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# A Survey on Automotive Seat and Factors Affecting its Design

Saif Tamboli<sup>1</sup>, A. P. Shah<sup>2</sup>

P.G. Student, Department of Automobile Engineering, Rajarambapu Institute of Technology, Sangli, Maharashtra  
India<sup>1</sup>

Associate Professor, Department of Automobile Engineering, Rajarambapu Institute of Technology, Sangli  
Maharashtra, India<sup>2</sup>

**ABSTRACT:**Automotive seat is very important and complex part of vehicle. It consists of various adjusting mechanisms for comfort and various components for safety purpose. Seat should be designed carefully taking into consideration ergonomics, comfort and safety. If seat is not designed properly then it may lead to accidents or damage to occupants and driver seating on seat. The aim of this paper is to study in detail about automotive seat and review all the parameters affecting design of seat. The present study describes the types of seats, functions of seat, and basic components of seat. All the major parameters related to ergonomics and safety, affecting design of seat are reviewed in detail.

**KEYWORDS:** Automotive seat, Comfort, Ergonomics, Safety.

## I. INTRODUCTION

**Background and evolution of automotive seats:**The first automotive seat was adopted from the horse-drawn carriage. There were springs to absorb road shocks but effective padding was non provided. Adjustability of seat was not considered at that time. Commencing around 1900, motorist safety while travelling over rough roads was improved by development of deeply contoured seats that reduced the likelihood of motorist ejection as the car body pitched and rolled. Longitudinal arrangement of seat was not available until about 1929 when adjustable front seats for the driver became a feature of higher priced automobiles. Later, occupant comfort became more important. Improvements in seat design continued and by the mid 1930's, seats, tracks and runners closely resembled those of the mid 1960's. During the period between the thirties and the sixties, the only significant innovation in seat design was the introduction of power seats and adjustable reclining backrests during the early 1950's, but by the mid-seventies the height of backrests on many models had declined to levels less effective than thirty years ago. Seatback strength has not increased significantly over the past thirty years and remains inadequate to resist even moderate collision forces. Seventy percent of adjustable head restraints are used in the downmost position. Little effective protection is afforded the motorist unless the head restraint is positioned behind or slightly above the head and remains in such support position during collision. The main function of seat is not only to provide a seating space to occupants but also support, protect and provide comfortable seating posture to the occupants. Design of seat is very important because poorly designed seat affect badly on human health as well as psychological condition of driver hence increases the chances of accidents[1].

**1.Types of Seats:** Following table shows the evolution of driver seats with period and car where it is used.

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Table 1: Evolution of automotive seats [1]

Introduced	Type	Example
1890-1900	Bench Seats	Philion
1900-1910	Deep Bucket Seats	Thomas
1910-1915	Fold-forward ackrests	Model-T Ford
1910-1915	Pedestral Seat	Agro Electric
1910-1915	Consol Between Seats	Wescott
1910-1920	Swivel Seat	Cole
1920-1925	Fold- down armrest	Dusenberg
1925-1930	Fore- and –aft Adjustment	Viking
1950-1952	Power Seats	Packard
1960-1963	Optional Head Restraints	All U.S
1968	Integrated Head Restraints	Volkswagen
1969	Standard Head Restraints	All U.S
1997	Pro Active Head Restraint	Toyota

The seat can be classified in to four basic types which are as follows:

**Folding Back:** It consists of full or split bench with an option of folding back as shown in figure below.

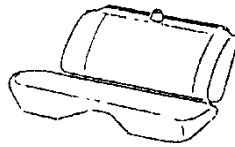


Fig. 1. Folding back

Folding back allows access to trunk space or to use as load floor. Generally, this type of seats can be seen for rear seats of passenger cars to allow trunk access and storage of large items.

**Split Bench Type:** In this, seat is splitted in two parts as shown in figure below.

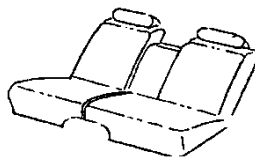


Fig. 2. Split bench type

They are used for rear row of vehicles for providing more comfortable seating postures to occupants seating behind, with an option of foldable armrest. The seat is splitted ether in the ratio of 50:50 or 60:40. The seat is splitted in such a way that independent adjustments of seat such as forward, backward and recline can be done for each part.

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**Split back type:** The split back type seat is as shown in figure below. It consists of single seat base and split back.



Fig. 3. Split back type

In this only seat back can be adjusted for getting access to trunk space. This type of seat is observed in rear row, but it can be also used for first row of driver seat in vehicles having transmission located on instrument panel or having automatic transmission. This type of seats are used for accommodating more occupants on front row of driver seat.

