# DESIGNING DRIVER SPACE FOR LARGE CAR

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## ABSTRACT

For the last few decades, three-dimensional human simulation tools have complemented the traditional method of using 2D templates. Human simulation tools are, for example, used for optimizing comfort, fit, reach and vision. In this study, two other methods will be adopted to assist present method of using a 2D SAE template. The other methods will be by measurements and using ergonomic software. Measurement is done by using general layout drawing of benchmark vehicles.. Ergonomic tool that will be used for this study is Ramsis. Anthropometrics data used will be based on 95%tile USA/Canada population and 5%tile Japanese/Korean/Malaysian population. The 95%tile manikin size is used to get the maximum space accommodation while for smaller percentiles will be accommodated with the range of adjustability. Using 5% tile women for the minimum space accommodation, it was found that the SgRP at the most comfortable position for 5% tile women stature is situated lower and toward the front of vehicle. From original SgRP point for 95%tile male, the preferred SgRP point for 5%tile women is 50 mm lower and 200 mm closer to instrument panel. Conclusively, the adjusting range for the seat should be at least 200 mm while it is preferable to have seating height adjustment of 50 mm.

**Keywords**: Driver, Ergonomics, Automotive

## INTRODUCTION

Comfort at driving seating position is a one of the factors studied in Automotive Ergonomics. Usually seat, steering, gearshift and pedal positions are determined by means of comparing against 2D SAE manikin (spelling taken from SAE). However, to determine comfort level for driver using this method is not possible because of incomplete database and reference. The only thing that can be done is to compare with other cars that have received good feedback in the market. In this case study, a large car driver space will be designed based on dimension comparison with other large cars and by evaluating with vehicle ergonomic software, Ramsis.

The general research objective is to design driver space for a large car, mainly car that has a wheelbase dimension of more than 2600 mm. The goal is to evaluate other large cars that have been successful in the market and to implement it in a new model with the help of general layout drawing of comparison cars and vehicle ergonomic software, Ramsis. In order to meet these objectives, comfort level of benchmark cars will be studied and the positive or negative aspect to car users will be discussed. Through dimension measurement and general layout analysis, driver space parameter for this new large car will be suggested and confirmed with Ramsis. Virtual comfort measurement will be used to determine the comfort level based on Ramsis library. The end result will give dimension suggested for this new large car.

## LITERATURE REVIEW

The driver's posture is essential in vehicle design. After the accelerator heel point is set (after defining the type of car, ground clearance and desired chair height and underbody structure), posture determines the arrangement of, for instance, seat position, steering wheel position, control positions and the roof line.

The vehicle, in particularthe cockpit, is designed around the driver. It may be that no optimal posture exists. Drivers show great differences and variationsin their applied posture (Sundström, 2003). He found that each driver applied a rangeof 2-4 postures, though one favourite posture dominated the overall seating behaviour. The changes in posture could be correlated to events in the driving environment or handling of artefacts, tools or equipment. Several studies, for instance, Rebiffe (1969), Grandjean (1980), Tilley and Dreyfuss (1993), as well as Porter and Gyi (1998) have examined driver posture and come up with recommended joint angle intervals. Others, e.g. Andreoni et al. (2002), use joint angle means. Several car driver posture prediction models are available and integrated in the human simulation tools. One commercial model is based on laboratory experiments with subjects driving German vehicle mock-ups (Seidl, 1994). This model simulates the joint-angle comfort trade offs and is used in RAMSIS. Another model, the Cascade Prediction Model, is based on laboratory experiments with American subjects in different specific vehicle package set-ups (Reed, 1998). This model is integrated in JACK and focuses on eye and hip location. There are also posture prediction models developed by vehicle manufacturers for internal purposes (e.g. Quattrocolo et al.,2002).

The human simulation tools provide posture evaluation in terms of biomechanical analysis, i.e. the calculation of forces and torques acting on joints which can be compared to NIOSH lifting recommendations (Waters et al., 1993). Furthermore, the tools provide posture analysis with methods such as OWAS (Karhu et al., 1977) and RULA (McAtamney and Corlett, 1993). However, these methods are not applicable for evaluating the driver's posture, a sitting posture with relatively low forces. These methods are more applicable for analysing loading and unloading luggage, for instance. Driver posture may instead be evaluated in terms of discomfort. Comfort/discomfort tools are available in the human simulation tools (e.g. Krist, 1994). These methods are questioned, but considered suitable when comparing concepts (Nilsson, 1999). The SAE accommodation guidelines are integrated and can be used as control measurements and for evaluation. In addition, animations and pictures generated by the human simulation tools are used for expert judgment: ergonomic experts using their knowledge and experiences from formal education and previous analysis.

