

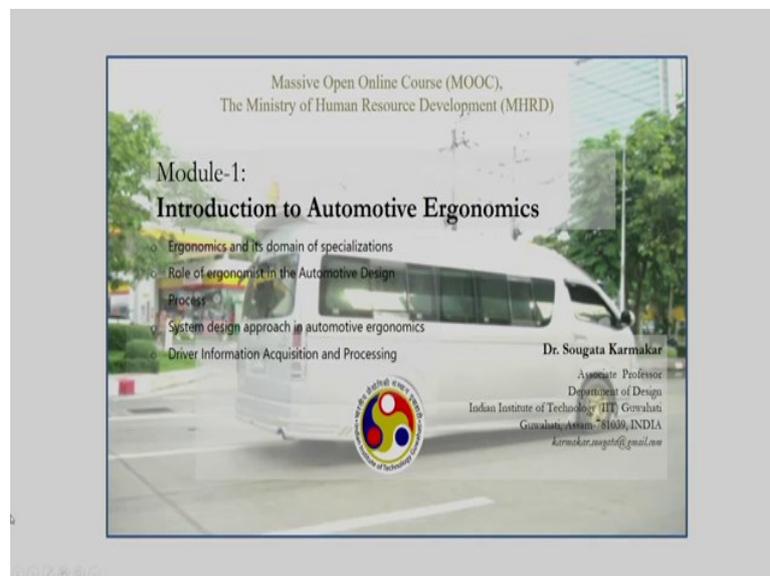
**Ergonomics in Automotive Design**  
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**Module - 01**  
**Part - I**  
**Lecture - 01**  
**Ergonomics and its domain of specializations**

Welcome to the course Ergonomics in Automotive Design. So, this course; from the title, it is evident that this is related to, how we can apply Ergonomic principles in the automotive design process.

And this automotive design, here we are discussing automotive design; this automotive design, means, not only an automobile but all other automotive products; including on-road vehicle, off-road vehicle and different types of two-wheeler, four-wheeler, three-wheeler. So, all are coming under these automotive products. But during the course; we will mainly concentrate on four-wheelers, and that is the passenger car.

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Now; today we are going to discuss our first module; that is Introduction to Automotive Ergonomics. And in this module; there are four topics. So, the first topic is, Ergonomics and its domain of specialization; this one. Next; role of Ergonomist in automotive design process; that is the second one; third one is system design approach in automotive

ergonomics and the last one; driver information acquisition and processing. So, now we are starting with the first topic; that is, Ergonomics and its domain of specialization.

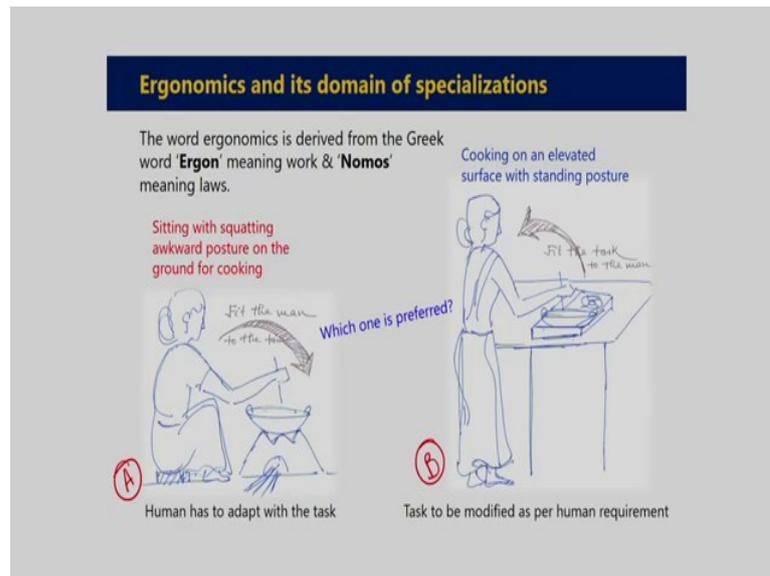
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Now, if you look at this picture; then what we can see, there are two-wheelers, there are three-wheelers; two-wheelers are there, three-wheelers are there. There are different types of vehicles; starting from on-road vehicle, off-road vehicle and their use purpose is also different; some vehicles are being used for civilian purpose, some for military purpose or defence purpose. So, there is huge variation in vehicle design. Now, while we are designing this type of automotive vehicle or automotive products; then what is happening?

It is very challenging for the ergonomist as well as for the designers to design this type of vehicle where we can accommodate the passenger or driver or even maintenance person or the assembly worker; that there is different variation in terms of their body dimension, in terms of their force capability, in terms of their various psychological needs. So, this is really challenging; that how we can make the automotive product compatible with the intended users. So, that is the biggest challenge for the designer as well as for the ergonomist. So, the varying anthropometrical abilities, biomechanical abilities as well as cognitive abilities; that need to be looked into while we are designing this type of automotive products.

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Now, what is Ergonomics? So, first; Ergonomics; this word actually came from Greek word 'Ergon' meaning work and 'Nomos' meaning law. So, in combination; this is the Law of Work. Now, if we look at these two images; one; one lady is cooking while sitting on the ground in squatting posture. And in another image; what we can see? We can see, the lady is standing and cooking on a raised platform.

So, if we consider this is a scenario A and this is the scenario B, then which one is preferable for us (in terms of or from the viewpoint of ergonomics)? So, what is happening here? That lady can sit on this stool, she is getting some support, and she can also view what she is cooking. But having difficulty in bringing utensils or other items, whatever required for the cooking. In this case; the lady is standing, she is free to walk, she can move around, and she can cook. So, out of these two scenarios; from the viewpoint of ergonomics, we can prefer; this one. Why we are preferring this one? Because in this scenario; what is happening? We are fitting the task to the human being, whatever the task, the task is being designed as per the requirement of human being. But on the other hand; if you look at scenario A; in this case; what is happening? We are forcing the human being to be fitted with the task. The task is on the ground, and we are forcing the human being; yes; you have to be fitted with this task.

So, that is not the motto of ergonomics; that is not the goal of ergonomics. In ergonomics, we always have to try that; how we can re-design the task, re-design the product, re-design the work accessories or in other words how we can design the whole system. So that, it is compatible, it is comfortable for the human being, and we can

improve the performance and efficiency. So, from ergonomics consideration; this is the preferable scenario.

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**Ergonomics and its domain of specializations**

- Fit the task to the person
- Use the "rules of work"
- Work smarter, not harder
- Make things user-friendly

Ergonomics can be defined as "science, technology & art of man at work" (Sen, 1979)

**Ergonomics (or human factors)** is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance. (IEA, 2000).

**Practitioners of ergonomics and ergonomists** contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people (IEA, 2000).