**Bucket seat:** It is a freestanding seat mounted to vehicle body which can accommodate only one occupant at a time as shown in figure below.



Fig. 4. Bucket seat

Some bucket seats have flexibility to swing 90 to 360 degrees [2]. Bucket seats are contoured seats for individual occupancy. Adjustable back rest angle is commonly available and provides improved comfort and reduced muscle fatigue. Direct attachment to the seat of lap and shoulder belts is a safety and convenience goal provided by bucket seats [1].

**2. Functions of seat:** The main/basic functions of automotive seat can be summarized as below.

**a. Support the occupant:** The basic function of seat is to support the occupant. Seat must keep occupant in a stable position for longer period of time. Seat should accommodate various weights, sizes and proportions of occupants without significant change in shape or function. If seat does not provides proper support to occupant then it may affect position, comfort and safety of the occupant.

**b. Position the occupant:** Seat must keep occupant in proper position. Positioning of occupant should be in such a way that occupant can easily access various controls, occupants should get proper field of vision and occupant should have good head, arm and leg room.

**c. Protect the occupant:** The seat play an important part in improving occupant safety during a car impact. Seat should provide proper safety to occupants. Seat should prevent occupant from moving about inadvertently due to adverse steering. Seat should be designed in such a way that sliding of occupant under the lap restraint is prevented. During accidental conditions seat should not move fore and aft or tilt forward & backward. Seat should prevent occupant from causing head and neck injuries with help of effective use of airbags and seat belts. Seat must absorb crash loads to prevent failure of the restraint system [3].

**3. Components of Seat:** When designing a new seat system it is important to understand the current system, and a good way of understanding this is to describe the different components in the system and what functions they perform. The subsystem shall provide all customers, for which the cars are designed, with the ability to adjust the seat manually or electrically to ensure that an ergonomically correct driving position is possible. It shall together with the seat belt, and side airbags protect the occupants in the event of an accident. In this section a breakdown of this sub-system is explained.

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Fig. 5. Components of seat[4].

The seat component sub-system consists of two major segments, the seat base and the seat back. The sliding rail and track segment acts as an interface between the seats and the BIW, and are bolted to the floor and the seat base frame. The seat base consists of lower frame, cushion pad and base cover. The main function of seat base is to support the driver's weight in the z direction. Another function of the seat base, is to prevent the driver to slip under the lap belt during a frontal crash, a phenomenon also called submarining. Therefore the seat base is always angled between 10° – 20° in order to absorb the kinetic energy that the driver's mass will produce during a frontal crash. The seat back consists of upper and lower cross member, side members, rear cover, pad and headrest which together mainly supports the driver in x-axis. It is also common in modern car seats for the seat back to incorporate an adjustable lumbar support as well some form of whiplash protection in the headrest. The seat back and seat base are connected together with the help of recliner bracket, which houses reclining mechanism. On both the seat back and seat base there are side cushions sticking out from the pads which supports the driver in y-axis. The connection between the seat base and BIW usually consists of four support legs and two rails, the latter being bolted to the BIW. The support legs are moveable which allows the seat to be adjusted in height via a lever that lifts the base frame upwards. The longitudinal adjustment of entire seat is enabled due to sliding motion of rails. Sliding rails, recliner mechanism and height adjuster make up the main adjustments of a car seat. An important aspect of the seat structure is that it should be able to transmit occupant and seat belt loads to the vehicle body in case of a collision. When trying to reduce weight it is interesting to look at how the weight of the seat sub-system is distributed across the different components. The seat mass allocation for various systems is as shown in figure below.

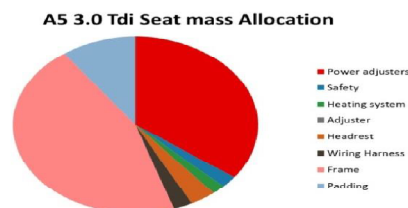


Fig. 6. Seat mass allocation [4]

As seen in the pie-charts of a selection of cars in different segments, the mass of the frame is the largest contributor to the seat sub-system total mass. It can also be seen that the power adjustment equipment make up a large fraction of the mass in seats that have this feature [4].