Traditionally, vehicle designers use SAE – Society of Automotive Engineers – two and a half dimensional accommodation tools to design the cockpit, including the layout of a recommended seat position, hand reach envelopes, head contours and eye ellipses (Roe, 1993). These accommodation tools and a human replica (Figure 3) were first available in plastic to serve as curves when using a pen and drawing table. Later they were integrated in CAD tools. For the last few decades, three-dimensional human simulation tools (Figure 4) have complemented the traditional ones. A human simulation tool is a computer tool that utilizes a two or a three dimensional human model in the creation, modification, presentation and analysis of a human machine interface. Human simulation tools are, for example, used for optimizing comfort, fit, reach and vision (Chaffin, 2001). Furthermore, these tools include biomechanical analysis methods.

Several human simulation tools have been developed during the last few decades andmhave been reviewed (e.g. Porter et al., 1993; McDaniel, 1998; Bubb, 1999). The early human simulation tools and manikins were frequently developed with characteristics chosen for a narrow application area, such as vehicles, or for a typical analysis, such as a biomechanical one. Today, the market offers a smaller number of human simulation tools due to company mergers. Instead, the application areas of each human simulation tool have expanded. Currently, there are three major actors on the market, JACK (Badler, 1993), RAMSIS (Seidl, 1994) and Safework. There are, of course, others such as MADYMO for vibration and crash analysis (Verver and van Hoof, 2002) and COSYMAN for pressure distribution (Schmale et al., 2002).

## METHODOLOGY

Traditionally, a 2D SAE template is used to determine whether a driver space is meeting all the basic aspects of vehicle packaging and ergonomics. This template is still used at present time due to its direct conformation to regulation aspect and also to its proven method for all the cars on the road that we see today. As shown below, a 2D template SAE is taken from statistical research by SAE (Society of Automotive Engineers, USA).

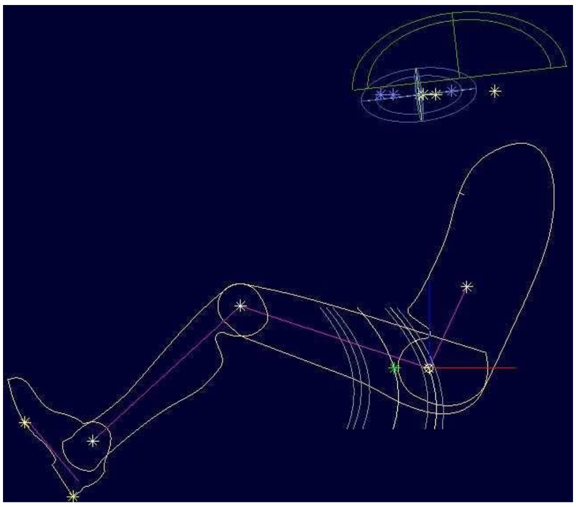

**Figure 1** SAE 2-D Manikin Template

In this study, two other methods will be adopted to assist present method of using a 2D SAE template. It consists of

a) Measurements
b) Ergonomic Software

3.1 Measurements

Measurement is done by using General Layout Drawing of benchmark vehicles. Specific dimensions that are related to Vehicle Packaging are measured. A standardize SAE notation is used for all the dimensions. These dimensions represent parameters that are closely interrelated to Human Factor. Measuring area is shown below:

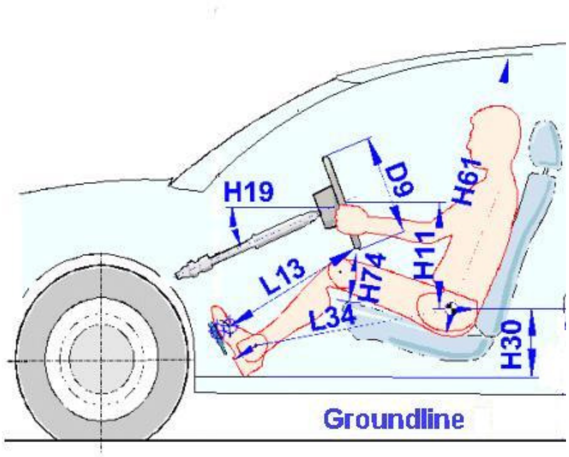


**Figure 2** Measurement Parameters

3.2 Ergonomic Tool Software (RAMSIS)

3.2.1 Background of RAMSIS

Increasing global competition and rising consumer expectations with respect to vehicle comfort and safety require a systematic approach to ergonomics when designing a new car. At the same time, development cycles must be shortened and costs reduced. Under these circumstances, the ability to evaluate and optimize vehicle concepts in a very early design stage and reduce the number of (time- and cost-intensive) design iterations is critical. Ever more physical tests and evaluations are replaced by digital procedures. The majority of early design decisions is made using a CAD model or digital (vehicle) mock-up (DMU).

RAMSIS is a digital human model, a highly efficient CAD tool for occupant simulation and ergonomic design of vehicle interiors. RAMSIS is an acronym for Rechnergestütztes Anthropologisch-Mathematisches System zur Insassen-Simulation, German for Computer Aided Anthropological Mathematical System for Occupant Simulation. It provides engineers with a detailed CAD representation of the human body (manikin) that can be animated to simulate driver behavior. It enables the user to perform extensive ergonomic analyses in the early stages of the product development process, using CAD data only, thereby reducing the number of costly design iterations and follow-up improvements at a later time. RAMSIS was developed in the 1980's by Human Solutions GmbH in association with the Lehrstuhl für Ergonomie (Ergonomics Department) at the Technical University of Munich and the collective German automotive industry. Their goal was to overcome the insufficiency of existing ergonomic tools, e.g. the widely used two dimensional SAE J826 template, and to improve ergonomic qualities of vehicles beyond legal requirements.

Conventional human models require the user to manipulate the joints of a manikin manually and one by one in order to move a manikin from a standing posture to a driver posture. This process is time consuming, highly subjective and not reproducible. Multiple RAMSIS users are likely to produce different and inconsistent results. RAMSIS offers an automatic posture calculation, based on extensive research on how real people sit and move in various real vehicle environments. Users must only define a list of tasks or constraints for the manikin, based on which RAMSIS calculates the most probable posture in which a manikin will perform these tasks in the actual vehicle model – in only a few seconds. This automated work flow ensures realistic, consistent and reproducible results and is one of the key reasons why RAMSIS has become the automotive industry's de facto standard for ergonomic design and is used by more than 70% of the world's major vehicle manufacturers. According to RAMSIS customers, costs for ergonomic studies can be reduced by up to 50% and ergonomic design decisions can be made 3-5 times faster, compared with using traditional methods.

### 3.2.2 Application

Ergonomic tool that will be used for this study is RAMSIS. Anthropometrics data will be based on 95%tile USA/Canada population and 5%tile Japanese/Korean/Malaysian population.

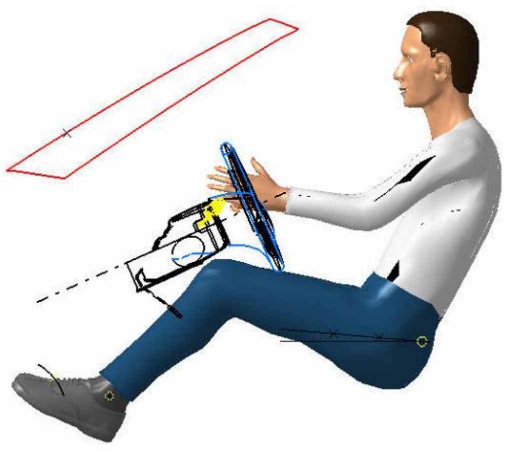

**Figure 3** Ramsis Manikin

The current posture of the manikin seated in a car is assessed with regard to fatigue, discomfort feeling, and the pressure load on the spinal column. The discomfort feeling is analyzed for certain body elements and for the entire manikin. It is based upon driver experiments made with about 100 test subjects at the technical universities of Munich and Eichstatt. The analysis of the pressure load on the spinal column is based upon research results about mechanisms damaging the intervertebral disks. The assessments are visualized in a bar chart. The exact values are indicated to the right of the bars. Low values, i.e short bars, signify high comfort and good health assessment (values up to 2.5) while values between 2.5 and 5.5 can be regarded as mediocre. and values above 5.5 as very comfortable or detrimental.