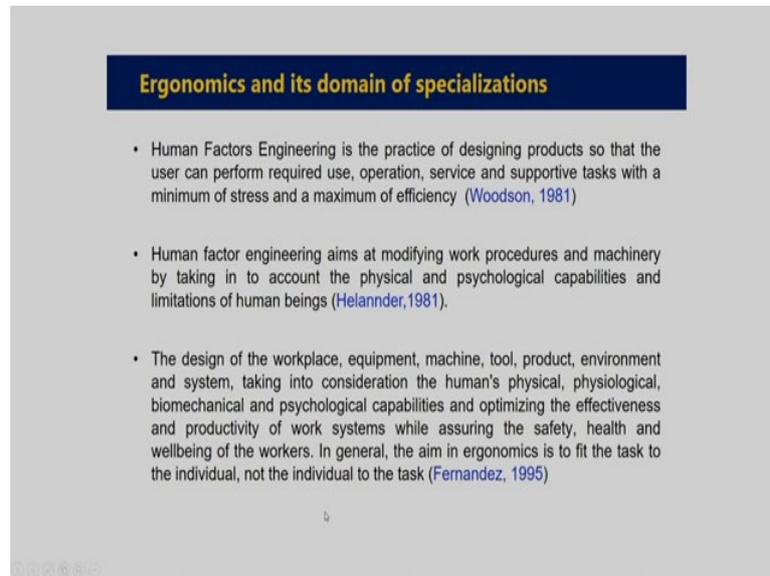
Now, as we mentioned; there are numerous definitions of Ergonomics. In brief, generally, various authors have defined ergonomics like this - four points. First one; fit the task to the person; use the rule of work, work smarter not harder and make things user-friendly. In India; this subject, Ergonomics was introduced long back, in 1945. The first course related to ergonomics was started in Calcutta University, and that is also by our pioneer ergonomist Professor R. N. Sen.

So, according to R. N. Sen, what is the definition of Ergonomics? Ergonomics is the science, technology and art of man at work. So, this is a nice definition, where he is mentioning that ergonomics is not only a science branch or a technology branch or art; rather this is the culmination of all these disciplines. International Ergonomics Association (IEA, 2000) they also defined Ergonomics. So, according to their definition, ergonomics or human factors is a scientific discipline concerned with understanding of interactions among humans and other elements of a system. And the profession that applies theoretical principle, data and methods to design in order to optimise human well-being and overall system performance.

According to IEA; what is the definition of ergonomist or practitioner of ergonomics? Practitioners of ergonomics and ergonomist contribute to the design and evaluation of

tasks, jobs, products, environments and system in order to make them compatible with the needs, abilities and limitations of the people. So, what is the definition of Ergonomics, as well as who are Ergonomists; that definition has been provided by IEA.

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**Ergonomics and its domain of specializations**

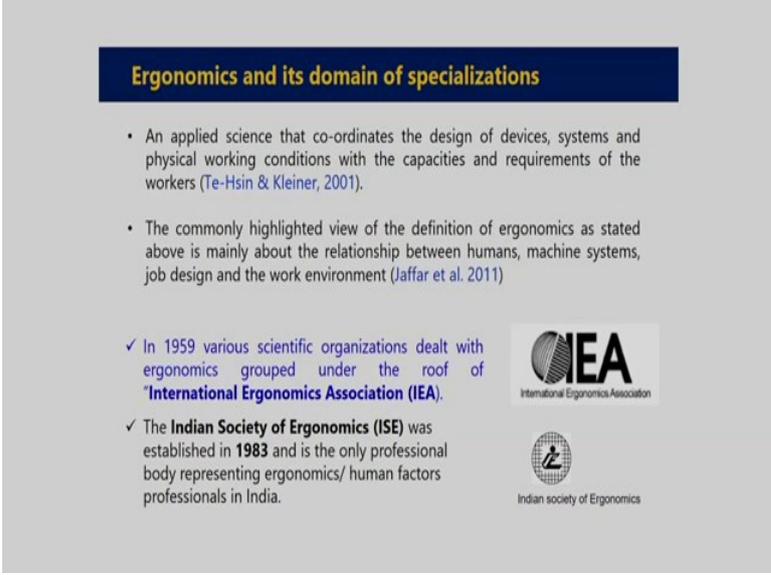
- Human Factors Engineering is the practice of designing products so that the user can perform required use, operation, service and supportive tasks with a minimum of stress and a maximum of efficiency (Woodson, 1981)
- Human factor engineering aims at modifying work procedures and machinery by taking in to account the physical and psychological capabilities and limitations of human beings (Helander, 1981).
- The design of the workplace, equipment, machine, tool, product, environment and system, taking into consideration the human's physical, physiological, biomechanical and psychological capabilities and optimizing the effectiveness and productivity of work systems while assuring the safety, health and wellbeing of the workers. In general, the aim in ergonomics is to fit the task to the individual, not the individual to the task (Fernandez, 1995)

Now, there are so many other definitions by other authors, other researchers. So, to mention a few, here, three definitions are mentioned; if we look into this. So, first one; Human Factors Engineering is the practice of designing products so that the user can perform required use, operation, service and supportive tasks with minimum stress and maximum efficiency. Now another definition by Helander (1981); according to this definition, Human Factors Engineering aims at modifying work procedures and machinery by taking into account the physical, psychological capabilities and limitation of human beings.

Similarly, there are so many other definitions. The definition provided by Fernandez (1995); so, according to this; the design of workplace, equipment, machine, tool, product, environment and system taking into consideration the human's physical, physiological, biomechanical, psychological capabilities and optimizing the effectiveness and productivity of work systems; while assuring the safety, health wellbeing of the workers. In general; the aim of ergonomics is to 'fit the task to the individual' not 'individual to the task', which we have also mentioned earlier; with this scenario; that always we should try; that is the main principle of ergonomics,

we should try to fit the task as per the requirement of human being. We will never try to force a human being to be accommodated with the task; this is not our goal. Our goal is that; from the viewpoint of ergonomics; that we have to fit the task as per the requirement of a human being.

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**Ergonomics and its domain of specializations**

- An applied science that co-ordinates the design of devices, systems and physical working conditions with the capacities and requirements of the workers (Te-Hsin & Kleiner, 2001).
- The commonly highlighted view of the definition of ergonomics as stated above is mainly about the relationship between humans, machine systems, job design and the work environment (Jaffar et al. 2011)

✓ In 1959 various scientific organizations dealt with ergonomics grouped under the roof of **International Ergonomics Association (IEA)**.