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## II. RELATED WORK

Severy et al. [1] investigated the back ground of automotive seats and discussed there types, functions and components. The paper further revealed seat design concepts. Bhat et al. [2] proposed approach for design and development of automotive bucket seat frame using parametric modelling and finite element analysis methodology. Dolan and Oiler [3] carried out research to determine how characteristic of seat design affect occupant safety. Kale et al. [6] presented all the parameters of driver seat such as anthropometry of human, ergonomics related parameters, seat materials, safety related parameters, comfort related parameters as well as weight and aesthetics with classifications and basics of driver seat. Jeong et al. [7] identified the new mechanism of rear seat reclining that enhances the comfort. Kim et al. [8] investigated the potential benefits of seat belt pretensioners and load limiters in the rear seat for the new EuroNCAP condition.

Park et al. [9] presented overview of recent evolution of seat structures and development of seat along with its design, optimization and validation. Through their study, they proposed a competitive seat frame, design guidelines and standard development procedure. Kole [10] developed an Integrated Structural seat that provides the benefits of an integrated three-point safety belt while minimizing the weight and cost. Patil and Kumar [11] illustrated use of composite materials for light weighting bus seat. Modelled the seat by taking into consideration the ergonomics, safety, weight and cost related issues. Arienti et al. [12] designed lightweight seat for high performance car taking into account a rear impact, i.e. the crash due to an impulse applied from the rear. The basic parameters of the seat structure were derived resorting to simulations of a crash with a test dummy positioned on the seat. Vink et al. [13] performed three experiments to test the effects of light weight seats and parts of a seat on comfort. Prasad [14] carried out weight optimization of a seating structure of TATA ACE 2nd Row Bench seat which is already a validated model, without compromising the performance, regulatory and non-regulatory compliances of the seating system. Khode et al. [15] designed light weight seat structure for wheeled armoured amphibious combat vehicle, and carried out shape optimization without affecting strength and comfort of soldier. Reynolds and Paul [16] combined a systems anthropometry model with a force deflection model of the seat and soft tissue digital human model (DHM) to design seat specifications for the driving package. With the systems anthropometry model, they optimized seat design for calculated driver positions and postures.

## III. FACTORS AFFECTING SEAT DESIGN

Wide varieties of parameters must to be considered while designing a driver seat in order to deliver the basic functions of seat as discussed earlier effectively.

**1. Ergonomics related parameters:** Ergonomics is branch of design engineering applied to automotive seat design requires that we take into consideration how the products we design fit the people that are using them. When seat fit to the driver it gives more comfort, less stress and maintains good psychological and health condition of driver. Ergonomics can be an integral part of design, manufacturing and use. Knowing how the study of anthropometry, posture, repetitive motion, and work space design affects the user is critical to a better understanding of ergonomics as they relate to end-user needs.

**i. Anthropometry:** Anthropometry is the branch of science that deals with human body measurement. Anthropometrical data is used for dimensioning of seat. The figure below represents the average European Anthropometry [5].

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No. (see fig.)	Description of Measurement	Percentile		
		5	50	95
9	sitting height	790	905	985
10	eye height	680	790	860
11	shoulder height	510	623	695
12	shoulder-elbow length	288	346	410
13	elbow height	190	243	280
14	thigh clearance	112	146	170
15	elbow-wrist length	240	279	318
16	elbow to elbow breadth	380	478	540
17	shoulder breadth, bi-deltoid	395	474	485
18	shoulder breadth, bi-acromial	320	380	425
19	hip breadth	333	368	440
20	lower leg length (popliteal height)	380	444	495
21	abdominal depth	195	237	350
22	knee height	460	530	602

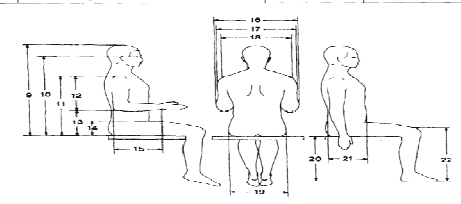


Fig. 7. European anthropometrical data [5]

- In this 95<sup>th</sup> percentile dimensions should be considered to ensure that human of any category can comfortably accommodate on seat.
- Seat Base width: In the above figure we can see that Hip breadth for 95<sup>th</sup> percentile human is 440mm. Thus, width of seat base should be greater than 440mm.
- Seat back height: The min. seat back height should be shoulder height minus half of thigh clearance, i.e. 695-85=610 mm.
- Seat back Width: The min. seat back width should be greater than the shoulder width that is 425 mm.
- Seat base Depth: The European anthropometry used for deciding depth of seat base is as shown in fig. below.

For proper ergonomics seat should be designed taking in to consideration the anthropometrical data of that particular region.

**ii. Comfort Related Parameters:** Comfort is feelings like relief, encouragement, enjoyment and stable. Comfort is dependent on pressure distribution over the seat, thermal comfort, vibration at driver body, geometric parameters etc.