Dimensions and Masses | Coordinates | Angles

Body Dimension

| Element Name | Value (mm) |
|---|---|
| body-height | 1859.7 |
| body-height-with-shoe | 1890.7 |
| sitting-height | 999.1 |
| head-height | 228.9 |
| head-width | 154.1 |
| head-depth | 194.8 |
| neck-length | 117.1 |
| shoulder-width-deltoidal | 471.3 |
| upper-arm-length | 337.3 |
| forearm-length-with-hand | 479.9 |
| forearm-circumference | 273.6 |
| chest-width | 292.8 |
| chest-depth | 205.6 |
| waist-circumference | 819.6 |
| pelvis-width | 304.2 |
| hip-width | 343.3 |
| buttock-knee-length | 621.0 |
| knee-height-sitting-with-shoe | 603.0 |
| hip-width | 343.3 |
| buttock-knee-length | 621.0 |
| knee-height-sitting-with-shoe | 603.0 |
| foot-height-with-shoe | 109.0 |
| foot-length-with-shoe | 342.2 |
| foot-width-with-shoe | 126.6 |
| upperarm-circumference | 245.4 |
| calf-circumference | 338.0 |
| thigh-circumference | 522.2 |

Dimensions and Masses | Coordinates | Angles

Body Dimension

| Element Name | Value (mm) |
|---|---|
| body-height | 1480.1 |
| body-height-with-shoe | 1496.3 |
| sitting-height | 783.2 |
| head-height | 187.5 |
| head-width | 147.0 |
| head-depth | 178.4 |
| neck-length | 84.7 |
| shoulder-width-deltoidal | 392.1 |
| upper-arm-length | 307.7 |
| forearm-length-with-hand | 391.8 |
| forearm-circumference | 229.2 |
| chest-width | 279.3 |
| chest-depth | 223.7 |
| waist-circumference | 693.0 |
| pelvis-width | 273.3 |
| hip-width | 312.2 |
| buttock-knee-length | 511.9 |
| knee-height-sitting-with-shoe | 457.3 |
| hip-width | 312.2 |
| buttock-knee-length | 511.9 |
| knee-height-sitting-with-shoe | 457.3 |
| foot-height-with-shoe | 84.0 |
| foot-length-with-shoe | 220.6 |
| foot-width-with-shoe | 86.9 |
| upperarm-circumference | 210.0 |
| calf-circumference | 325.6 |
| thigh-circumference | 496.9 |

**Figure 4** Anthropometry of 95% tile USA/Canada and 5% tile Japanese/Koreean/Malaysian

## RESULTS AND DISCUSSION

From general vehicle layout of comparison cars, each relevant dimension is measured using CAD tool i.e Catia. The results are put into table below.

**Table 1** Interior Car Dimension Comparison

| Cars \ Dimension | H30 | L34 | H61 | H11 | H74 | L13 | H19 (deg) | D9 |
|---|---|---|---|---|---|---|---|---|
| Citroen C4 | 280 | 735 | 905 | 380 | 157 | 650 | 24 | 385 |
| Honda Accord | 268 | 808 | 856 | 357 | 138 | 659 | 26 | 380 |
| BMW 5-Series | 253 | 816 | 874 | 368 | 142 | 625 | 22 | 395 |
| Volkswagen Passat | 247 | 814 | 915 | 391 | 176 | 668 | 23 | 380 |
| Proton Perdana | 242 | 850 | 900 | 394 | 200 | 660 | 26 | 375 |

From above table, deduction can only be made if there is one ideal specific condition for all cars. However, we can see all the variations of dimension for all five cars even though all cars are in large segment. One major dimension that dictates all other driver space dimension is seating height of H30. It can be seen that if H30 is large, other upper dimension will be decreased. Reason being that once H30 is increased; clearance to roof and steering will be compromised. Reach to pedal will be varied also. So rood and steering as well as pedal are the limiting factor. It is crucial to set a roof line that is comparable to other cars in the market while at the same time trying to improve the comfort or space from previous products. While the argument can be that the roof can be as high as possible if comfort or space is the priority, one also has to see other structures involved with may increase material and cost unnecessarily. One important aspect is styling as one would despise a high roof sedan as it is not suitable with current trend. Furthermore, high roof and steering is in the MPV architecture.

Therefore, to start a parameter for a new large car driver space, a proper seating height will need to be decided. Comparing with other large cars in comparison, the dimension ranges from 240 mm to 280 mm. Taking reference for all other types of vehicles, the ranges of H30 are as below.