✓ The **Indian Society of Ergonomics (ISE)** was established in **1983** and is the only professional body representing ergonomics/ human factors professionals in India.

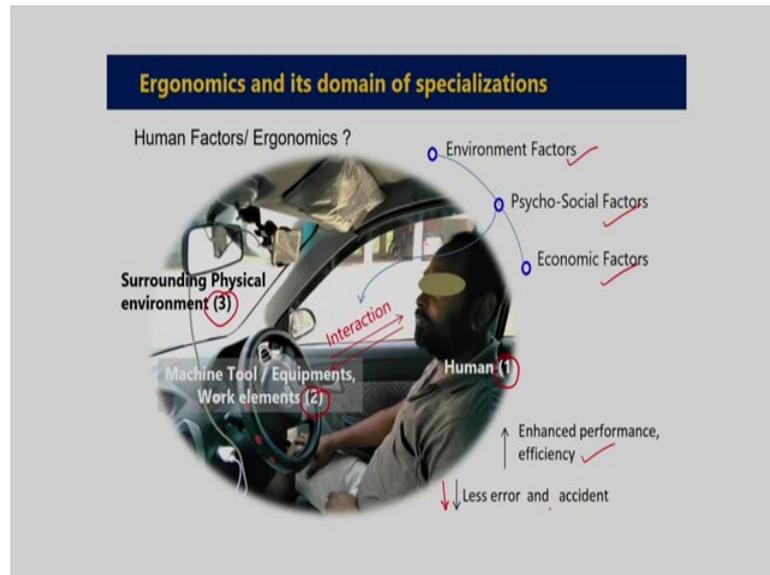


Now; few other definitions. So, what is Ergonomics and Human Factors Engineering; this is an applied science that coordinates the design of devices, system, physical working conditions with the capabilities and requirements of the workers.

So, this definition is from the industry's perspective. The commonly highlighted view of the definition of ergonomics as stated above is mainly about the relationship between humans, machine systems, job design and the work environment. So, this definition was provided by Jaffar et al. in 2011. Now in this context; while we are discussing about; what is ergonomics, its definition and about various definitions provided by various authors; in this context, it is important to know about the society or association of ergonomics which is present all over the world.

So, in 1959, various scientific organizations dealing with ergonomics grouped under the roof of International Ergonomics Association (IEA). This International Ergonomics Association (IEA) was established in 1959. On the other hand; In India, in 1983, the Indian Society of Ergonomics was established, and this is the only professional body representing the ergonomics and ergonomics related professionals in India.

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Now, we are coming to the Automotive Ergonomics. So, earlier we have discussed about the general definitions of ergonomics. Now particularly; what is Automotive Ergonomics? Automotive ergonomics is nothing but consideration of ergonomic principles and use of ergonomic tools and techniques in the field of automotive design process.

Now, if you look at this image, so, this is one driver, and the driver is interacting with the vehicle components; there is steering wheel, brake, clutch and so many other controls/displays. So, while this driver is interacting; driver (that human being) is interacting with this machine, tools, equipments or work elements inside the vehicle, even outside the vehicle; while this interaction is happening, this interaction is actually being influenced by so many other factors; what are those factors? Environmental factors are there, psycho-social factors are there, economic factors are there.

So, all these factors are ultimately affecting this interaction; how will be the interaction? Whether this interaction is good or bad; that is actually being decided by various factors, which are the influencing factors. Now, during this interaction, there are three components; one component - that is the human being, another is the work accessories and the third component is the surrounding physical environment. These three components - human, work accessories or tools or equipment and the surrounding

physical environment; these three components are together making the whole system. Then, what is the goal of Automotive Ergonomics?

The automotive ergonomics is actually dealing with this type of interaction; not only with the driver or passenger and the vehicle component; but on the other hand, all other people who are engaged in this process, who are those people? Say, for example, those who are designing these vehicles, those who are designing vehicle components, those who are making or assembling the parts or developing the vehicle. Then, there is also maintenance operation; there is also personnel who are engaged in service, so, all these people. While they are interacting with the vehicle or vehicle system; then what is happening?

If we can consider the ergonomic principle in the design process, then what will happen? It will ultimately lead to enhance performance, productivity, efficiency, at the same time reduction of error and accident. So, what is the overall definition? So, from this scenario, how we can define ergonomics? So, from this scenario, we can define ergonomics or automotive ergonomics; that automotive ergonomics is a specialized branch of ergonomics where we are discussing about the human compatibility with automotive products and all other factors which affect that interaction; these are those factors. Here we discuss about all other factors which are affecting these interactions. Why? So, that we can improve the performance, efficiency, productivity of the overall system; not only the user's performance will be increased, at the same time overall system performance; (that system comprises of human, surrounding environment, equipment, surrounding physical environment). The whole systems performance, efficiency, productivity should be increased; at the same time there should be less chance for error and accident.

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## Ergonomics and its domain of specializations

### Human Factors vs. Ergonomics

**Human factors** puts much emphasis on the integration of the human considerations into the total system design process.

**Country of origin:** In USA, a discipline emerged (known as 'Human Factors')

**Subjects of origin:** Psychology (applied experimental psychology, engineering psychology and 'human engineering') (Bridger, 2003).

**Ergonomics** is traditionally been more tied to its basic sciences or to a particular topic or application area.

**Country of origin:** European countries.

**Subjects of origin:** The emphasis was on equipment and workspace design and the relevant subjects were held to be anatomy, physiology, industrial medicine, design, architecture and illumination engineering. (Bridger, 2003).

In USA, the Human Factors Society has recently changed its name to the **Human Factors and Ergonomics Society**.



Now, as these two terms are repeatedly coming; one is Human Factors, and other is Ergonomics; Human Factors Engineering and Ergonomics. So, now for the students, they are confused; whether these two terms are different, or they are synonymous? So, what is the actual difference, or you can also think; are these two terms; we can use these terms interchangeably? Yes. Now, we can use these two terms interchangeably, and we can assume that these two terms are synonymous, means, their meaning is similar.

But if we look into history, then what we will find? The human factors, in terms of country of origin, wherefrom it originated; this subject Human Factors Engineering or human factors, it evolved from USA, United States of America. On the other hand; the subject ergonomics originated from European countries.

Now, subjects of origin - from which subjects; this Human Factors originated; or which are the mother subject of this subject Human Factors? So, its origin subjects are mainly psychology, means; it started from cognitive ergonomics perspective. While human factors started, it actually evolved from the psychology background; applied experimental psychology, engineering psychology, and human engineering. It means; initially the subject Human Factors was actually dealing with the cognitive aspects of ergonomics or human factor. But in case of ergonomics; it originated from subjects like anatomy, physiology, industrial medicine, design, architecture, illumination engineering, like this type of subjects.

