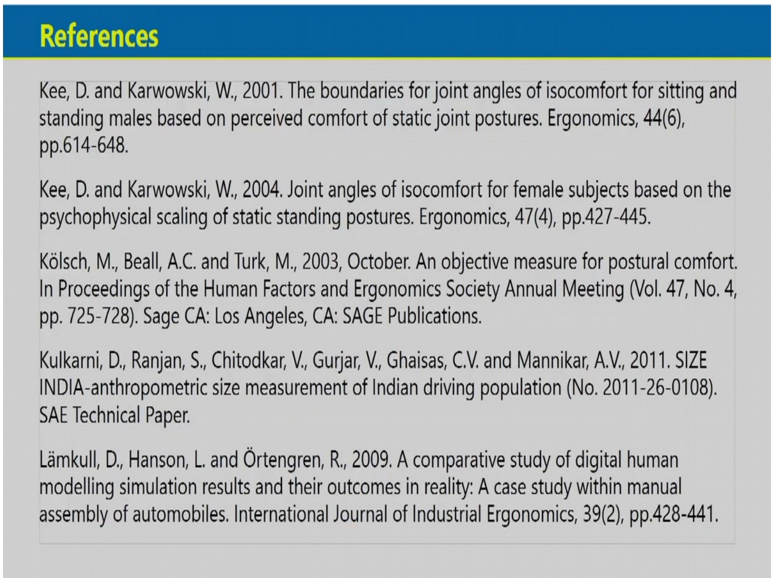

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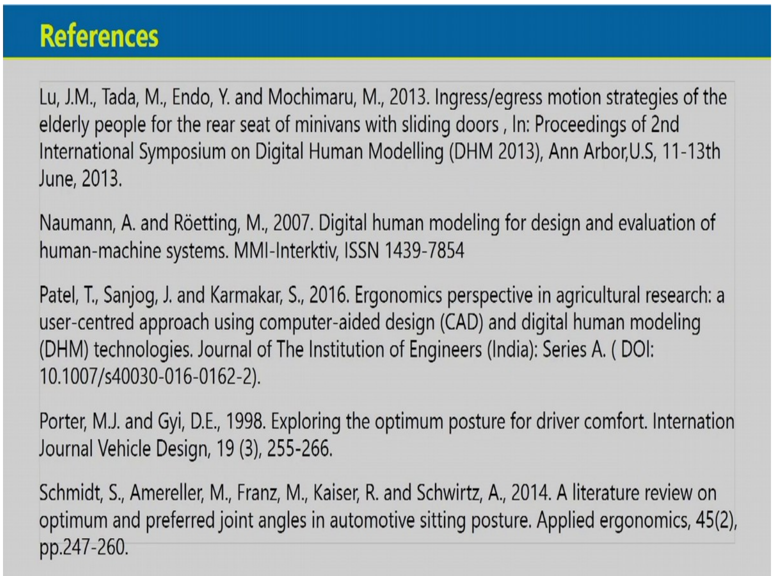

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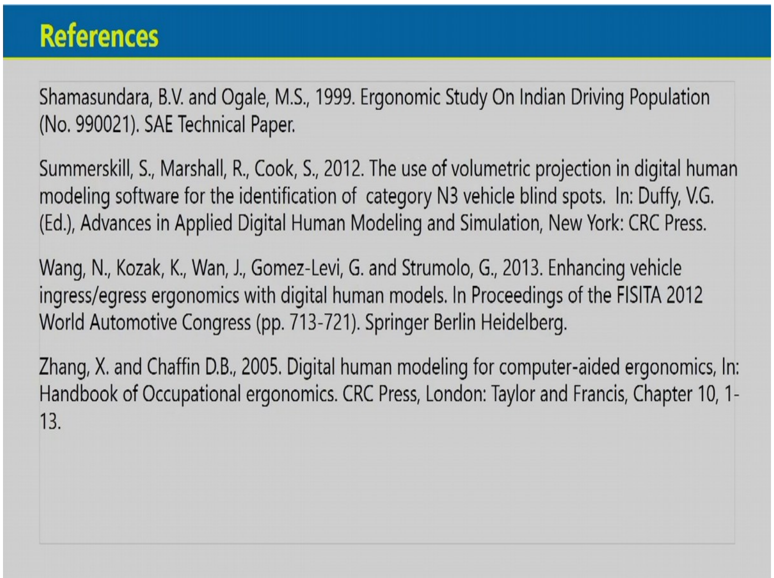

Thank you.