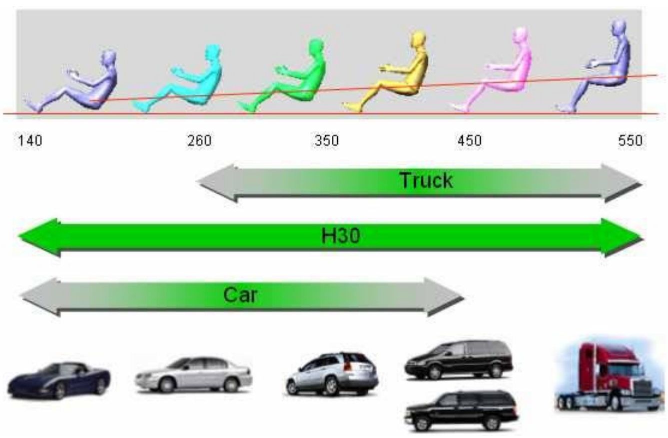


**Figure 5** H30 Dimension for Different Segement

Hence, there are large variations and it is crucial to have benchmark cars in place so that when the car enters a market, it will compete with a right segment. So to decide for H30 value, it should be between 240mm and 280mm. For qualitative purpose, software that has a predetermined posture intended for drive will be used to seek for a preferable H30 dimension in terms of ergonomic evaluation. From Ramsis, a preferable posture for driver is taken for reference to come up with below preferable driver posture for the new large car.

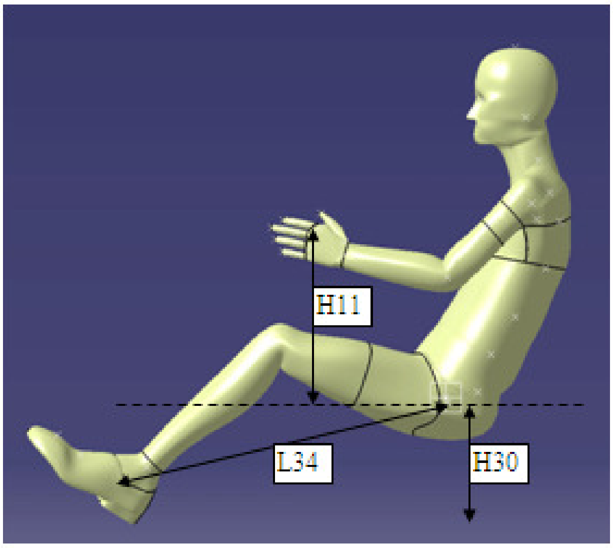


**Figure 6** Preferred Driver Posture

**Table 2** Preferred Posture Dimension

| Dimension (mm) Cars | H30 | L34 | H11 |
|---|---|---|---|
| Ramsis Posture | 288 | 737 | 393 |

Comparing between values 240 mm to 280 mm for comparison cars and 288 mm exact value preferred by Ramsis, it seems that higher H30 value is preferred for better posture. But 288 mm as suggested by Ramsis is more than the comparison cars H30 range. So this will require other parameters to be taken into account. This parameter related to exterior dimension of this new car, called Overall Height, Seating Reference Point to Ground, and Head Clearance. Since these parameters are not covered in this paper except for head clearance, a generic average value for overall height and sgrp to ground for sedan cars will be used.

Ground clearance for sedan cars ranges from 140 mm to 200 mm. As no regulation requirement for this parameter, manufacturers usually opt for the road condition their markets are intended for. Ground clearance is directly related to SgRP to Ground. Ground Clearance is measured from the lowest point of car structure to ground or road while SgRp to Ground is measured as the vertical dimension from Seating Reference Point to Ground or road.