And so, during its origin; ergonomics mainly looked after the issues related to physical aspects; while human factors were dealing with cognitive aspects. But later on; what happened? In human factors; all these issues related to physical aspects came under; that is why; now in human factors; we are dealing with both physical aspects as well as cognitive aspects. On the other hand; in case of ergonomics; when it originated it was mainly physical aspect related, means, physical ergonomics aspects. But later on; it also included the cognitive aspects, that is why there is as such no difference among these in present time scale.

So, we can use ergonomics and human factors interchangeably. In the USA; the Human Factors Society recently changed its name to Human Factors and Ergonomics Society (HFES); earlier it was Human Factors Society. As the human factors and ergonomics are similar or you can use synonymously; that is why they changed its name to Human Factors and Ergonomics Society.

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### Ergonomics and its domain of specializations

- ✓ Human Factors/ Ergonomic issues are considered from the **very beginning** of the automotive the design process (since inception of **pre-conceptual phase**).
- ✓ The purpose is to address and accommodate the various needs/ expectations of the users/ customers including
  - (a) the occupant (e.g. drivers and passengers), and
  - (b) the personnel involved in assembly line, maintenance, service etc.

Basic need of the drivers			
Features	Safety	Efficiency	Aesthetics
Mobility ↑ ✓	Crash Avoidance ↑ ✓	Cost/mile ↓	Entertainment ↑
Comfort ↑ ✓	Crash Protection ↑ ✓	Pick-up ↑	Stylish Looks ↑
Convenience ↑ ✓	Accident Prone ↓ ✓	Fuel economy ↑	Well Crafted ↑

Now, ergonomics and its domain of specialization; under that; we are discussing about what are the human factors or ergonomic issues (when we consider) in automotive design process. So, frankly speaking, there is no specific point to start; Ergonomics is actually present throughout the whole design process of automotive products.

It starts from the very beginning stage, that is the conceptual phase of automotive design process. The purpose is to add and accommodate the various needs and expectations of

the users or customers. The users and customers include the occupants (that is the driver, passengers, different vehicle occupants). On the other hand, the personnel involved in assembly line maintenance service.

So, while we are thinking about the automotive ergonomics or automobile ergonomics; then we are not only considering passengers and driver but we also need to think about the other personnel who are involved in its assembly line, component design, maintenance, service; so, all these people we have to consider. Then how we can develop the automotive design? How can we make the automotive design process more human-friendly, more user-friendly?

So, now the basic needs of the driver; what are the basic needs while designing the automotive product? Particularly, say; for passenger car. So, obviously; we to have to think about various features like mobility, comfort and convenience. We also have to think about the various safety aspects; how we can avoid crash, how we can protect from the crash, how we can reduce the accident proneness; similarly, we have to think; how using ergonomic principles; we can increase the efficiency; that is the cost, mileage, how we can increase the pickup, how we can increase the fuel economy?

On the other hand; we have to also think about the aesthetic part, that is entertainment, stylish look, then craftsmanship. So, these aspects also we have to consider while developing that automotive products.

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### **Ergonomics and its domain of specializations**

#### **Why ergonomics is necessary for automotive design?**

- Developing superior automotive products by enhancing user satisfaction in terms of functionality, usability and aesthetic.
- Ergonomically designed automotive products are generally more user compatible, efficient and safer.
- Accommodating wide range of user population with varied age, gender, somatotypes, anthropometric and biomechanical characteristics.
- Consideration of ergonomics helps in reduction of both physical and cognitive load during operation (driving, manufacturing, maintaining etc.) of the vehicle.
- Ensures various usability dimensions, e.g. effectiveness, efficiency, engaging, error tolerance and easy to learn.
- Helps to meet all pre-selected ergonomic standards & requirements.

Now, why ergonomics is necessary for automotive design? Firstly, for developing superior automotive products, by enhancing user satisfaction in terms of functionality, usability as well as aesthetic. Ergonomically designed automotive products are generally - more user compatible, efficient and safe, can accommodate a wide range of customers or user population (who have variation in terms of age, gender, somatotype, anthropometric and biomechanical characteristics). So, all these features need to be accommodated in the automotive product.

If we consider one automotive product like passenger car; then while we are designing that passenger car; we cannot mention that this passenger car is only for this particular group of people. We have to think that how we can accommodate in that product; all type of people (with variation in their age, sex, somatotype, difference in physical capabilities, as well as their aesthetic needs). Consideration of ergonomics helps in reduction of both physical and cognitive load during operation.

So, the vehicle should be designed in such a way that, while the operator, means, any user is using that vehicle or automotive product, his cognitive as well as physical load for operating that vehicle should be as less as possible. Further; various usability dimensions like effectiveness, efficiency, engaging, error tolerance and easy to learn; these have to be ensured. Then it helps to meet all pre-selected ergonomic standards and requirements. If we consider ergonomic design principles in the automotive design process, then what will happen? Obviously, it will help to meet the pre-selected ergonomic standards and requirements.

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## Ergonomics and its domain of specializations

<p>✓ <b>Physical Ergonomics</b></p> <ul style="list-style-type: none"> <li>➢ Human Anatomy</li> <li>➢ Anthropometry</li> <li>➢ Physiology</li> <li>➢ Biomechanics <ul style="list-style-type: none"> <li>◆ Posture ◆ MMH ◆ Safety</li> <li>◆ Repetitive movements</li> <li>◆ MSD</li> </ul> </li> </ul>	<p>✓ <b>Cognitive Ergonomics</b></p> <ul style="list-style-type: none"> <li>➢ Mental Processes <ul style="list-style-type: none"> <li>▪ Perception</li> <li>▪ Memory</li> <li>▪ Reasoning</li> <li>▪ Motor Response</li> </ul> </li> </ul>	<p>✓ <b>Organizational Ergonomics</b></p> <ul style="list-style-type: none"> <li>➢ Socio-technical Systems <ul style="list-style-type: none"> <li>▪ Organizational Structures</li> <li>▪ Policies</li> <li>▪ Processes</li> </ul> </li> </ul>
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Physical aspect

- Seating comfort
- Ease of maneuverability of controls (steering wheel, brake etc.)

Cognitive aspect

- Information access and processing from infotainment system
- Distraction of attention due to various stimuli from road

Organizational aspect

- Deciding the requirement of developing an advanced model following market research

Now, after discussing about human ergonomics, its importance in automotive design, now we are coming to the next portion. In this sub-topic; we are discussing about the domain of specialization. The subject Ergonomics or Human Factors can be categorized mainly under three domains of specializations; one - physical ergonomics, second - cognitive ergonomics and third one is the organizational ergonomics.