**a. Pressure Distribution over Seat:** For better comfort and proper maintenance of driver health uniform pressure distribution along the human body over the seat is very important parameter. Pressure distribution over a seat is dependent on the properties of cushion material such as stiffness, deflection and design of cushion. Also it depends on nature of loading, seat pan design and backrest design. A proper seat pan contour distributes a uniform pressure over seat and avoids concentration of stress in human buttocks. Properly inclined back rest avoids stresses at buttocks [6].

**b. Thermal Comfort:** It is most important ergonomic parameter on which comfort as well as health of occupant is dependent. Generally seat cushion materials (seat cover, PU foam and coconut fibres) absorb heat from occupant body and acts as heat reservoir, this phenomenon is good for health in winter season but responsible for discomfort in summer season. This problem can be overcome by using different types of seat covers depending on seasons [6]. For seat to be thermally comfortable, most of the advanced automotive seats provide localized heating and cooling (i.e. HVAC) within seat itself.

**c. Vibration:** Non uniform road surface is responsible for vibrations of automotive seats. Human body can sustain 4-7 Hz frequency vibrations. Some tractor semi-active hydraulic and active mechanical hydraulic actuators (i.e. suspension systems) are used to attenuate vibration transferred to the driver. Driver seat is so designed that very less vibrations



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transferred to driver. If the seat natural frequency matches with vehicle ride frequencies, the seat may affect vehicle ride handling characteristics, causing squeaks, rattles and high magnitudes of vibration, leading to occupant discomfort. If the seat natural frequency matches with human body frequencies, then the occupant body components may undergo large motions resulting in extreme discomfort [6].

**d. Lumbar Support:** Driver works extended periods of times therefore proper lumbar support is very important in order to maintain the position of vertebrae. Large number of anthropometric data is required for proper design of seat which provides support to lumbar. Proper lumbar support can be achieved by maintaining profile of seat cushions of PU foam material [6].

**e. Seat adjustments:** Depending upon the anthropometry proper adjustments should be provided to seat. The longitudinal (forward & backward) adjustment of seat should be in such a way that it accommodates occupant of any shape and size comfortably[7]. The reclining and height adjustment mechanism should be provided depending upon type of vehicle. All the adjustments should be provided such that they provide following parameters,

- Proper reach to various controls and devices.
- Good visibility.
- Good headroom, legroom and knee clearance.

**f. Virtual pivot point location:** The pivot point location for seat is as shown in figure below.

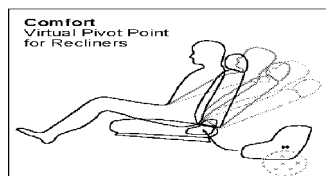


Fig. 8. Virtual pivot point location

Various parts of human body have a virtual pivot point. For ensuring comfort, pivot point of recliner and pivot point of human being should match each other.

**g. D- Point:** It is the lowest point on the buttocks contour of human being. It measures how far occupant will sink into the seat in  $-Z$  direction. It is used to avoid hard points or in other words human to metal contact in the seat that may make the occupant uncomfortable.

**iii. Theseating reference point (SgRP):** It is the location of a special hip point (H-point) designated by the vehicle manufacturer as a key reference point to define the seating location for each designated seating position. Thus, there is a unique SgRP for each designated seating position (e.g., the driver's seating position, front passenger's seating position, left rear passenger's seating position). An H-point simulates the hip joint (in the side view as a hinge point) between the torso and the thighs, and thus it provides a reference for locating a seating position. In the plan view, the H-point is located on the centreline of the occupant.

**iv. Occupant Packaging:** Seat should be designed to ensure proper occupant packaging as shown in figure below.

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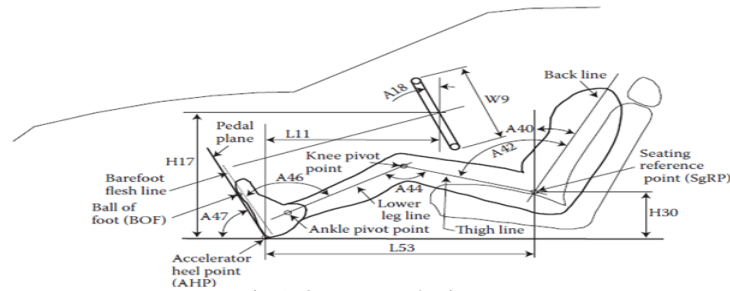