**Table 3** Seating to Ground Dimension Comparison

| Cars \ Dimension | Overall Height | Ground Clearance | SgRP to Ground |
|---|---|---|---|
| Citroen C4 | 1512 | 200 | 580 |
| Honda Accord | 1400 | 160 | 483 |
| BMW 5-Series | 1447 | 147 | 528 |
| Volkswagen Passat | 1464 | 145 | 508 |
| Proton Perdana | 1395 | 162 | 471 |
| Average | **1444** | **163** | **514** |

Next, average value is taken from comparison cars to get the new car respective parameters for Overall Height, SgRP to Ground, and Ground Clearance. With this, a new driver layout is drafted in Catia to outline the boundary and dimension for this new large car. First, a preferred posture model from Ramsis as used as the manikin for the driver setup. From SgRP to Ground value taken from average of benchmark cars, a ground line is drafted. One must keep in mind this is Kerb ground clearance, where no passengers and luggage are in except some fuel. This is to simulate maximum ground clearance. While ground clearance with full load is necessary to simulate minimum ground clearance, for this study only Kerb ground clearance is used to simplify it. Definitions are as follows:

Kerb Weight: The weight of a vehicle equipped for normal driving conditions. This includes fluids such as coolants, lubricants, and a fuel tank filled to a minimum of 90%. Also included are the spare tire kit, tool kit, and car jack.

Design Weight: Vehicle curb weight plus the weight of three passengers (68 kg each, with luggage 7 kg each) with 2 passengers in the front seat and 1 passenger in the rear seat.

Gross Vehicle Weight: Vehicle curb weight plus maximum payload (5 passengers plus luggage)

Once the ground line is made, the heel point will be decided based on ground clearance and floor structure. This way the heel point from the original position as suggested by Ramsis has to be moved up a about 15 mm to accommodate ground clearance. So the new H30 value is decided at 276 mm, lower than the preferred position as analyzed by Ramsis. Then, all other dimensions are just propagated from heel up except for H74, H19 and D9 values where it cannot be deducted from Ramsis manikin. So the average values from comparison cars are chosen for H74. While for H19 or steering wheel angle, a minimum value from comparison cars is chosen because according to ergonomic software, a more upright steering position is preferred e.g inclining towards small H19 value. For D9 or steering wheel diameter, a minimum value from comparison cars is chosen due to the fact that at preferred posture in Ramsis, the optimal distance from right palm to left palm during driving is about 275 mm (Fig 8). Since it is way lower than the values of benchmark cars, the lowest value is picked for the reason of competitive advantage.