Under physical ergonomics we discuss about human anatomy, anthropometry, physiology, biomechanics and under biomechanics - posture, manual material handling, safety, repetitive movement, musculoskeletal disorders, this type of various aspects; physical aspects of human being and its compatibility with the automotive components are discussed under physical ergonomics.

So, here you can see while this person (that driver) is driving this vehicle then; if we want to study physical ergonomics aspects; then what will we study? We will study the seating comfort, whether the person can see outside, how his visibility is inside and outside the vehicle; say, how much ease is there in operating steering wheel, brake etcetera. Similarly; in case of cognitive ergonomics; we are discussing about the mental processes; that while driver or passenger or any other maintenance person is using that vehicle or working on that vehicle; then we have to think about these aspects of the human being - the perception, memory, reasoning, and motor response.

Now, if we take one example of cognitive ergonomics in case of passenger car; then which aspect should we deal? In case of cognitive ergonomics, we discuss about how

various information from the road or from inside the vehicle, various information through various sensory channels or our sense organs (we are perceiving and accordingly we are interacting, or we are driving the vehicle). So, information access processing from infotainment system or from, say, speedometer. So, the driver is perceiving that information, perceiving that and accordingly doing some muscular activity to control various control operations for navigating that vehicle.

Now, the third area is the organizational ergonomics; the organizational ergonomics is dealing with socio-technical system, organizational structure, policies, processes. In case of automobile design; what is the organizational aspect? Say, while one new automotive vehicle is being planned and is going to be designed, then deciding the requirement of developing an advanced model is happening inside that company, who is making that decision?

The decision of developing a new vehicle is actually taken by the industry management following market research. This type of decision making related to, what type of vehicle is required for a particular market segment; is coming under organizational ergonomics.

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**Role of Ergonomist in the automotive design process**

Automotive design process?  
The focus point from the start to end of a vehicle development program remains the same and that is the user/customer (either occupant or the personnel for manufacturing, assembly, maintenance, service etc.). User is considered as the **prime system component in Ergonomics**.

Major steps in vehicle development process (Bhise, 2016)

1. Understanding customers' need/ expectation
2. Product planning
3. Automotive styling and engineering
4. Detailed engineering
5. Prototyping, testing, and validation
6. Tooling design
7. Plant design and construction
8. Production of vehicles
9. Obtaining feedback after product usages

*The primary goal of ergonomist is to work with the vehicle design team to produce ergonomically superior vehicles. (Bhise, 2012)*

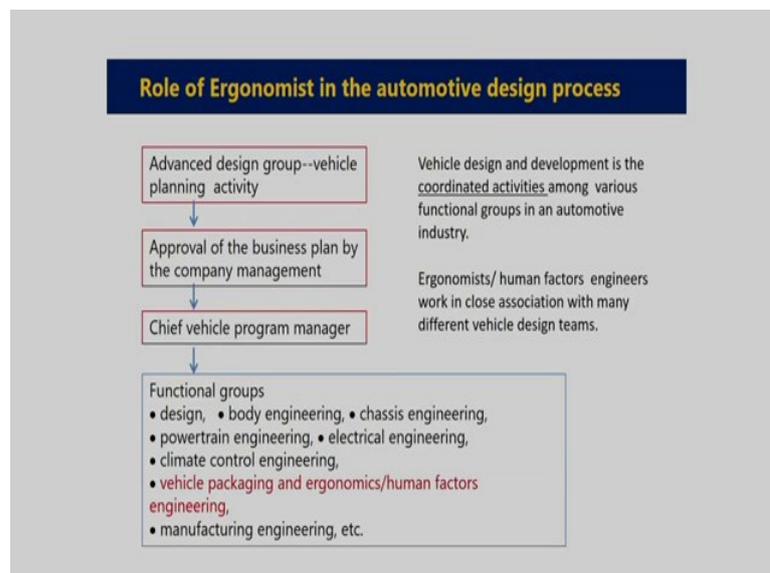
Now, the automotive design process; the focus point (from the start to end) of any automotive design process is a human being, means, user or customer. Who are those users or customer? Already we have mentioned; that this user is occupants and all other personnel who are involved in manufacturing, assembly, maintenance, and service.

So, they all are the key points. Focus of ergonomics is always starting with the human being; that is the user or customer. And even the whole automotive process is also ending with obtaining the feedback from the user or customer. So, the starting point; that is the understanding the customer needs and expectation (that is also with the human being) and it is also ending with the human being i.e. obtaining the feedback after the product uses. So, this is also coming from the human being, that is the user and customer.

So, major steps involved in the automotive design process, as mentioned by Bhise in his book Automotive Ergonomics (2016). So, he mentioned - understanding customer need and expectation, that is the first step. All these steps happen concurrently, not like one after another; it is a concurrent process. So, first one - understanding the customer needs, second - product planning, third - automotive styling engineering, then detailed engineering, then prototype, testing, validation, tooling design, plant design and construction, production of vehicle and obtaining feedback from the users.

The primary goal of ergonomist is to work with the vehicle design team to produce ergonomically superior vehicles. So, that is the main goal of ergonomist.

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Now, the role of ergonomist in the automotive design process; under this heading, we are discussing about the automotive design process and how ergonomist plays an important role. So, in the automotive industry, for a particular company that is planning for a new

automotive product; the advanced design group plans for that product or that vehicle. So, vehicle planning activity starts after approval from the higher authority or the management; then the business plan is decided by the company management, then they give the responsibility to the chief program manager.

And then, chief program manager constitutes the functional groups; these functional groups will actually be dealing with various members (who are looking after design aspects, body engineering, chassis engineering, power engineering, electrical engineering); in this way various functional groups are there who are also looking after climate control engineering, then vehicle packaging and ergonomics or human factors engineering, manufacturing engineering; so, various groups are working together. Out of these various functional groups; one important group is the vehicle packaging and ergonomics engineering group. These aspects are actually looked after by the ergonomists. So, vehicle design & development is actually a coordinated activity among various functional groups and among that groups; ergonomist or human factors engineers work in close association with many different vehicle design teams.