Fig. 9. Occupant packaging

The parameters affecting occupant packaging are described as below,

- a. AHP to SgRP location: The horizontal and the vertical distances between the AHP and the SgRP are defined as L53 and H30, respectively.
- b. Posture angles: The driver's posture is defined by the angles of the H point device (SAE J826). The angles shown in the previous slide are defined as follows:
  - Torso angle (A40): It is the angle between the torso line (also called the backline) and the vertical. It is also called the seat back angle or back angle.
  - Hip angle (A42): It is the angle between the thigh line and the torso line.
  - Knee angle (A44): It is the angle between the thigh line and the lower leg line. It is measured on the right leg (on the accelerator pedal).
  - Ankle angle (A46): It is the angle between the (lower) leg line and the bare-foot flesh line, measured on the right leg.
  - Pedal plane angle (A47): It is the angle between the accelerator pedal plane and the horizontal.
- c. Steering wheel: The centre of the steering is specified by locating its centre by dimensions L11 and H17. The steering wheel centre is located on the top plane of the steering wheel rim. The lateral distance between the centre of the steering wheel and the vehicle centreline is defined as W7. The diameter of the steering wheel is defined as W9. The angle of the steering wheel plane with respect to the vertical is defined as A18.

**2. Safety Related parameters:**Accidentals safety to the occupants is most important thing while designing anautomotive seat. Safety to head, leg and entire human body is very important. For safety of head, air bags and seat belts are provided in seat and its compartments. Also active head restraint is best device for the safety of driver neck.

**i. Pro active head restraint for neck safety:** Main function of any head restraint is to provide support to head during collision i.e. to minimize whiplash injury to neck. This is an advanced head restraint which uses a mechanism which activate during the rear end collision and catches driver head. By using such head restraint reduces the whiplash injury to neck by 10-20%.

**ii. Head safety through air bags:** Head is important part of human body, for its safety air bags are provided at front as well as at window side, which reduces the injuries to head during front and side collisions. Air bags such as pelvis restraint cushion and side airbags are provided within seat itself for advanced safety [6].

**iii. Safety through seat belts:** Seat belts are important part of seat from safety point of view. Seat belt holds the driver body on the seat. Seat belts should be designed and located properly. Parameters of seat belts such as seat belt pretensioning and load limiters should be carefully set. Seat belt anchorage should have sufficient strength and should not get ejected out during crash [8].



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**3. Health of Driver:** Long driving period effects on human body so seat must be designed for high comfort and safety. Spinal stability is important while driving a vehicle. A well-shaped seat cushion can support to the lumbar and maintain proper curvature of lumbar.

**4. Overall weight of Seat:** Weight of vehicle affects on the fuel consumption of vehicle. In order to maintain low weight of a vehicle, seat must be light in weight. Designer must study the lightweight materials and by using those materials a light weight seat can be designed. The performance and design criteria for seat systems require that the seat be lighter for reduced fuel consumption while still meeting the safety requirements specified by legislation[9].

**5. Aesthetic Related Parameters:** Apart from strength, life, safety and materials used for seat, physical appearance of seat is most important factor to attract the customers and to increase the sale. Colour, shape and size of seat are three important aesthetic parameters of seat.

- **Colour:** Trim is the outermost part of seat. So for better appearance its colour must be attractive and pleasant to the eyes. Also material of trim must be of better quality and it should not absorb water as well as does not attract particles of dust, can be clean just by wiping out.
- **Shape and Size:** Seat should be compact and well-shaped so that it look better and suit to the occupant body.

**6. Cost of Seat:** Seats are the second most expensive parts in car after engine. To reduce the overall cost of vehicle it is necessary to design low cost seat. For this purpose cost optimization and mass production of seat is very important aspect. For high end cars where cost is not an issue, designers can go for high quality of material and all advanced safety systems in a driver seat. Manufacturers are forced to make automobile seats which have improved safety and comfort performance while minimizing the manufacturing cost to be competitive [10].

### IV. CONCLUSION

For designing of seat it is necessary to understand which type of seat is to be designed, functionality of seat and accordingly various components associated with it. Once the type and functionality of seat are determined, various features of seat such as integrated or adjustable head restraint, continuous or discontinuous recliners, manual or power adjusters, with or without airbags etc. can be defined. The paper presents all the factors systematically one by one. All the factors discussed in this study directly or indirectly affects designing of seat. Factors affecting design of automotiveseat are very complex in nature and also requires detailed study of human anthropometry. Human anthropometry plays a major role in dimensioning of seat and delivering proper comfort to occupants. Among all the parameters presented in the paper, Ergonomics, comfort, safety, weight and cost are the main parameters that affect designing of seat. Weight and cost target of seat influences the material selection for seat, which is also one of the important factor which should be taken into consideration while designing of seat.

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