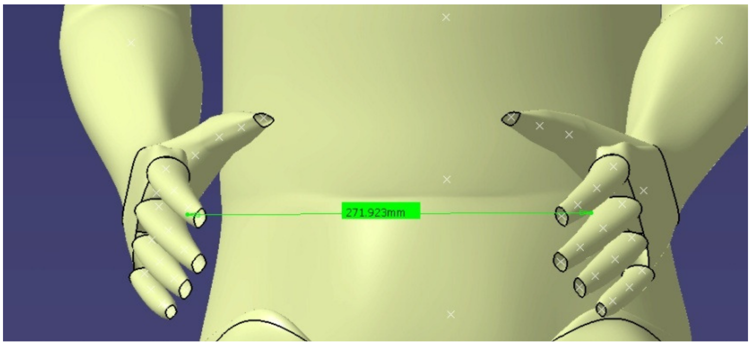


**Figure 7** Preferred Steering Hand Position

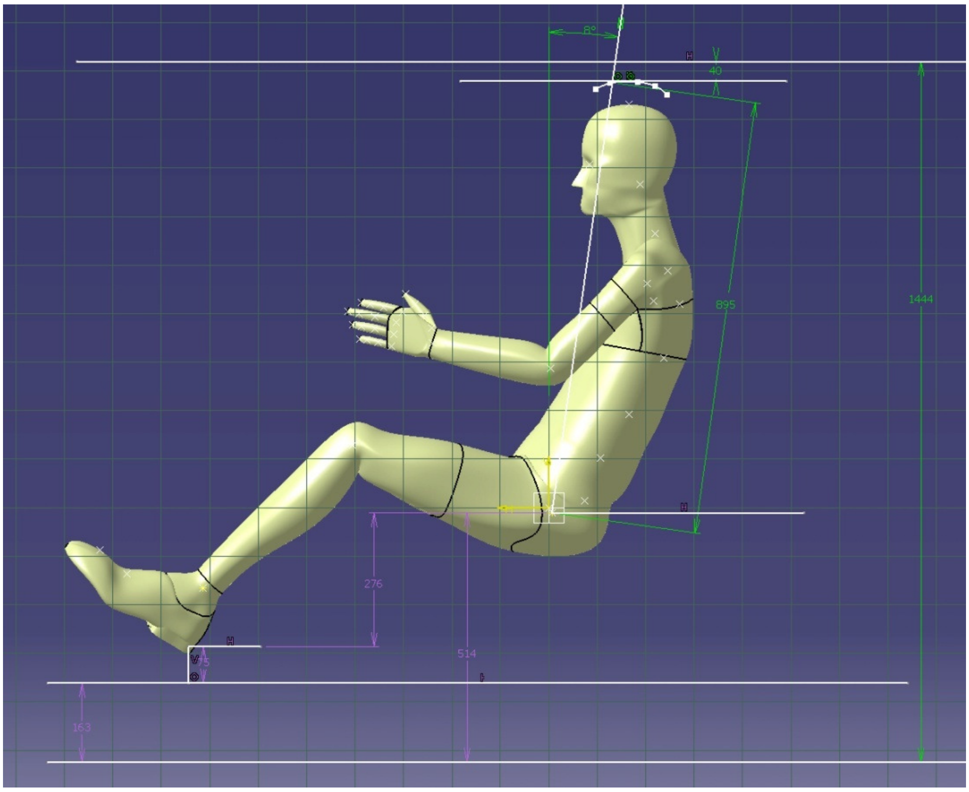


**Figure 8** Setup of Driver Space

**Table 4** Dimension of the Final Driver Space

| Dimension(mm) / Cars | H30 | L34 | H61 | H11 | H74 | L13 | H19 | D9 |
|---|---|---|---|---|---|---|---|---|
| New Large Car | 276 | 734 | 895 | 393 | 163 | 737 | 22 deg | 375 |

The optimum position suggested will at least guide design process later that now a range of values are known. The 95%tile manikin size is used to get the maximum space accommodation while for smaller percentiles will be accommodated with the range of adjustability. Using 5% tile women for the minimum space accommodation, it was found that the SgRP at the most comfortable position for 5% tile women stature is situated lower and toward the front of vehicle. From original SgRP point for 95%tile male, the preferred SgRP point for 5%tile women is 50 mm lower and 200 mm closer to instrument panel.

Conclusively, the adjusting range for the seat should be at least 200 mm while it is preferable to have seating height adjustment of 50 mm. Since sitting height adjustment is usually only equipped with expensive cars, tilt adjustment can be adopted for lower end cars so that at 5% tile women SgRP position, the thigh angle can be decreased thus reducing pain around that area.

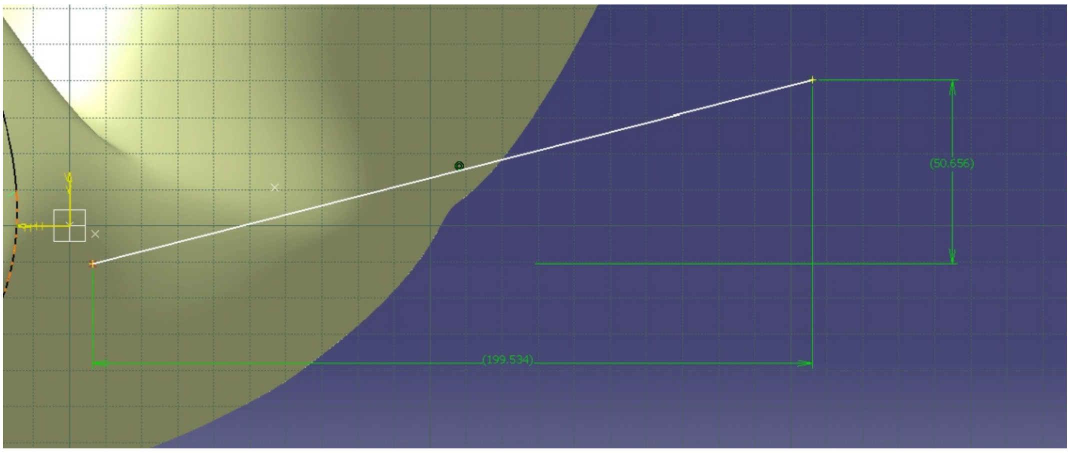


**Figure 9** Preferred Driver Seat Adjusting Range

## CONCLUSION

From preferred posture of ergonomic software, dimension parameters related to driver space for passenger cars are obtained. This parameters are then adapted for large car driver space by taking into account the larger space criteria and also the different sizes of human. Due to some restrictions such as roof and floor line as benchmarked from same segment competitors, the posture has to be adjusted to accommodate for pedal and steering. The resulting posture is then assessed using Ramsis which gives an acceptable comfort level. So the final driver space parameter for a new large car is completed.

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