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**Role of Ergonomist in the automotive design process**

Ergonomists conduct research in the following three areas

1. Descriptive Ergonomics Research	2. Experimental Ergonomics Research	3. Evaluative Ergonomics Research
Providing data describing user characteristics of different populations	Conducting experiments to determine the effects of different design variables (individual components or whole vehicle) on the physical, physiological and psychological/ cognitive aspects of the users.	Comparing the proposed or intended vehicle design concepts with other benchmarked vehicles.
e.g. measurements and distribution of <ul style="list-style-type: none"><li>Anthropometric Data</li><li>Biomechanical Data</li><li>Range of Motion Data</li></ul>	e.g. Redesigning of seat and its impact on occupant comfort.	e.g. Determining how the newly incorporated features are superior than the existing one in terms of customers' rating

Ergonomists conduct research in the following three areas in the automotive design. So, first one; that is the descriptive ergonomics research. Second one - experimental ergonomics research and third one is the evaluative ergonomics research.

In first one - descriptive ergonomics research. So, although these three types of ergonomics research are carried out, but it does not mean that these are mutually exclusive, there is always overlapping or combination of research is happening. So, first one; descriptive ergonomics research, so, what is the role herein for the automotive ergonomist - providing data, describing user characteristics and different limitations. In automotive scenario; we can take the example of measurement and distribution of anthropometric data, biomechanical data, range of motion data of the driver, passenger as well as the people who are working in the factory shop floor or in the assembly line.

In experimental ergonomics research; ergonomists or ergonomics engineer conduct experiments to determine the effects of different design variables, individual components or whole vehicle, on the physical/physiological/psychological cognitive aspects of the users. For example; re-designing the seat and its impact on occupant comfort; another example; how better design of steering wheel or brake, clutch, accelerator can be done, so that it will be much more convenient for the driver to operate; so, this is coming under experimental research. On the other hand; evaluative research; where evaluation is happening, comparison is happening - which design feature is better than another one.

So, in this case, comparing the proposed or intended vehicle design concept with other benchmarked vehicles; for example, determining how the newly incorporated features are superior than the existing one, in terms of customer rating.

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### Role of Ergonomist in the automotive design process

Major tasks of the ergonomist during the life cycle of the vehicle (Bhise, 2016):

Ergonomists provide the vehicle design teams with needed

- ✓ ergonomics design guidelines,
- ✓ Information/data regarding targeted users,
- ✓ Ergonomic evaluation during design and development process
- ✓ recommendations for product decisions at the right time (called the "gateways" or "milestones") in front of the right level of decision makers (e.g. program managers, chief engineers, senior management, etc.).

Role of ergonomists in the automotive design process. So, next, we are discussing major task of the ergonomist during the life cycle of vehicle design. So, this content is also taken from Bhise (2016). So, ergonomist provides the vehicle design teams with – needed ergonomics design guidelines, information or data regarding targeted users, ergonomic evaluation during design and development process, recommendation for product decisions at the right time, that is called the gateway or milestones in front of the right level of decision-makers.

So, who are those decision-makers? Program manager, chief engineer, and senior manager. So, while the particular company is thinking about a new product or modification of the existing product. Then, while the management is taking decision then ergonomists play an important role by providing various feedback.

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**Role of Ergonomist in the automotive design process**

**Pre-conceptual phase**

- Benchmarking of selected competitive vehicles to understand different designs and ergonomic issues with these designs
- Survey of users' need as per the intended market segment (using questionnaire, interview etc. in the field or in design clinic)
- Gathering anthropometric, biomechanical data along with segment specific (culture/ region/economy) preference data for aesthetic variables.
- Making ready availability of various corporate, and regulatory standards and design guides including the standards of Society of Automotive Engineers, Inc. (SAE) for the project team members.
- Actively participate in design limit selection (Use context, Targeted user/ population, Physical dimension, Material, Cost, Manufacturability, Sustainability etc.) along with other functional team members

Now, how ergonomist plays active role in the various phases of automotive design process. So, all of we know there are mainly four phases in any product design process. First one - pre-conceptual phase, second one - conceptual phase, then pre-design stage and the last one is a detailed design stage. So, in all these four stages, ergonomists play an important role and they guide the design team so that ergonomically superior automotive products can be designed.

So, in the first phase that is the pre-conceptual phase; in pre-conceptual phase mainly information are gathered and design limits are selected; that within these design

constants or within these boundaries, that automotive product has to be designed or the existing product has to be re-designed for advanced features. Now, in pre-conceptual phase, what is the role of ergonomist?

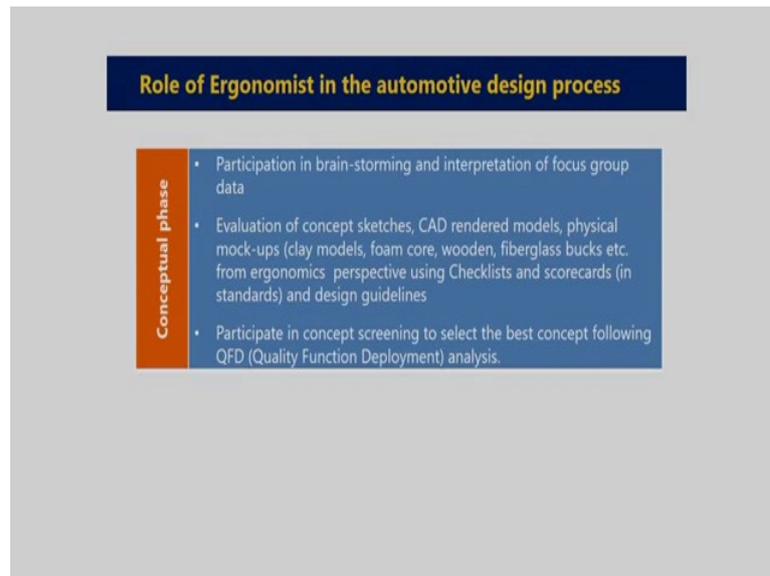
So, first - benchmarking of selected competitive vehicles to understand the different designs and ergonomic issues with these designs. Next, a survey of user needs as per the intended market segment using questionnaires, interview etcetera in the field or in design clinic. Gathering anthropometric data, biomechanical data, along with segment-specific preference data for aesthetic variables.

So, these different types of data related to customers or users physical body dimensional data (biomechanical data and various preference data), that - which type of form, which type of colour or which type of texture they like - that type of informations are to be gathered by the ergonomist and these information to be given to the design team.

Next, making ready, the availability of various corporate and regulatory standards and design guidelines including standards of Society of Automotive Engineers (SAE). So, that while the engineers or designers are conceptualizing that vehicle, they can take care of all these standard guidelines.

Next, ergonomist also actively participate in design limit selection, use context, targeted user population, physical dimension, material, cost, manufacturability, sustainability, so these different dimensions or different aspects of the design which are to be thought of before designing a vehicle or designing an automotive product. So, ergonomist plays a crucial role with other design team members.

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The next phase; that is the conceptual phase; in the conceptual phase, the vehicle concept is developed. There are various steps, starting from the sketching, mock-up development and evaluation of the mock-up. Now, how ergonomist or ergonomics engineer contributes in this second phase, that is the conceptual phase. So, they participate in brainstorming and interpretation of the focus group data. They also carry out evaluation of concept, sketches, CAD rendered models, physical mock-ups like clay models, foam core, wooden or fibreglass bucks etcetera; from ergonomics perspective using checklist, scorecards and design guidelines.

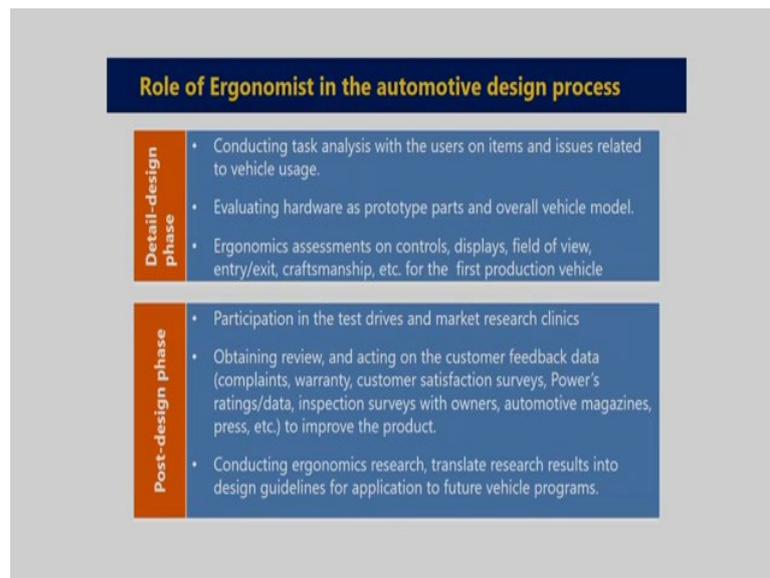
Ergonomists also participate in concept screening to select the best concept following QFD techniques, that is the Quality Function Deployment techniques. That out of various concepts which have been evolved; from the QFD technique they can also screen the best concept using these techniques. Next, the pre-design phase; in pre-design phase; mainly whatever the vehicle concept has been finalized, it is evaluated in terms of ergonomics aspect and engineering aspects. So, the ergonomist plays a crucial role in this phase because the CAD model or rendered CAD model is evaluated in virtual platform using CAD software with the help of digital human models.

So, ergonomists can create digital human models for the occupants and using those human models; they can evaluate various human factor issues in that vehicle design. Another activity is the user trial in the driving simulator and test bucks; to get insights of various human factor issues like occupant packaging, entry/exit, head clearance, field of view, visual obscuration, location of exterior lights, body cut lines, fuel filler location

etcetera. So, the various ergonomic aspects which are needed to be considered that are also tested through user trials in test buck.

Particularly, this is important; this type of testing is important or quick studies or experiments are required to resolve issues where sufficient information from available guidelines or earlier research is not available.

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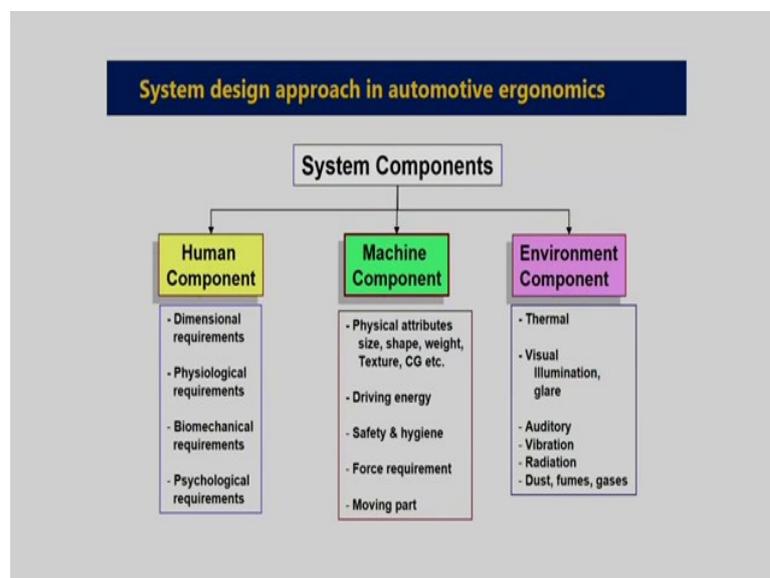
The next phase; that is the last phase - detailed design phase. In the detailed design phase, ergonomists conduct task analysis with the users in terms of issues related to vehicle usage. So, apart from task analysis they also evaluate hardware as prototype parts and overall vehicle model. Ergonomists also do assessments on control, display, field of view, entry/exit, craftsmanship for the first production vehicle. So, in the detailed design phase while the first production vehicle is coming; that first vehicle is also evaluated from various ergonomics perspective by the ergonomist or ergonomics engineer.

So, these are the main four stages in the design process. After that; while the design process is complete, and the product is launched in the market; then also ergonomists continue their role in the automotive design process; what they do? So, they also participate in the test drive and market research clinics to get; what are the difficulties which the test drivers are facing? And also, what type of feedback is coming from the market? So, they generally perform these activities in the market research clinics; they obtain reviews and act on the customer feedback data; that is the complaints, warranty,

customer satisfaction survey, power rating data, inspection survey with owners, automotive magazines and press.

So, from these various sources; they get the information and accordingly decide how further modification or improvement is required in the vehicle. Then conducting ergonomics research, they translate research results into design guidelines for application in future vehicle programs. So, this is the overall role of ergonomist in the various phases of automotive design process and also in post-design phases.

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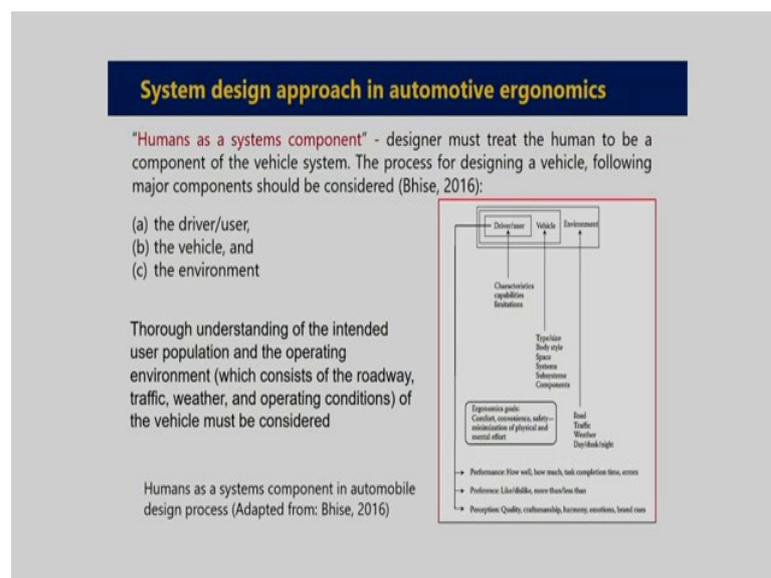


Now, we are moving to the next topic that is; the system design approach in automotive ergonomics. For any system, there are mainly three components; one is human component, machine component and the third one is the environment component. So, while we are talking about the system design approach in design; then we actually deal with all these three components. Under human component (that is the prime component). Human is the prime system component from the viewpoint of ergonomics; under human component; we discuss about the dimensional requirements or human compatibility with the machine components. Then human's physiological requirement, biomechanical requirements, psychological requirements. So, various human factor issues are considered under human component. Under machine components; various mechanical and physical properties of the machine components are discussed.

So, physical attributes of the machine or machine components like size, shape, weight, texture, centre of gravity location etcetera are discussed. Then, how is the driving energy, safety and hygiene issues, force requirement, moving parts and safety from the moving parts, these aspects are dealt in the machine component. The third one is the environment component; where that equipment or the machine is being used. So, there we are discussing about various physical environmental variables like temperature, humidity, illumination, vibration and noise. So, various environmental aspects are discussed under this environmental component.

So, overall while we are thinking about the whole system then, these three components and their relationship and how we can improve their interaction; we need to discuss, and we have to understand that one from the viewpoint of ergonomics.

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Now, human as a system component, thus designers must treat the human to be a component of the vehicle system. So, in automotive design; human is also a prime component, as in that automotive system, like as we mentioned earlier; three components are there; that is the driver, user, vehicle and environment - that driver or user is a prime component. Apart from that; there are other components like vehicle and its various characteristics; then environmental factors.

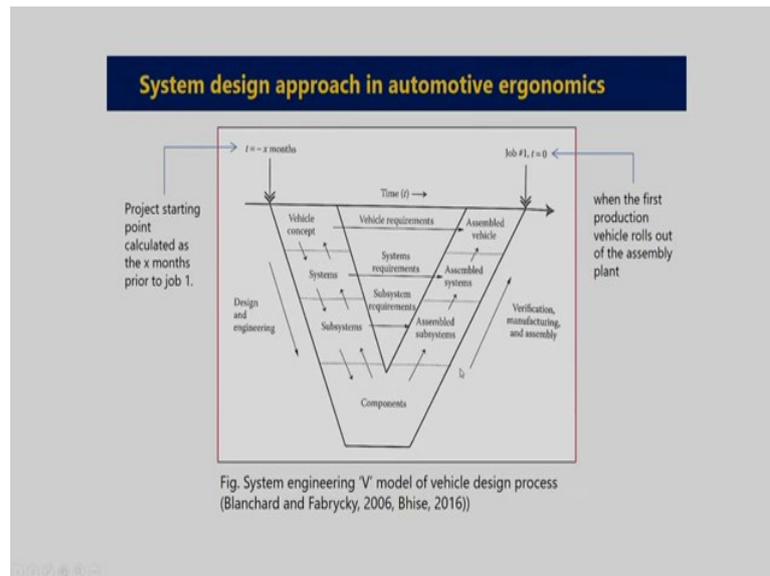
The whole system comprising of these three components have to be studied in detail. So, that, there should not be any compatibility issues. So, while we are designing a vehicle

these three components and these various characteristics, we have to study, like what are the driver characteristics or user characteristics? So, their physical capabilities, limitations, these aspects we have to look into. Similarly, in terms of vehicle component - type, size, body style, space, systems, subsystem components; these have to be taken care of. In terms of environment - road condition, traffic condition, weather condition, then the illumination level on the road.

So, these types of various factors, which can ultimately affect driving performance or these various environmental factors which can create driver distraction; we have to think about that one. Thorough understanding of the intended user population and the operating environment which consists of roadway (already we mentioned of the vehicle) must be taken into consideration; to overall address the system approach. Under this, so if we can consider the whole system; then what will happen? We can think about the performance - how well, how much task completion time, error of the driver; we can improve.

Preferences - like/dislike, more than/less than for a particular requirement; we can also study. Then the perception of the driver or user in terms of quality, craftsmanship, harmony, emotions, brand cues that are also needed to be discussed. So, in automotive design, while we are thinking about the ergonomics, we have to look ergonomics from the system perspective; not for the particular individual component (only for human being or only for vehicle component); not like that way. We have to think the whole system together.

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Now, we are going to discuss system design 'V' model in a vehicle development process. So, while one new vehicle proposal is accepted in the industry; then, it started with the 'job 1'. So, first we define the 'job 1'; 'job 1' means the time when the first production vehicle rolls out from the plant, so that is the first consideration. That is mentioned as 'job 1' and time is expressed at zero; that is the zero time. Now, when that product will ultimately be delivered and from that time in the negative direction; we consider the time period where the project is to be started; that is expressed like 'minus x' month, from this time 't' that is zero.

So, generally for a particular vehicle development process, while the industry is planning for the first production; from that point; 12 to 24 months on an average; they start the project. So, project starting point is calculated as the negative months. So, while the project is accepted, the designers or the whole functional design team (who are there) as already discussed, there are various team members, so they think about the vehicle concept. Then, that overall vehicle concept is divided into various systems and sub-system levels. And each of the sub-systems are then degraded to components level.

Now, this side of the 'V' that is from top to down, so top-down approach, design and engineering. So, in design and engineering processes; first, the overall vehicle concept is developed; then in that vehicle, what will be the system/sub-system and how will be the component; that is decided. In the next level; this side; verification, manufacturing and assembly is happening. This is happening in bottom to up direction; where the components - small components are assembled to develop the sub-system; while the sub-

system is ready; they are assembled to make the system; while the individual systems are ready then those are assembled to make the full vehicle.

So, there are actually three levels, so vehicle concept; so, first, level we can consider like this way; the vehicle requirements. So, what is the vehicle concept and how will be the actual (fully developed vehicle); then what are the system requirement and how we are developing the assembled system? Sub-system; sub-system requirements; based on the sub-system requirements we are assembling the sub-system, and these are the components.

So, in this way, in the automotive design process as described by this system design 'V' model; so we start from the vehicle concept and step by step it proceeds, like this way, and finally the assembled vehicle gets ready and it comes out from the factory.